Augmenting Urban Resilience through Land Use Planning

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Outline

- Motivation
- Process of land use planning: change monitoring, modeling and generation of plans (with consideration of resilience)
- Summary

Definition

"Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity**".**

Source: Meerow, S., Newell, J. P., Stults, M., 2016, Defining urban resilience: A review, *Landscape and Urban Planning* **147:**38-49.

- **Conceptualization of "urban"**
- **The notion of equilibrium**
- **Resilience as a positive concept**
- **Pathway to resilience**
- **Adaptation**
- **Timescale of action**

Process of Land Use Planning

1. Image fusion for generating dense time-series high-resolution land surface imagery

2. Land use change modeling and analysis

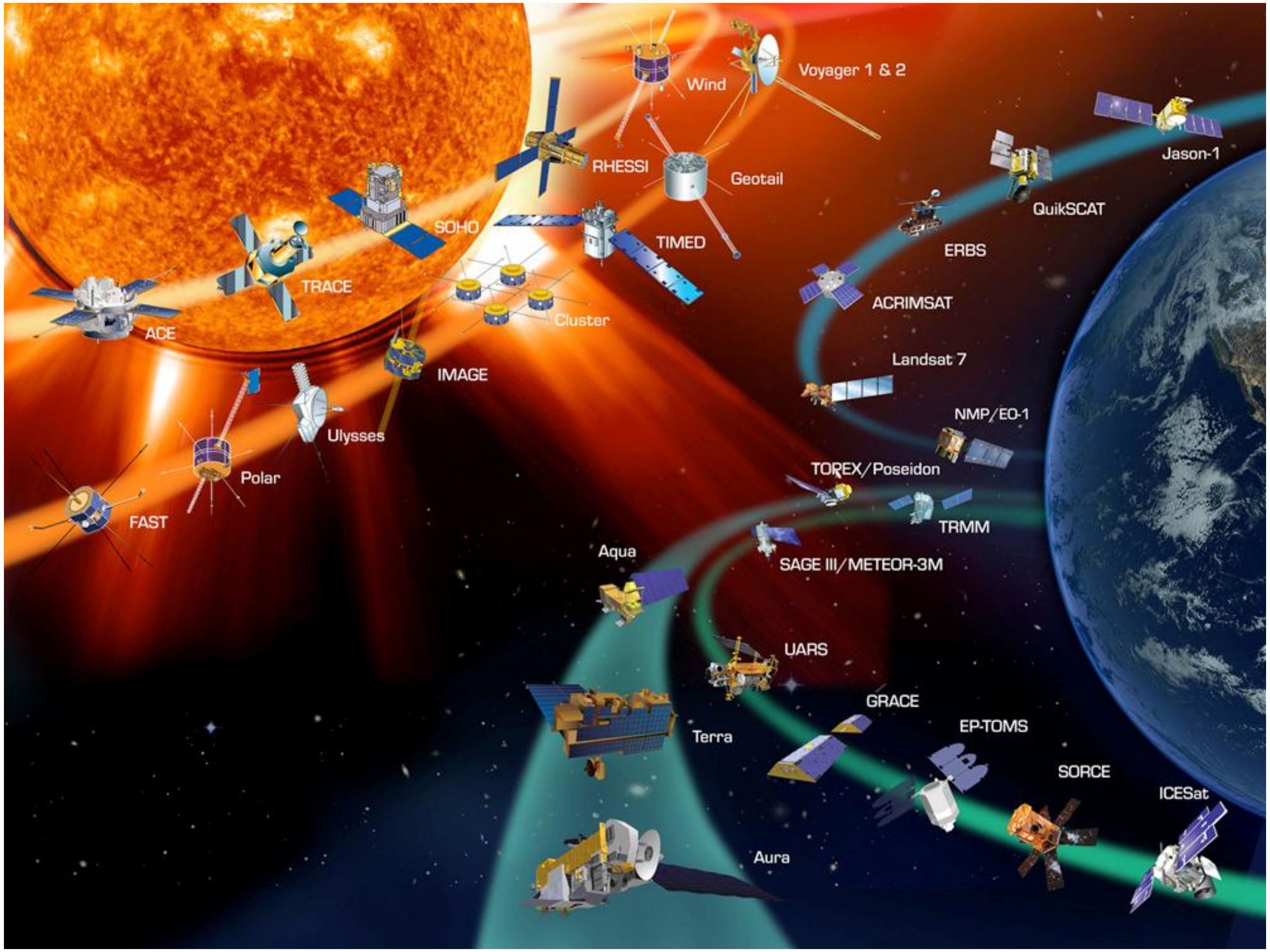
3. Multiobjective change optimization for land use planning

Resilience related objectives

Spatio-temporal image fusion for generating dense time-series high-spatial-resolution imagery

Funded by:
863-Hightech Program of China
Hong Kong Research Grants Council
National Science Foundation of China

Numerous RS satellites have been launched…..



Problems of Current Satellite Remote Sensing

- Remote sensing instruments still need to trade off between spatial and temporal resolution
    - High spatial resolution → Low temporal resolution
    - High temporal resolution → Low spatial resolution
- Limited the applicability of remote sensing technology

Motivation for Spatiotemporal Fusion

MODIS:

♀ Low spatial resolution-250~1000 m

♀ High temporal resolution - 1 day

Landsat:

♀ High spatial resolution - 30 m

♀ Low temporal resolution - 16 days

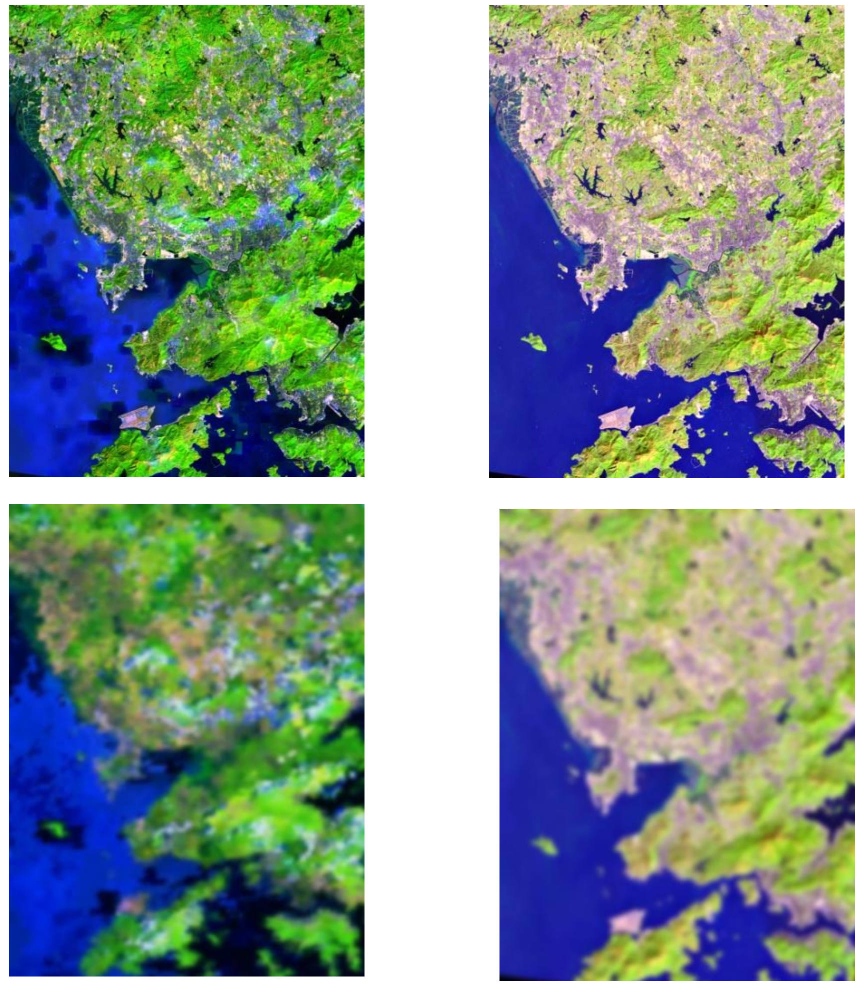
- Possible solution: blending two types of images

Spatio-Temporal Image Fusion

Seasonal change

LANDSAT
(EVERY 16 DAYS)

MODIS
(EVERY DAY)



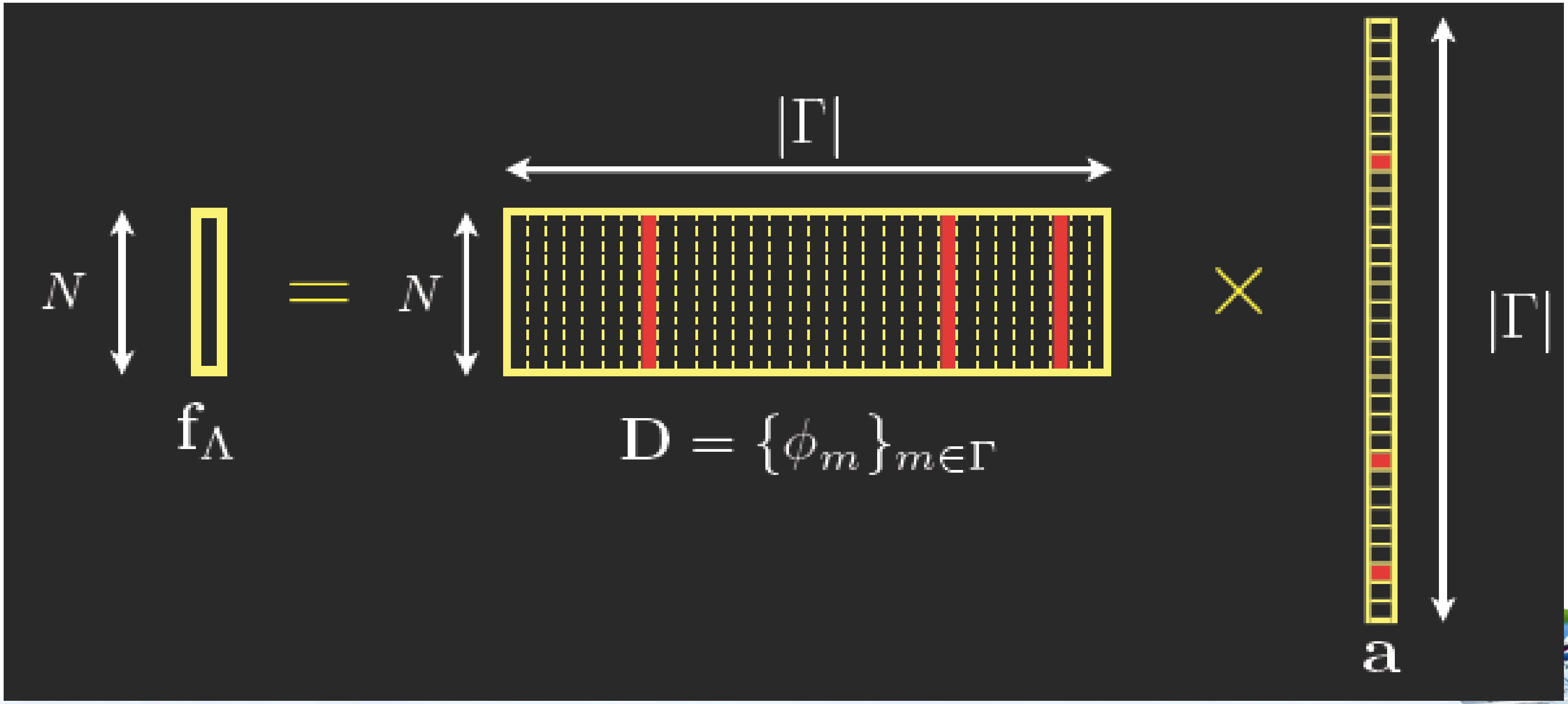
2001-07-28 **2001-12-03**

Different acquisition dates

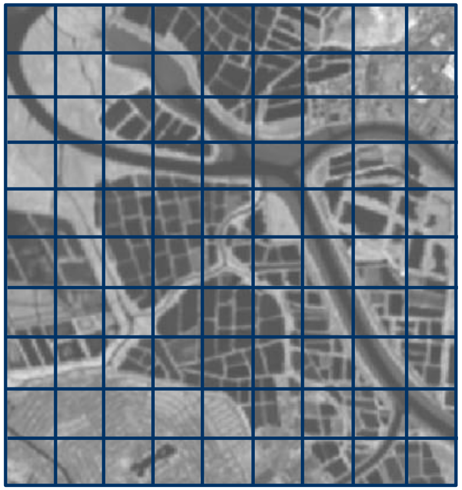
Implementation Methodology

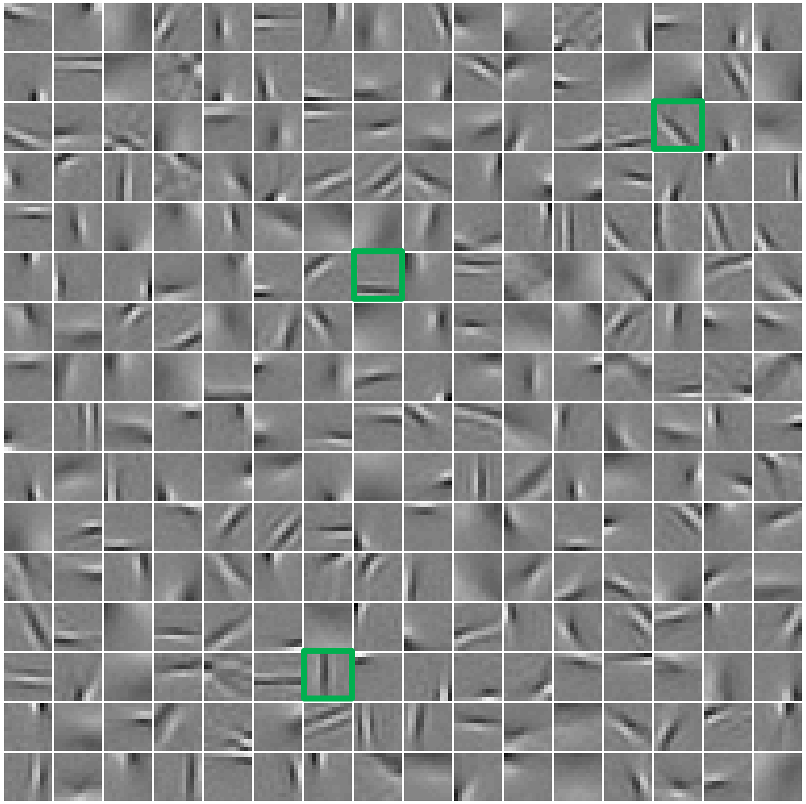
Sparse Representation

$$f_\Lambda = D\alpha \qquad \begin{cases} f_\Lambda : \text{signal to be represented} \\ D : \text{Dictionary containing } |\Gamma| \text{ atoms} \\ \alpha : \text{representation coefficients} \end{cases}$$

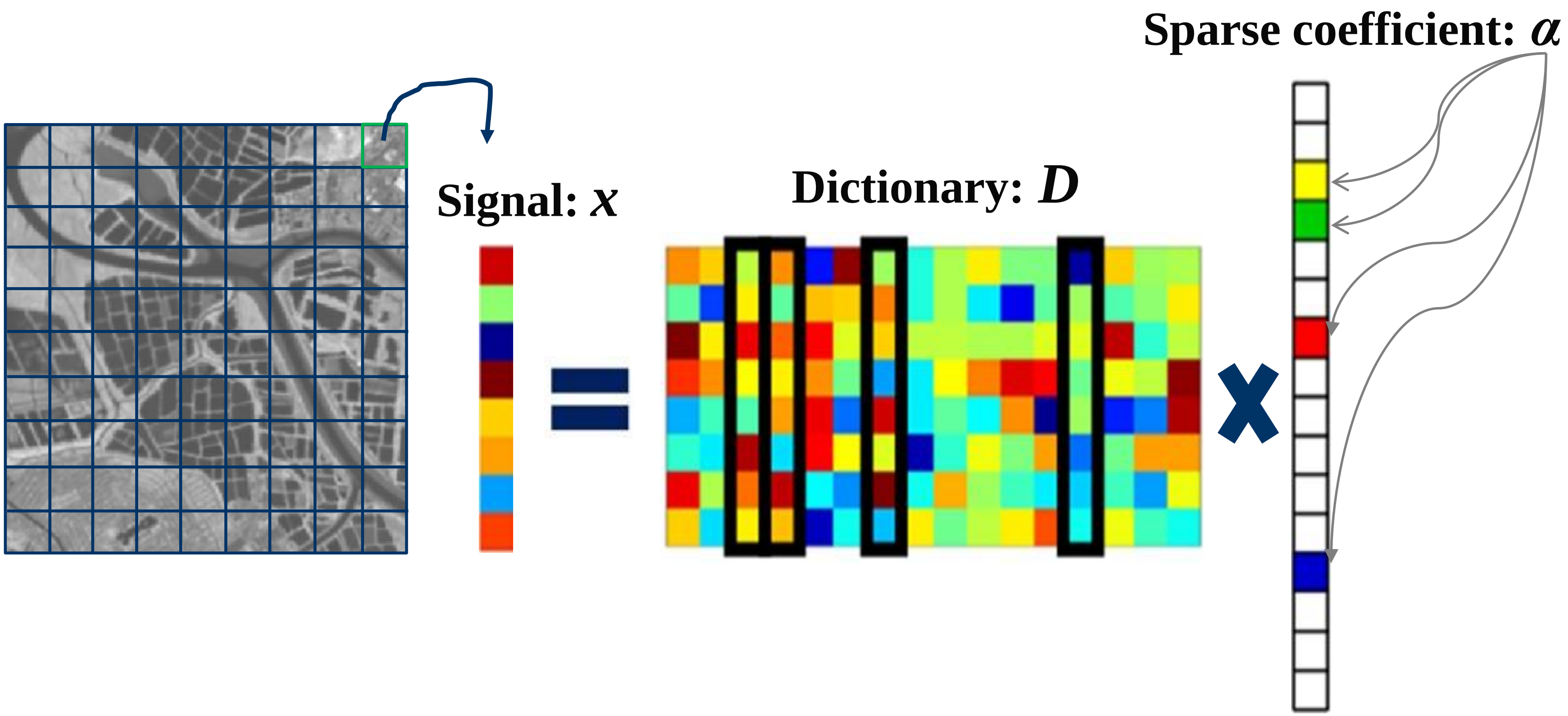


Dictionary Construction



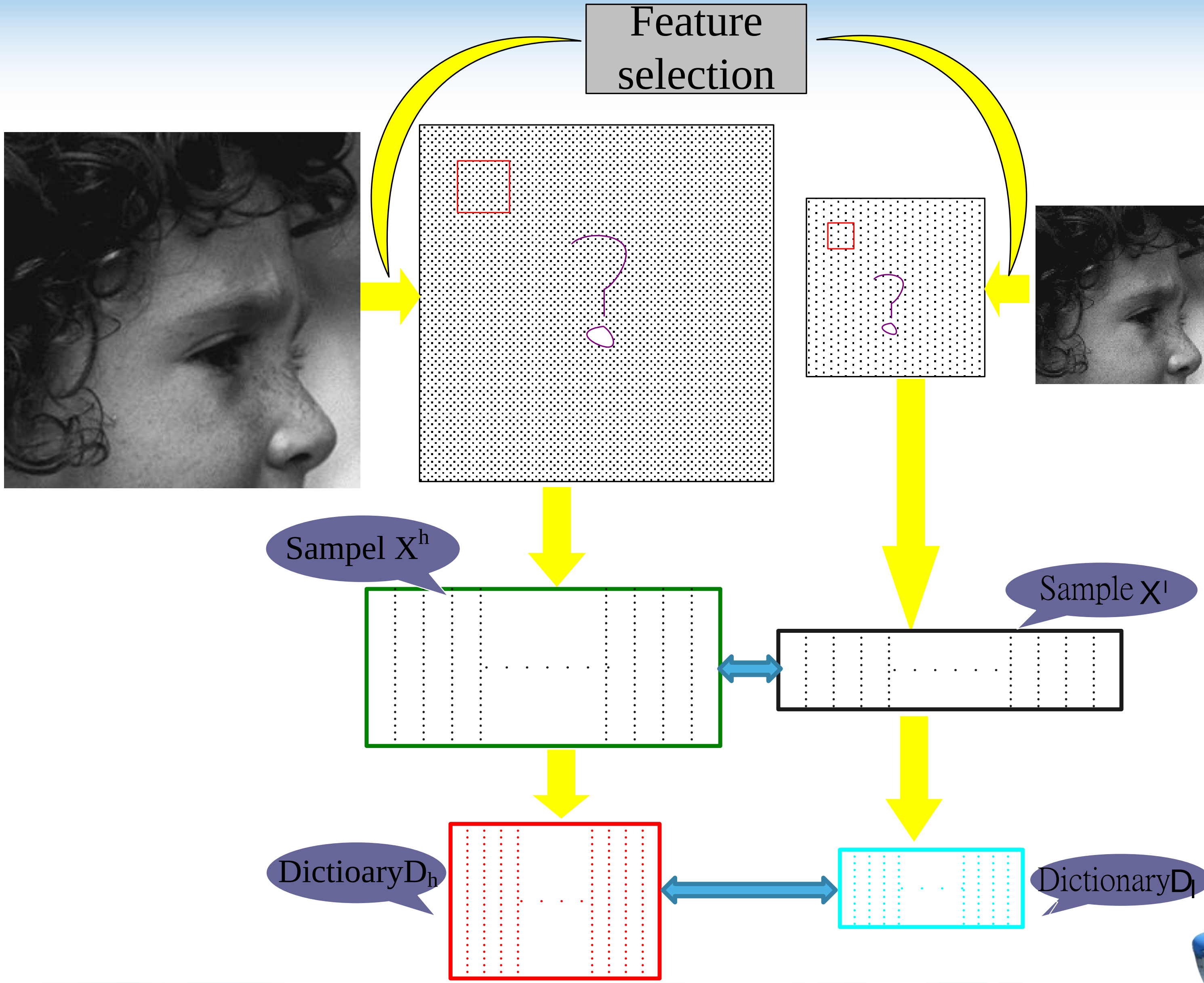


Sparse Representation



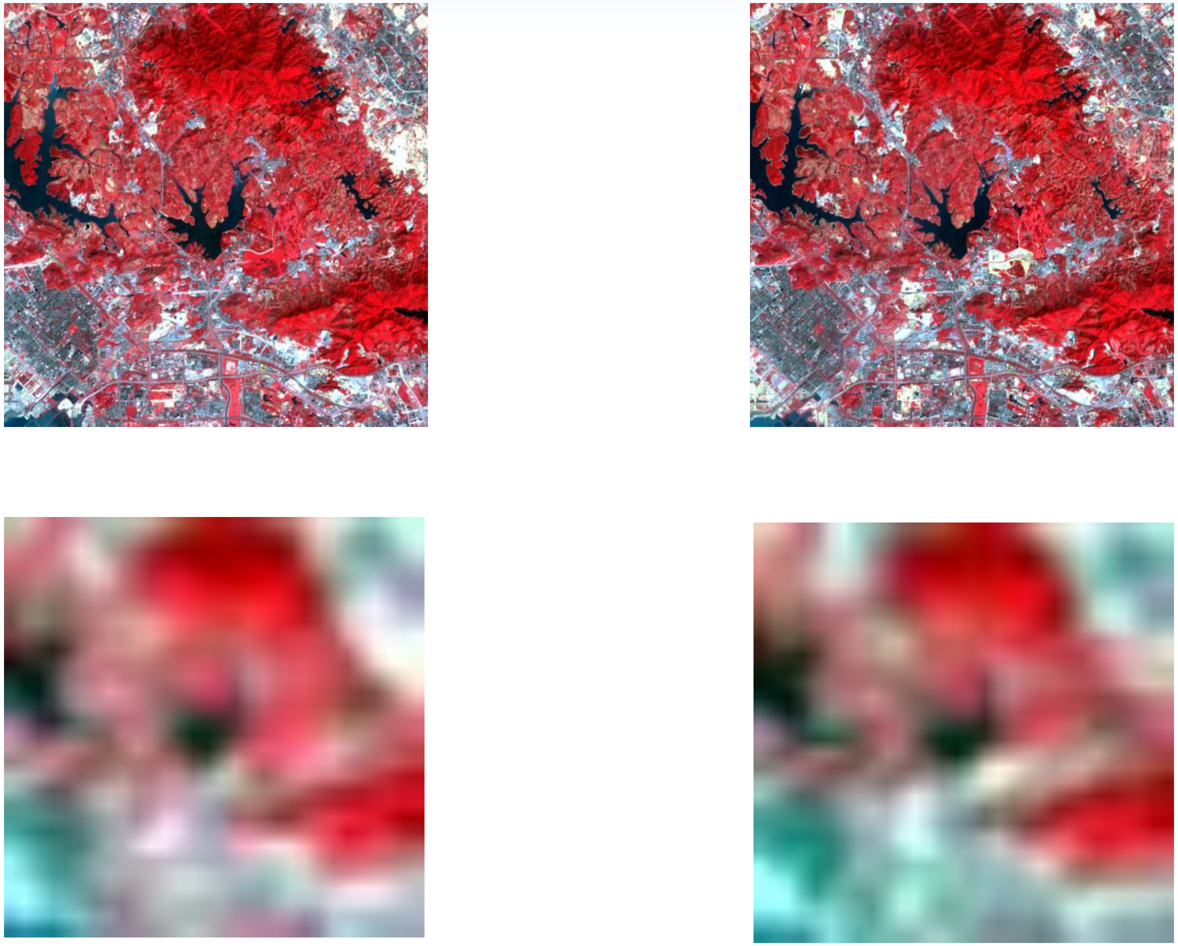
Sparse Representation

- **Two steps:**
  - Dictionary training
    - To obtain dictionary *D* from training samples.
    - Many developed algorithms available, such as maximum likelihood (ML) dictionary learning method, K-SVD method.
  - Sparse coding
    - To solve representation coefficients *α*;
    - Many developed algorithms available, such as orthogonal matching pursuit (OMP), homotopy, iterative-shrinkage thresholding (IST);



Feature selection
Sampel X^h
Sample X^l
DictioaryD_h
DictionaryD_l

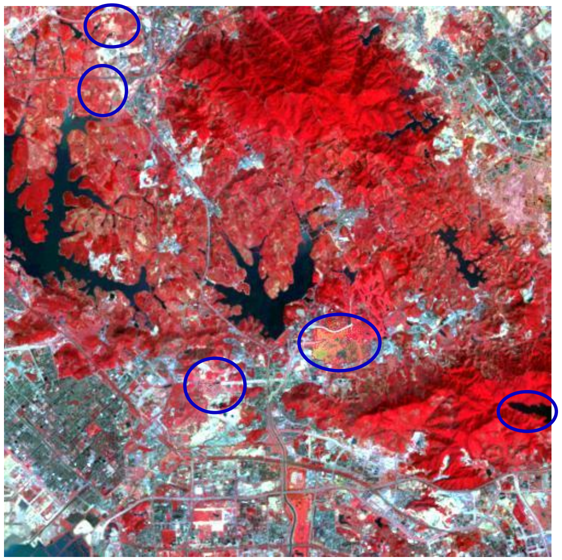
Land-cover (type) Change



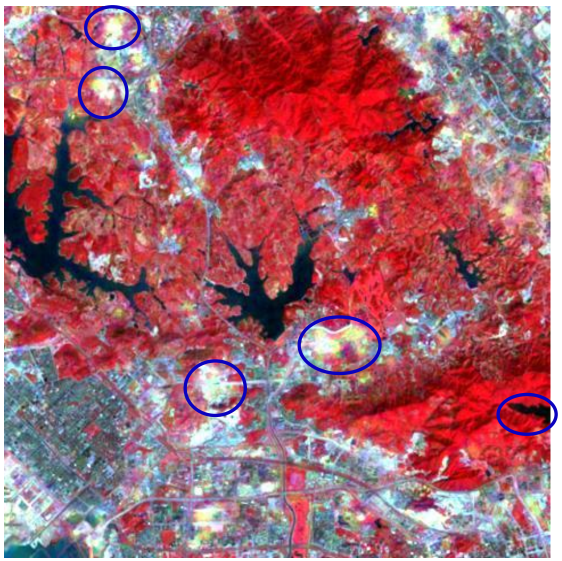
2000 2002

Song, H. and **Huang, B.**, 2013. Spatiotemporal satellite image fusion through one-pair image learning. *IEEE Transactions on Geoscience and Remote Sensing*, 51(4): 1883-1896

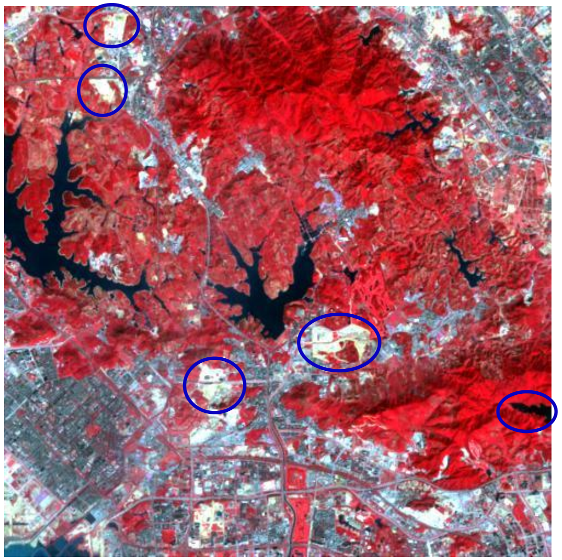
Result Comparison



(a) STARFM result



(b) Our result

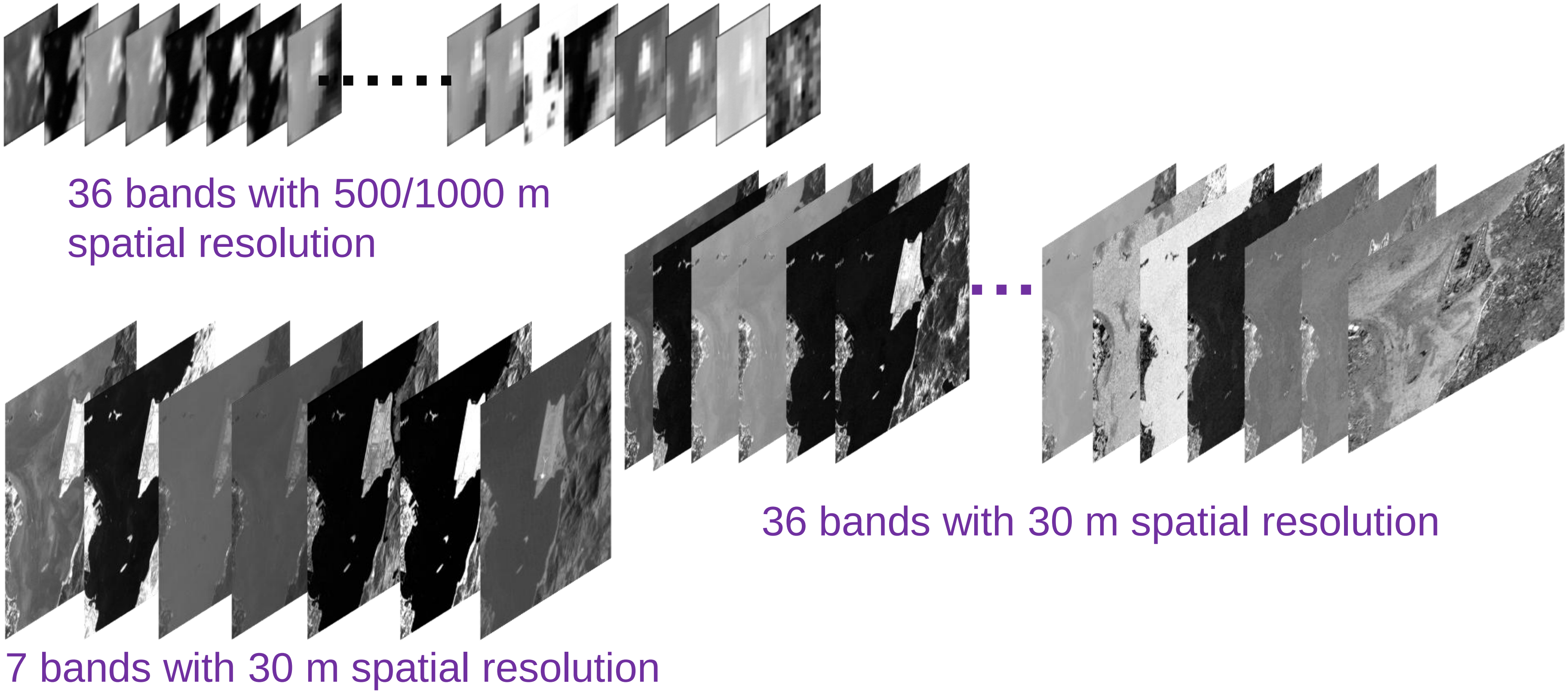


(c) Actual image

Quantitative Evaluation

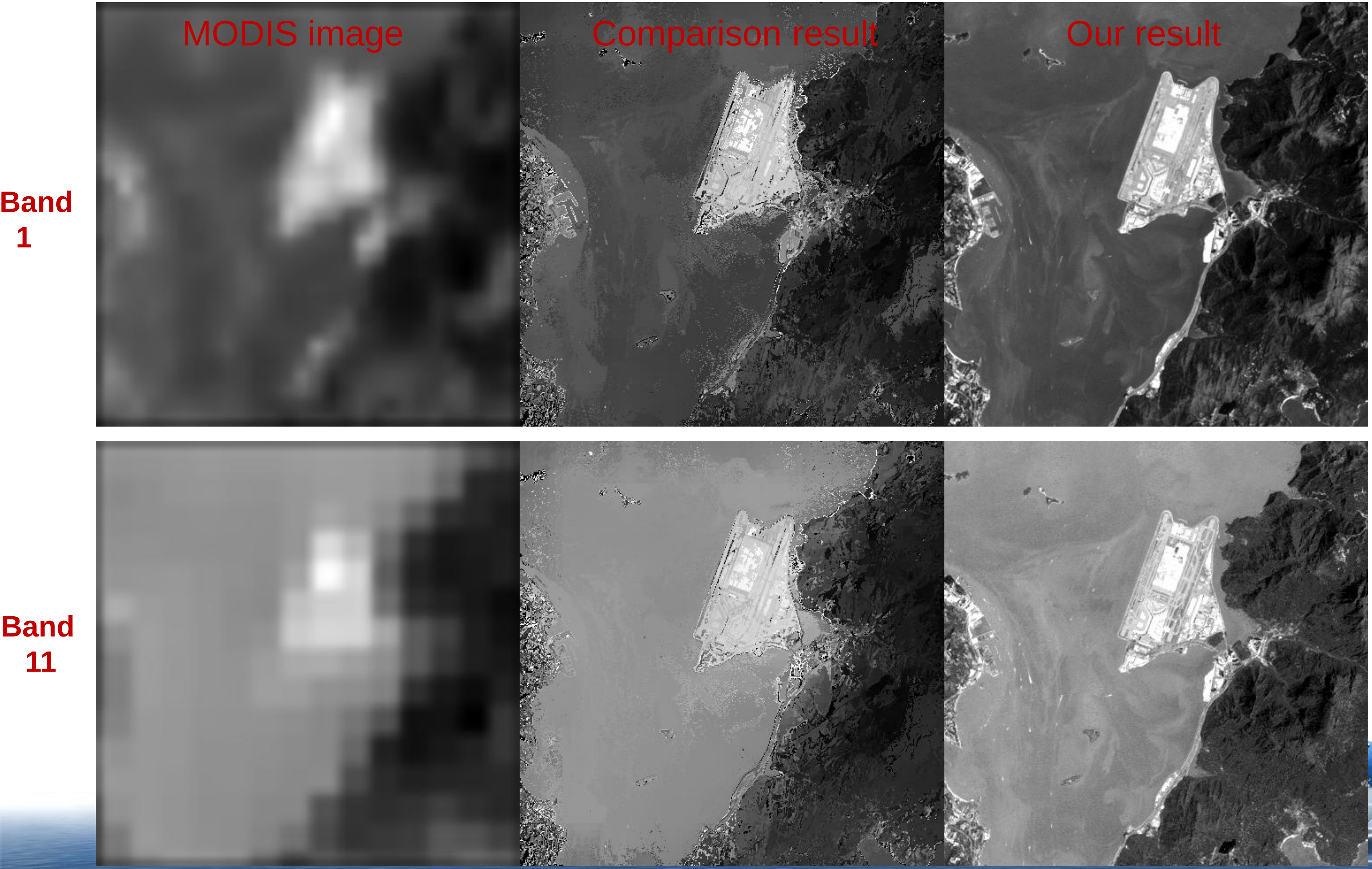
Method	AAD	RMSE	SSIM	ERGAS	SAM
STARFM	0.0132	0.0208	0.7635	1.9229	3.0838
Our method	**0.0107**	**0.0163**	**0.7799**	**1.4687**	**2.6645**

Spatio-spectral Image Fusion

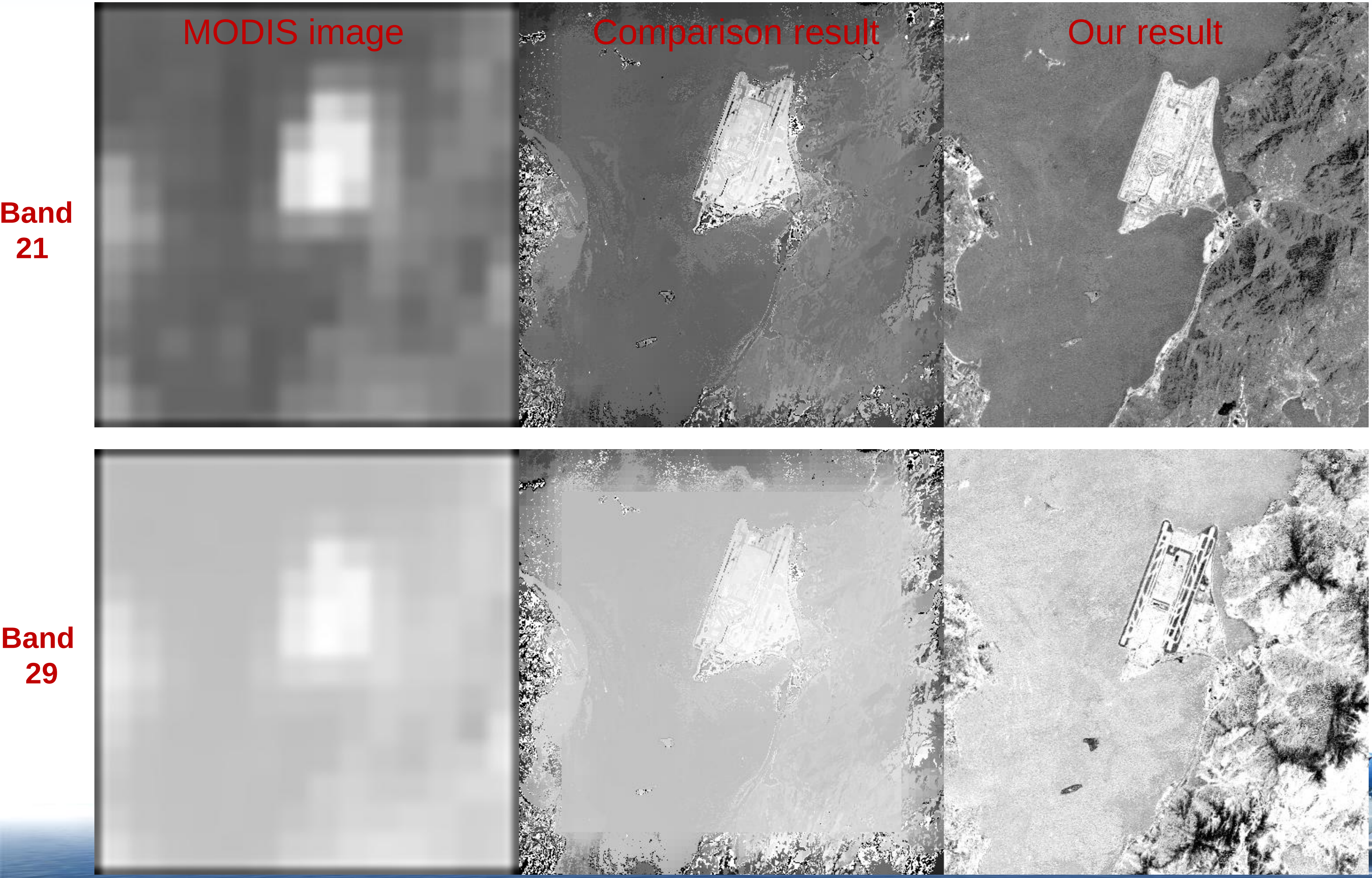


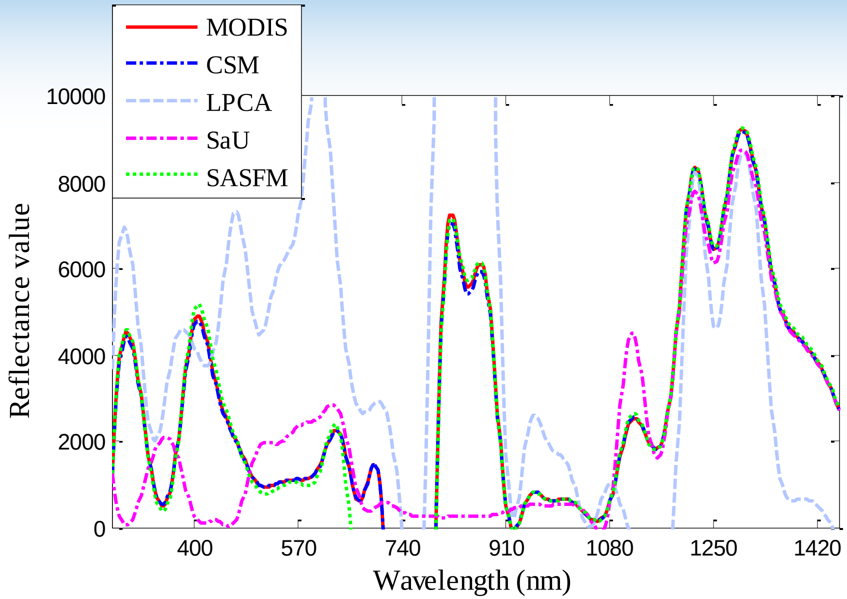
Huang *et al.*, 2014,. Spatial and spectral image fusion using sparse matrix factorization. *IEEE Transactions on Geoscience and Remote Sensing*, 52(3): 1693-1704.

Result Comparison

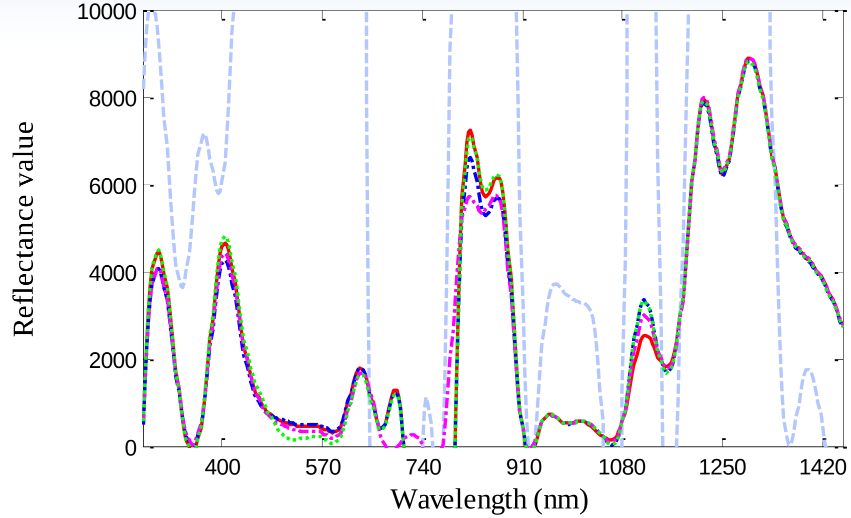


Result Comparison

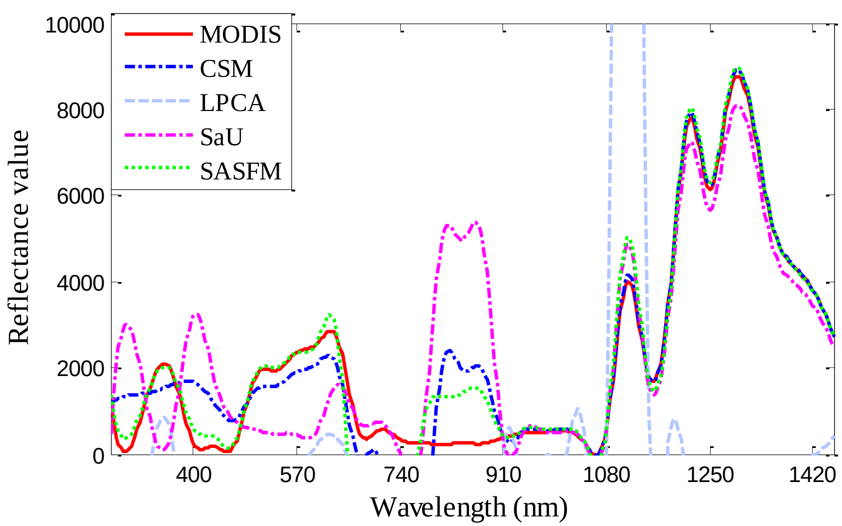



MODIS
CSM
LPCA
SaU
SASFM
10000
8000
6000
4000
2000
0
400
570
740
910
1080
1250
1420
Reflectance value
Wavelength (nm)

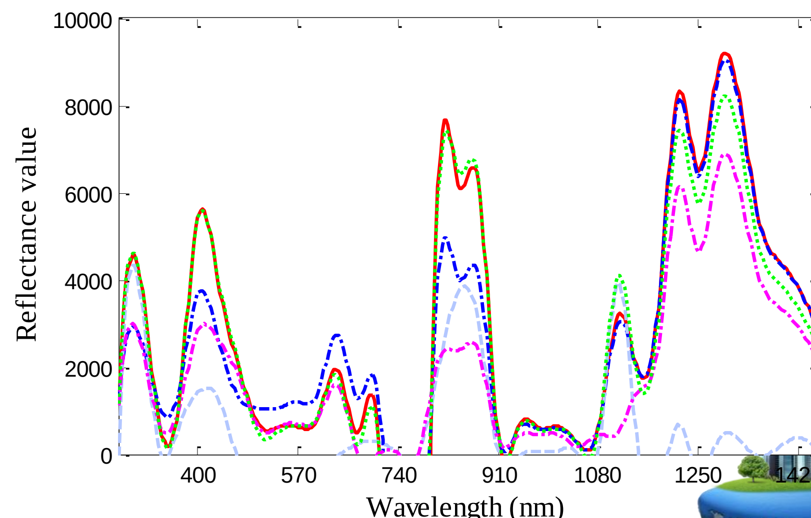
(a)


10000
8000
6000
4000
2000
0
400
570
740
910
1080
1250
1420
Reflectance value
Wavelength (nm)

(b)

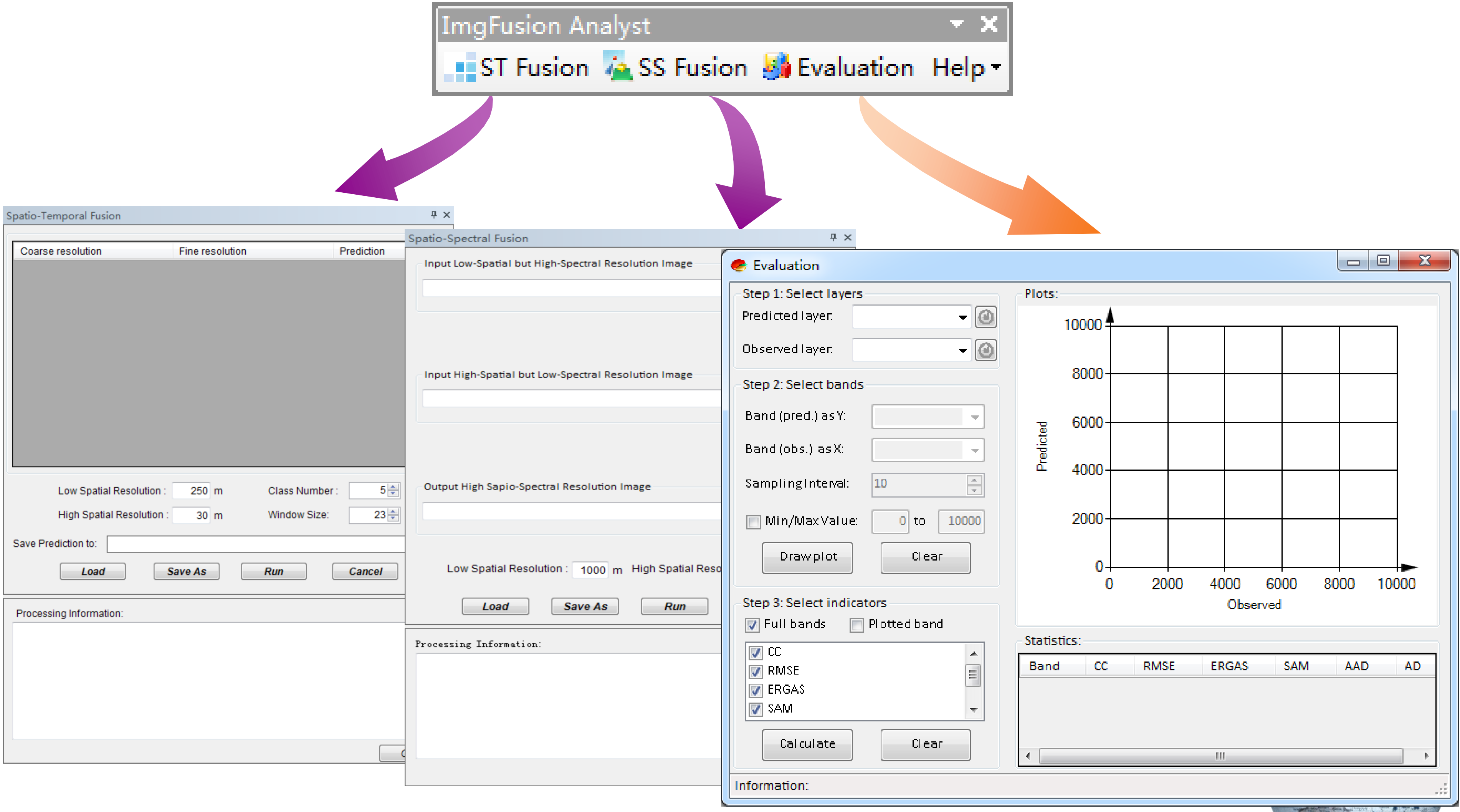

MODIS
CSM
LPCA
SaU
SASFM
10000
8000
6000
4000
2000
0
400
570
740
910
1080
1250
1420
Reflectance value
Wavelength (nm)

(c)

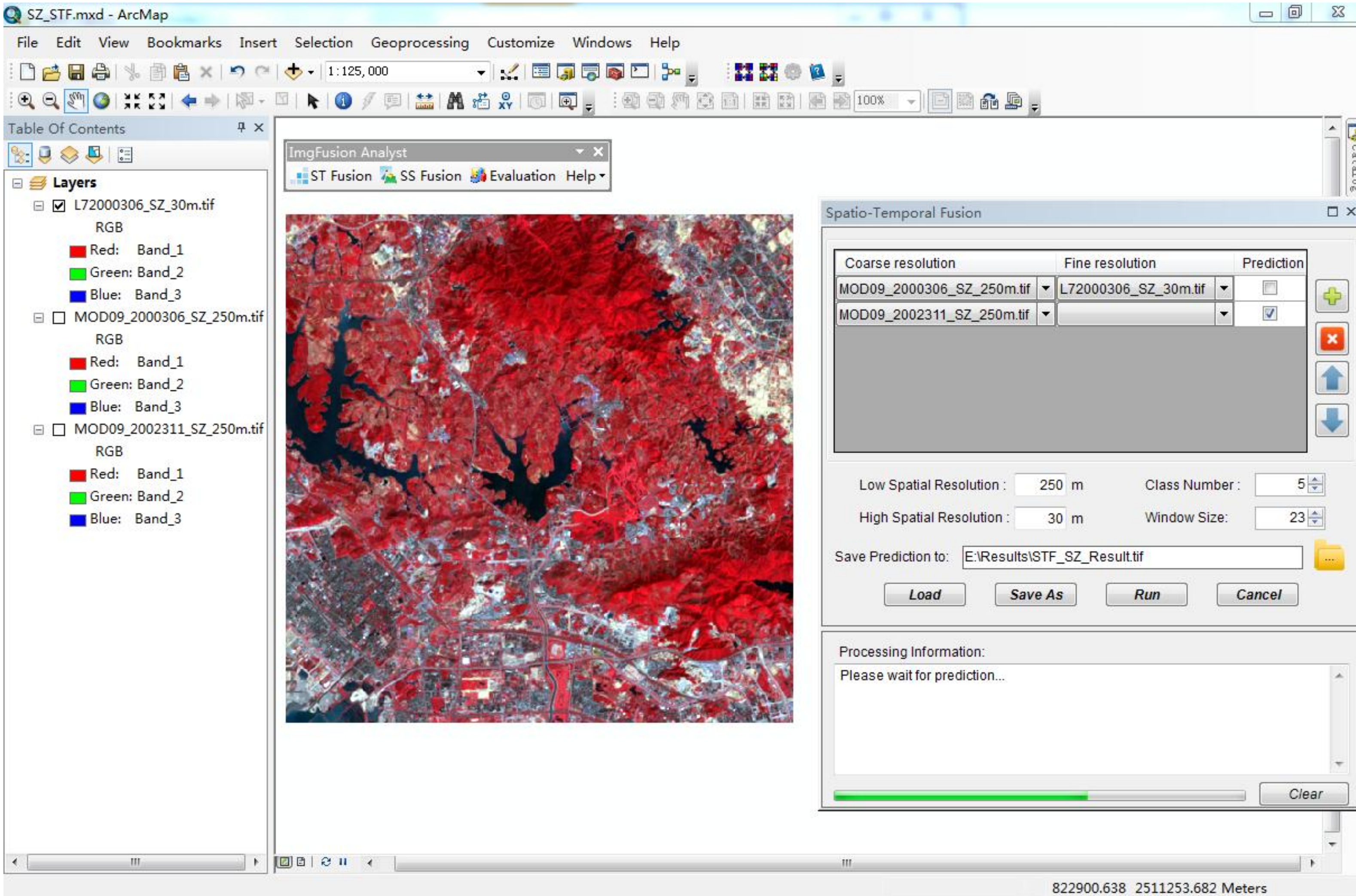

10000
8000
6000
4000
2000
0
400
570
740
910
1080
1250
1420
Reflectance value
Wavelength (nm)

(d)

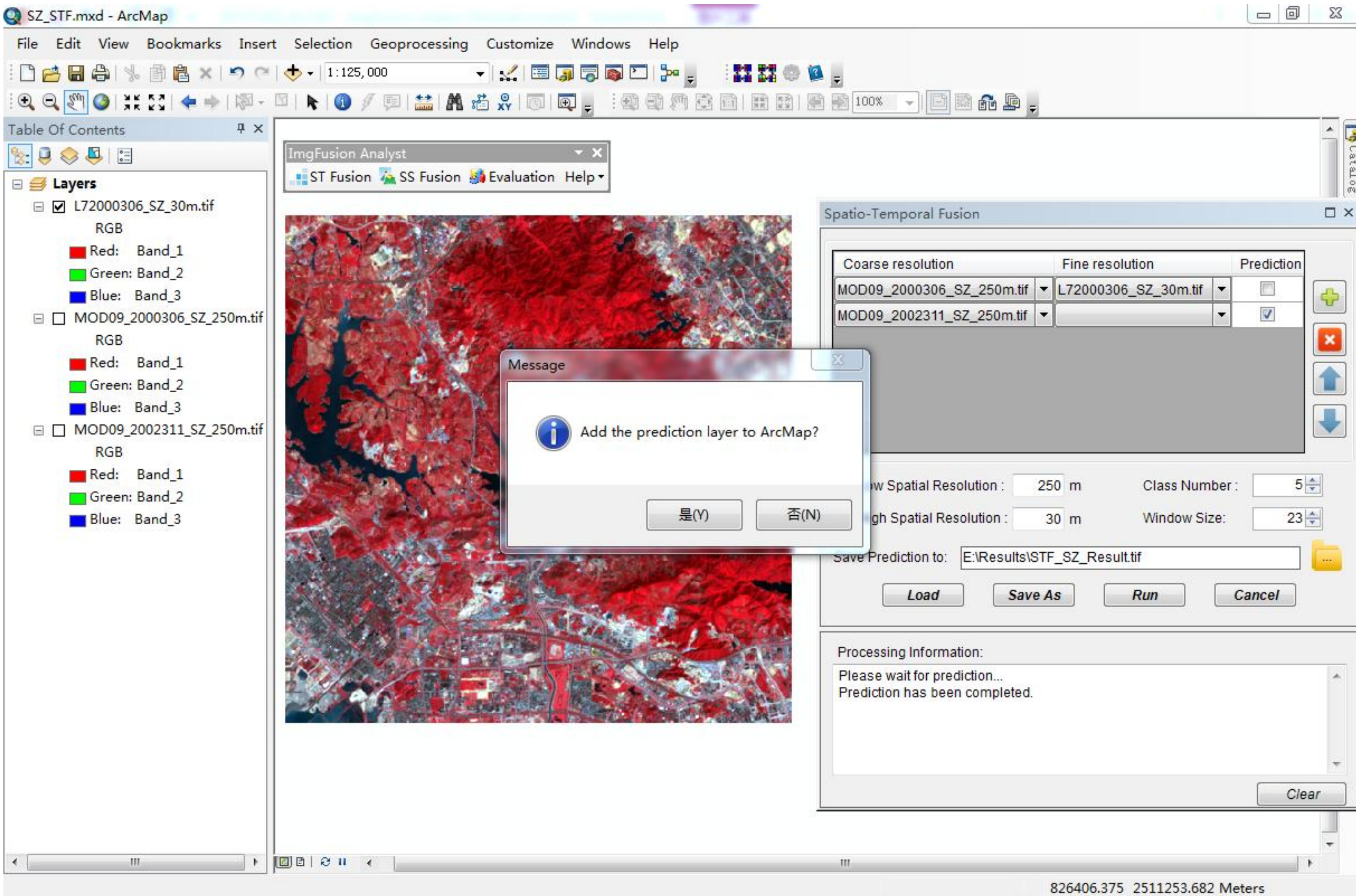
ImgFusion Analyst



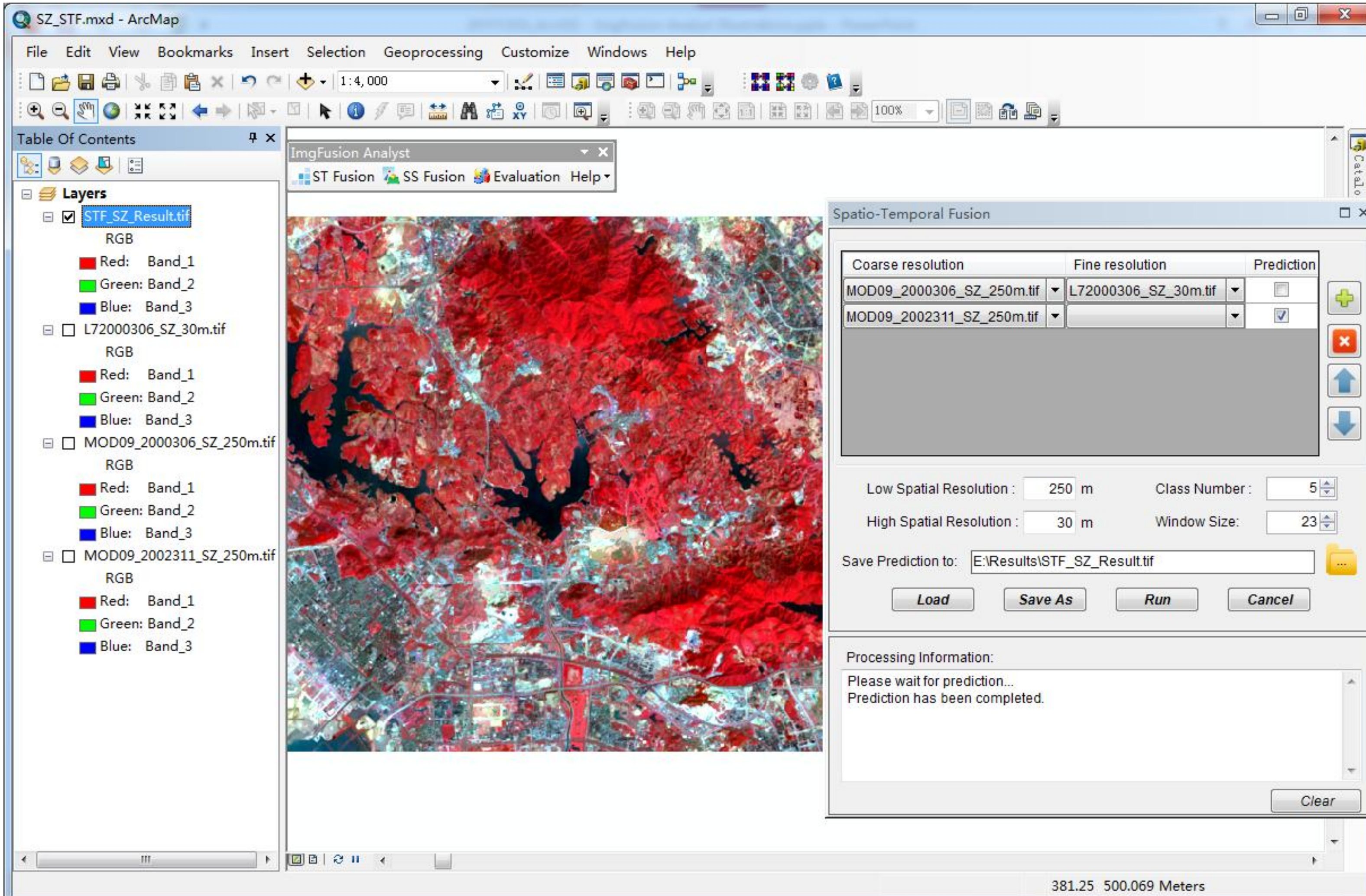
Spatiotemporal Image Fuiosn



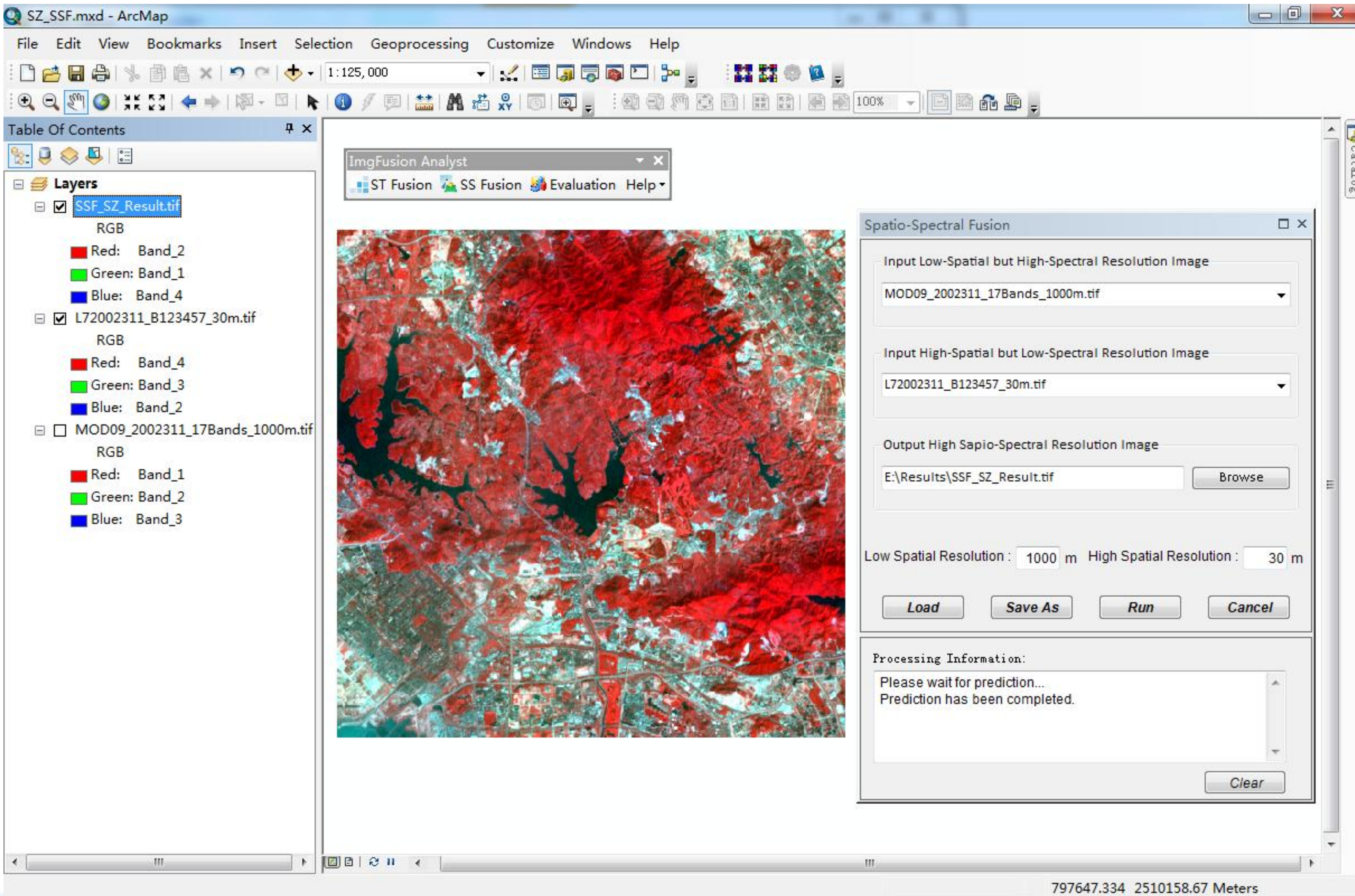
Spatiotemporal Image Fuiosn



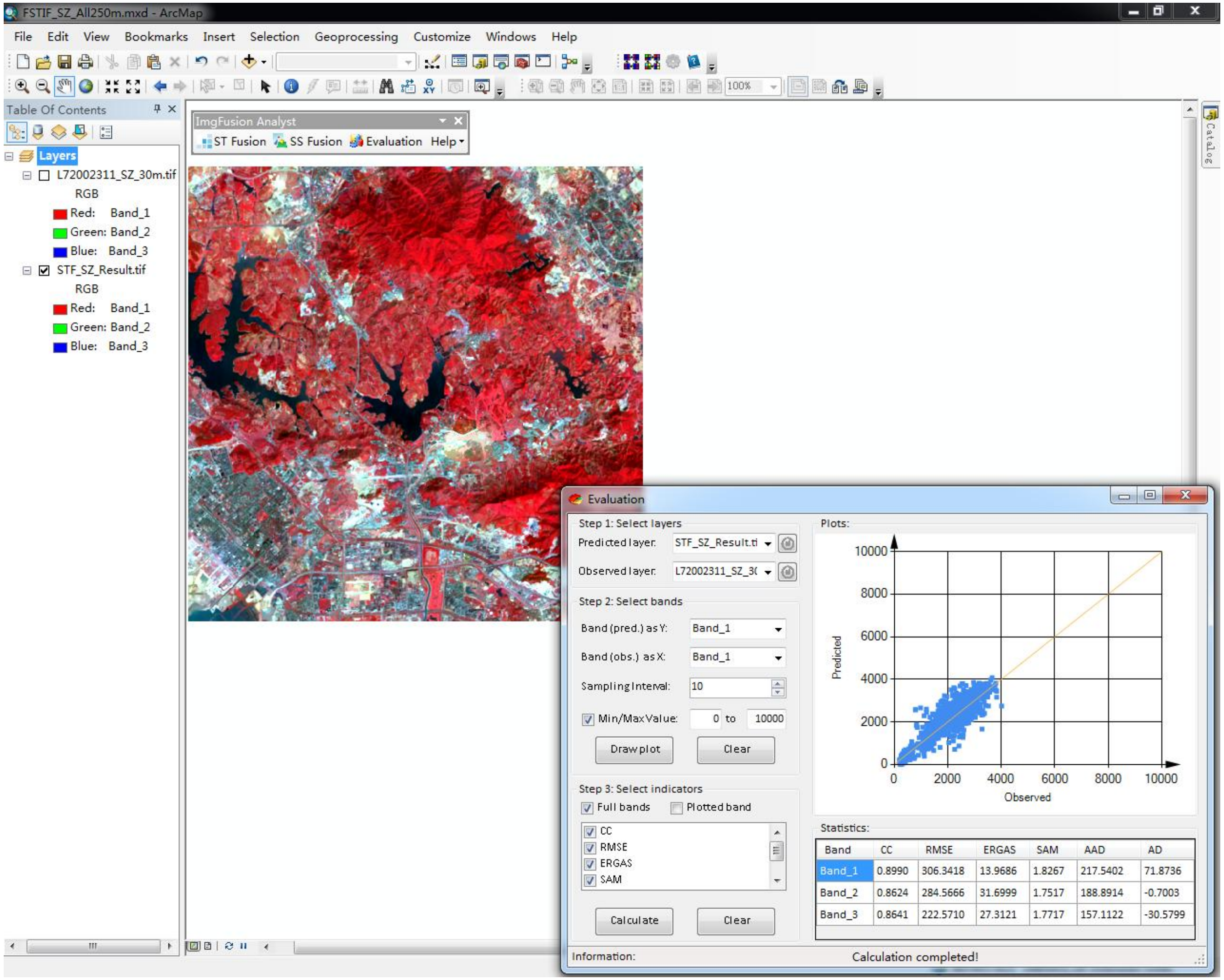
Fusion Result



Spatio-spectral Image Fusion



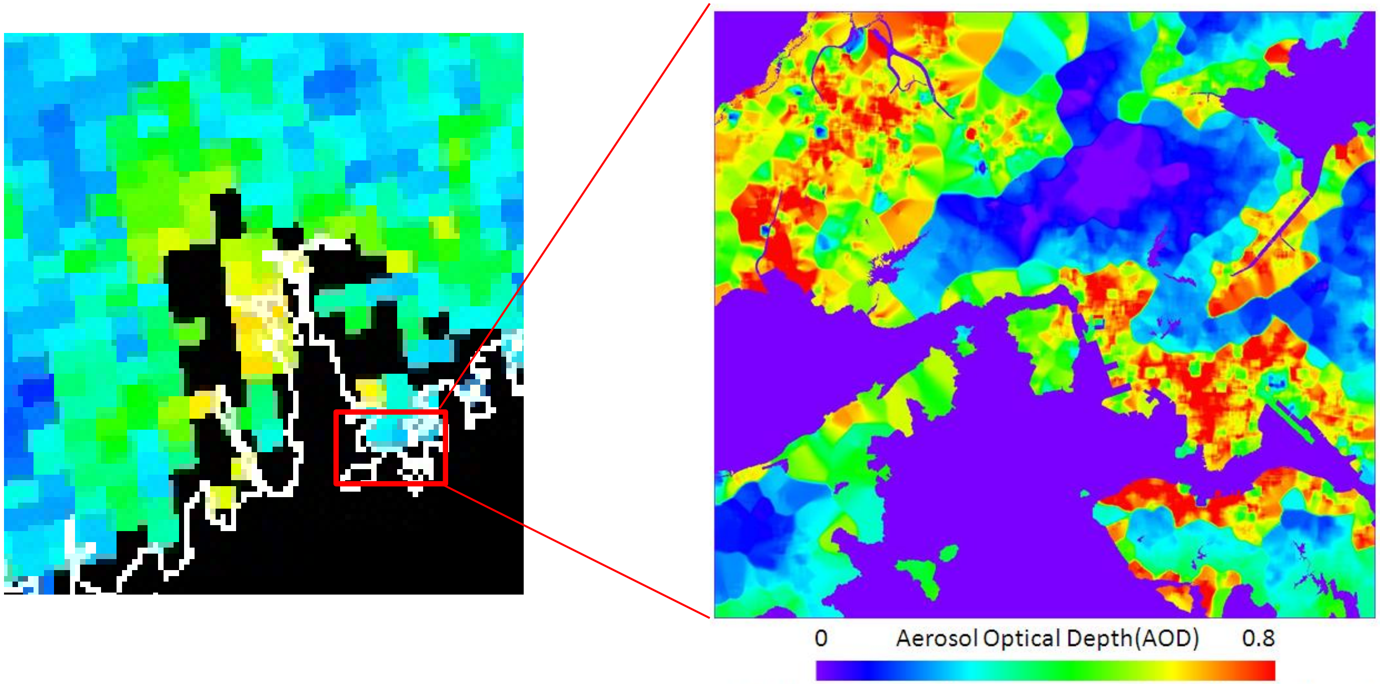
Result Evaluation



Applications

Retrieval of Aerosol Optical Depth (AOD)

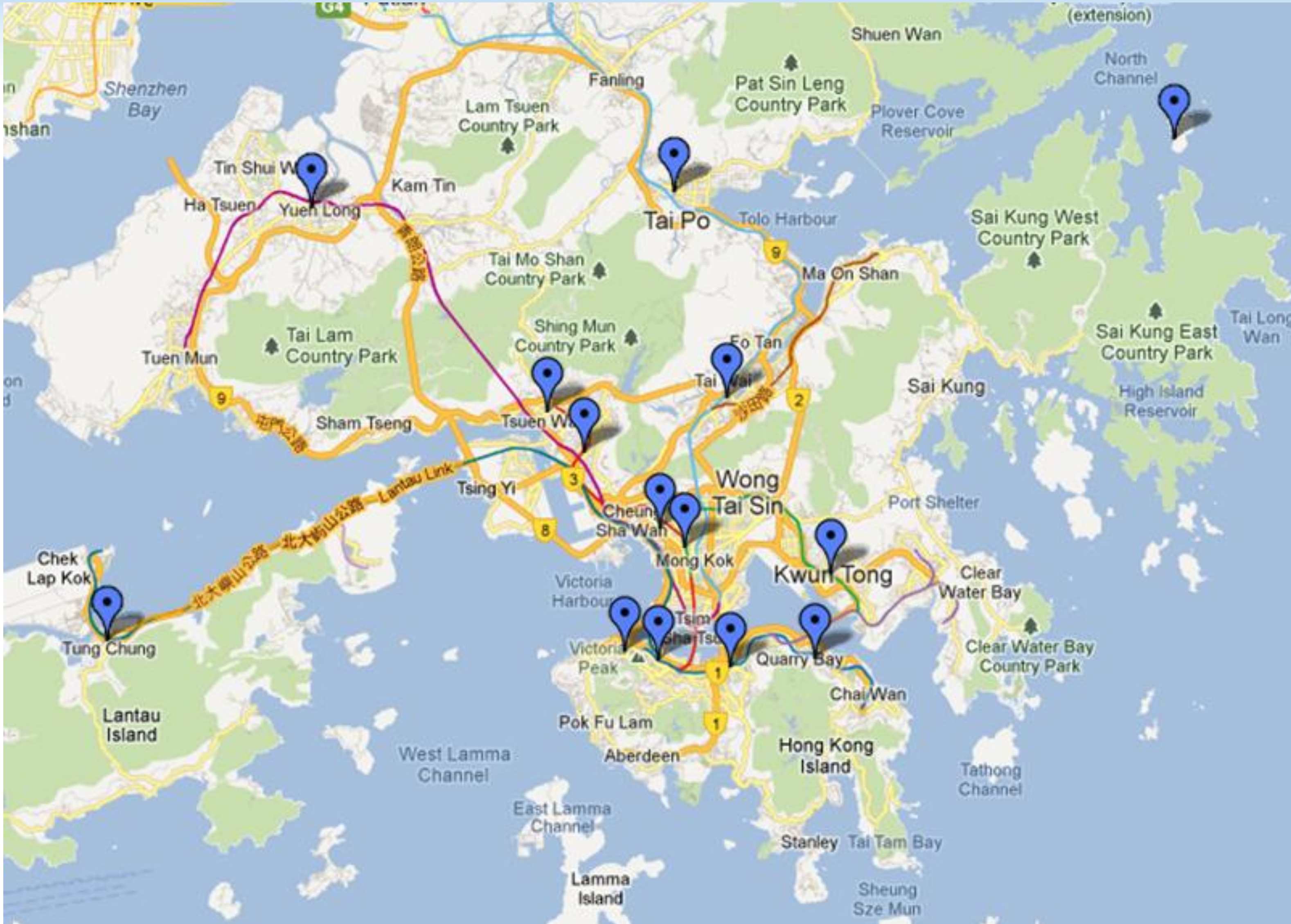
Generating High Resolution (30 m) Daily Aerosol Optical Depth Image



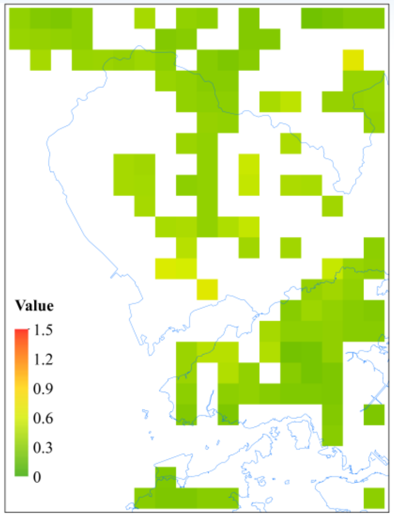
AOD distribution at 10:40 am on Nov 23, 2005 (λ = 0.55 μm)

AOD retrieved from MODIS

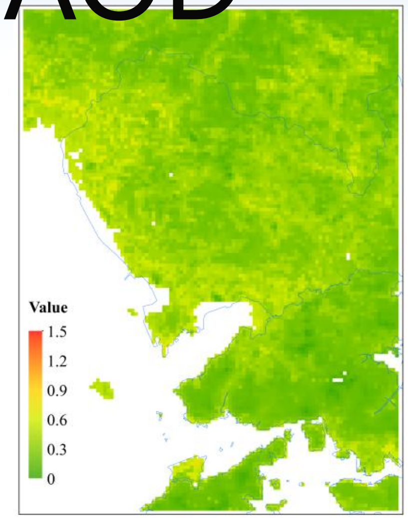
AOD retrieved from predicted ETM+

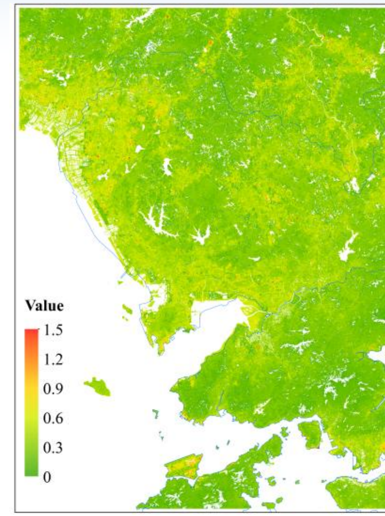

(extension)
Shuen Wan
Shenzhen Bay
Fanling
Pat Sin Leng Country Park
North Channel
Lam Tsuen Country Park
Plover Cove Reservoir
Tin Shui Wai
Kam Tin
Ha Tsuen
Yuen Long
Tai Po
Tolo Harbour
Sai Kung West Country Park
Tai Mo Shan Country Park
Ma On Shan
Shing Mun Country Park
Fo Tan
Tai Long Wan
Sai Kung East Country Park
Tai Lam Country Park
Tuen Mun
Tai Wai
Sai Kung
High Island Reservoir
Sham Tseng
Tsuen Wan
Lantau Link
Tsing Yi
Wong Tai Sin
Port Shelter
Cheung Sha Wan
Mong Kok
Kwun Tong
Clear Water Bay
Chek Lap Kok
Victoria Harbour
Tsim Sha Tsui
Tung Chung
Victoria Peak
Quarry Bay
Clear Water Bay Country Park
Chai Wan
Lantau Island
Pok Fu Lam
West Lamma Channel
Aberdeen
Hong Kong Island
Tathong Channel
East Lamma Channel
Stanley
Tai Tam Bay
Lamma Island
Sheung Sze Mun

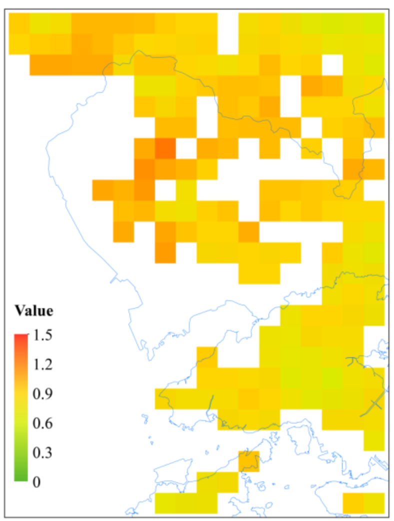
High Spatiotemporal Resolution AOD



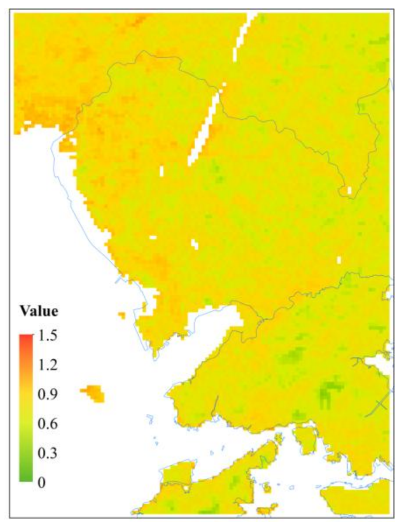
Nov 20, 2001

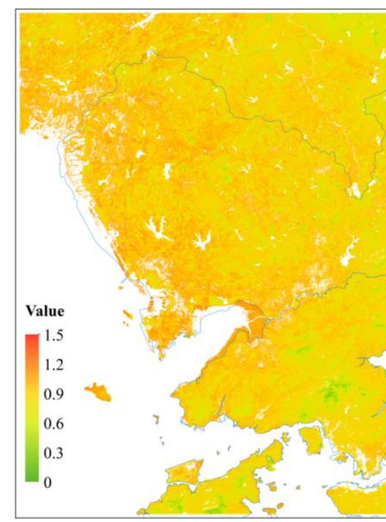






Jan 7, 2002





MOD04 AOD 3 km

MODIS AOD 500 m

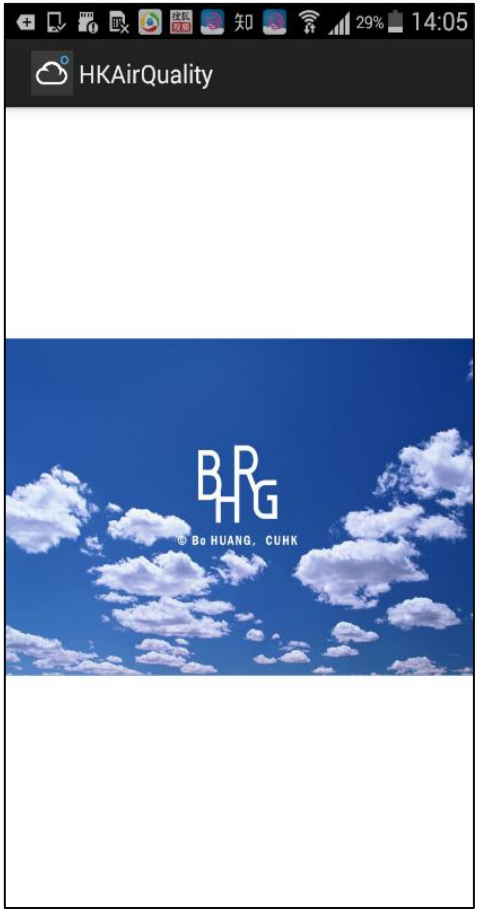
ETM+ AOD 30 m

A Mobile App for Real-time Air Pollution

Air Quality App

- The App allows you to access air pollution concentrations at any location any time in a city
- Crawls environmental monitoring station data and meteorological data from the web
- Interpolates (/predicts) the missing data using a complex spatiotemporal regression model

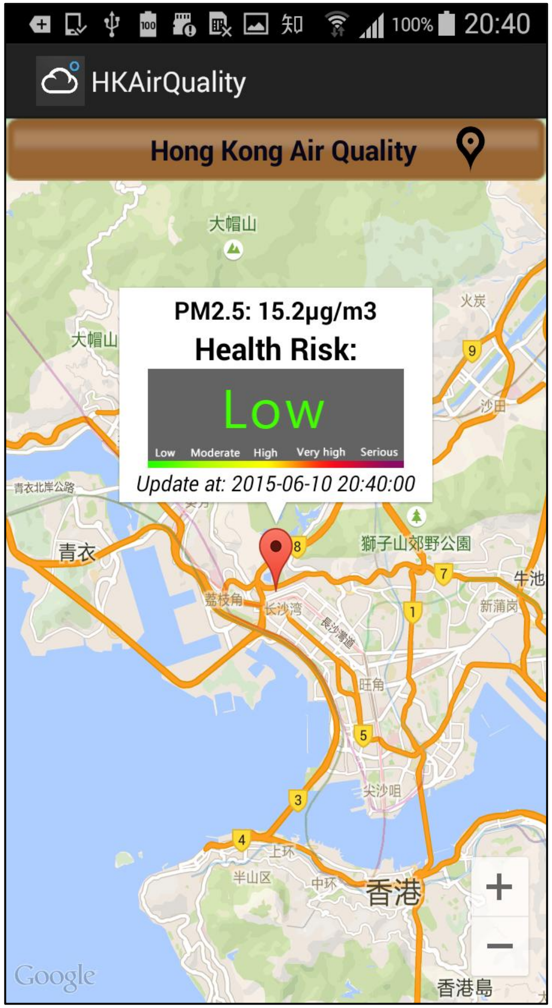
Initial interface

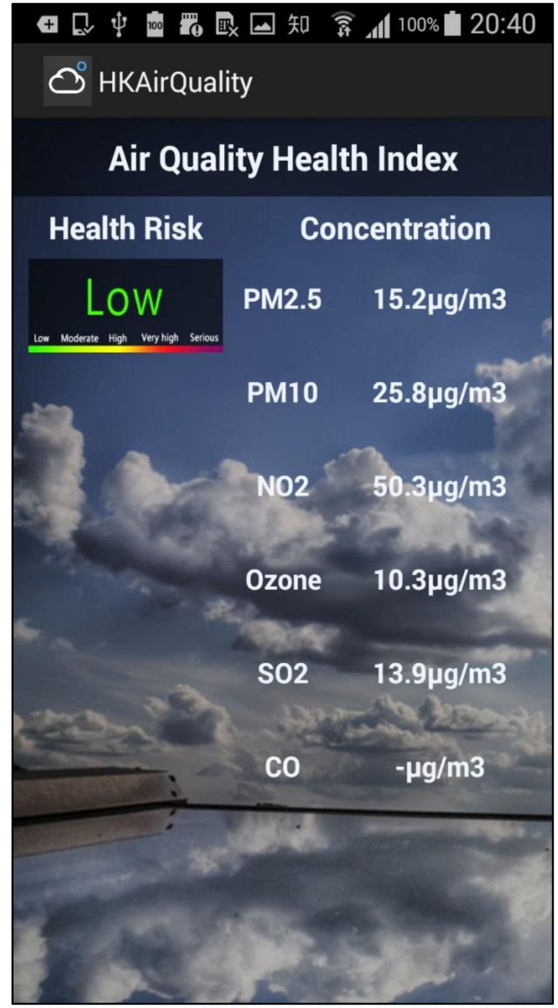


Android platform

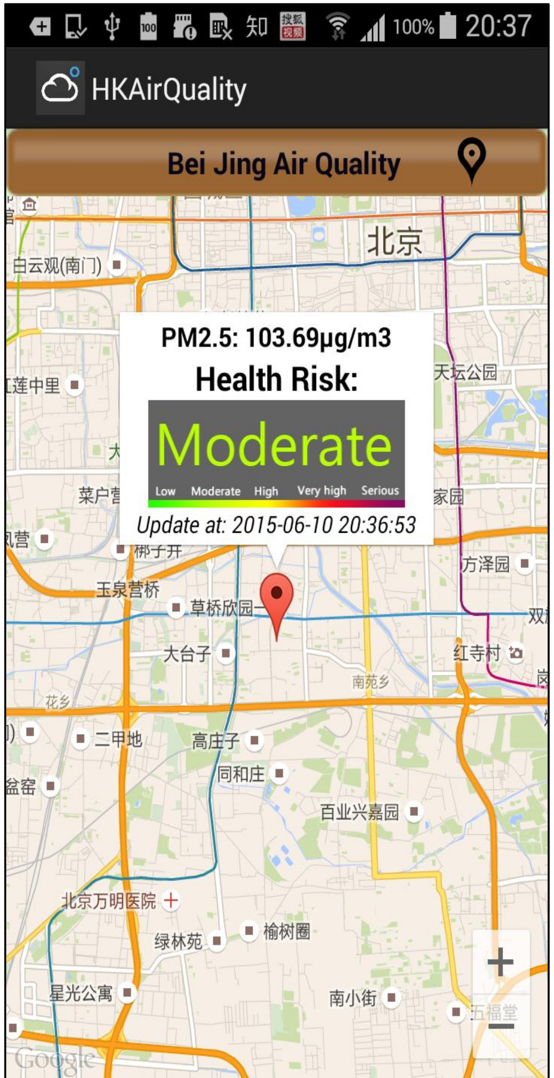
iOS platform

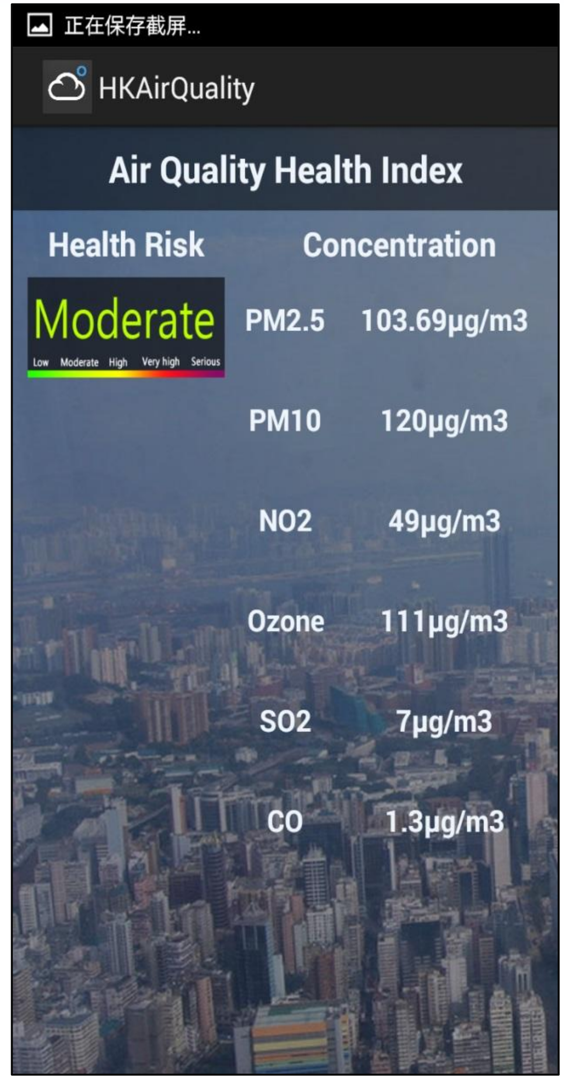
PM2.5 and other pollutants – Hong Kong





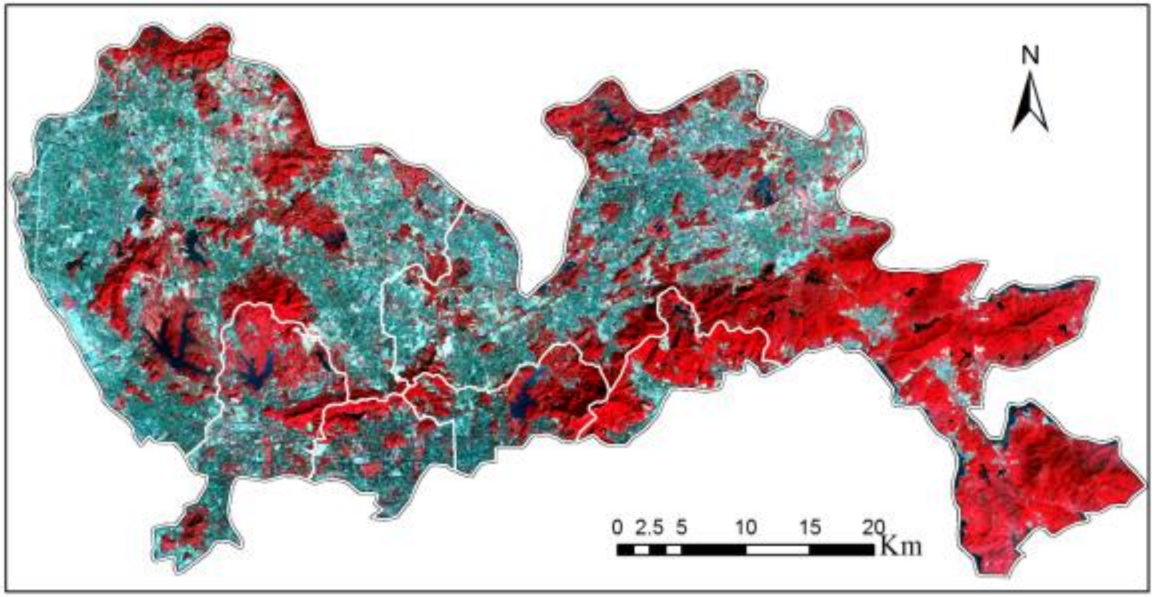
PM2.5 and other pollutants - Beijing





Fine Land Cover Classification in Shenzhen

Study site



Identified Land cover types:

(1) Water;
(2) Forest;
(3) Arable land;
(4) Bare land;
(5) Impervious area;
(6) Shrub.

Study area and the nir-red-green composite of mosaic Landsat OLI images acquired on Nov. 16, 2014.

Fine land cover classification

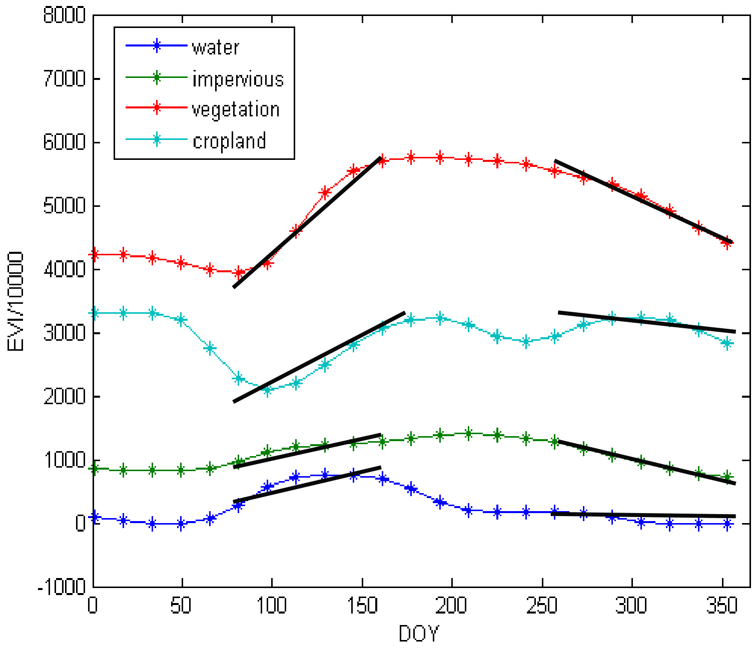
Through spatiotemporal fusion

Time-series fused Landsat-like images

Feature extraction

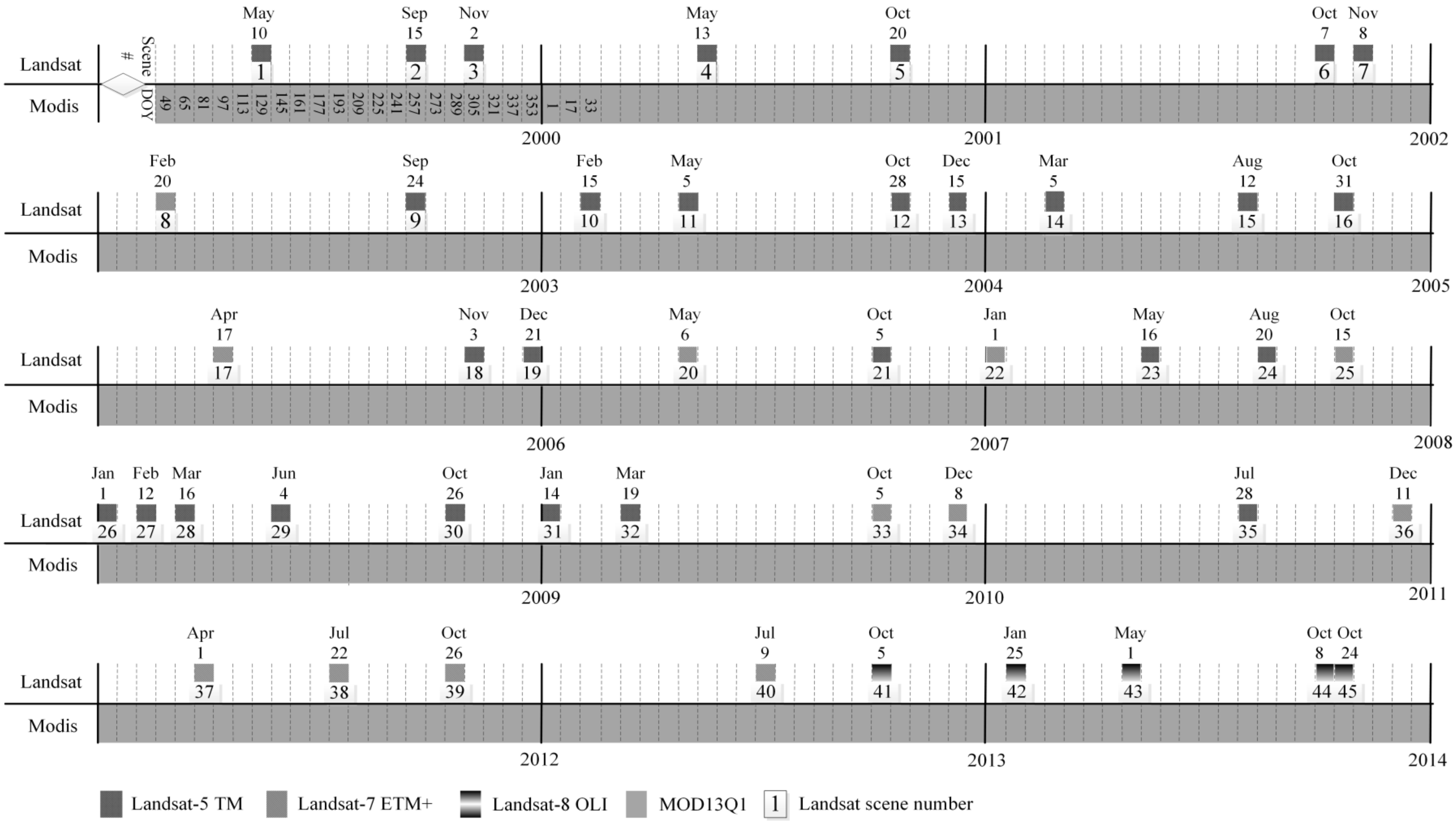
Max/min Enhanced Vegetation Index (EVI)

Growing/senescence mean/std value



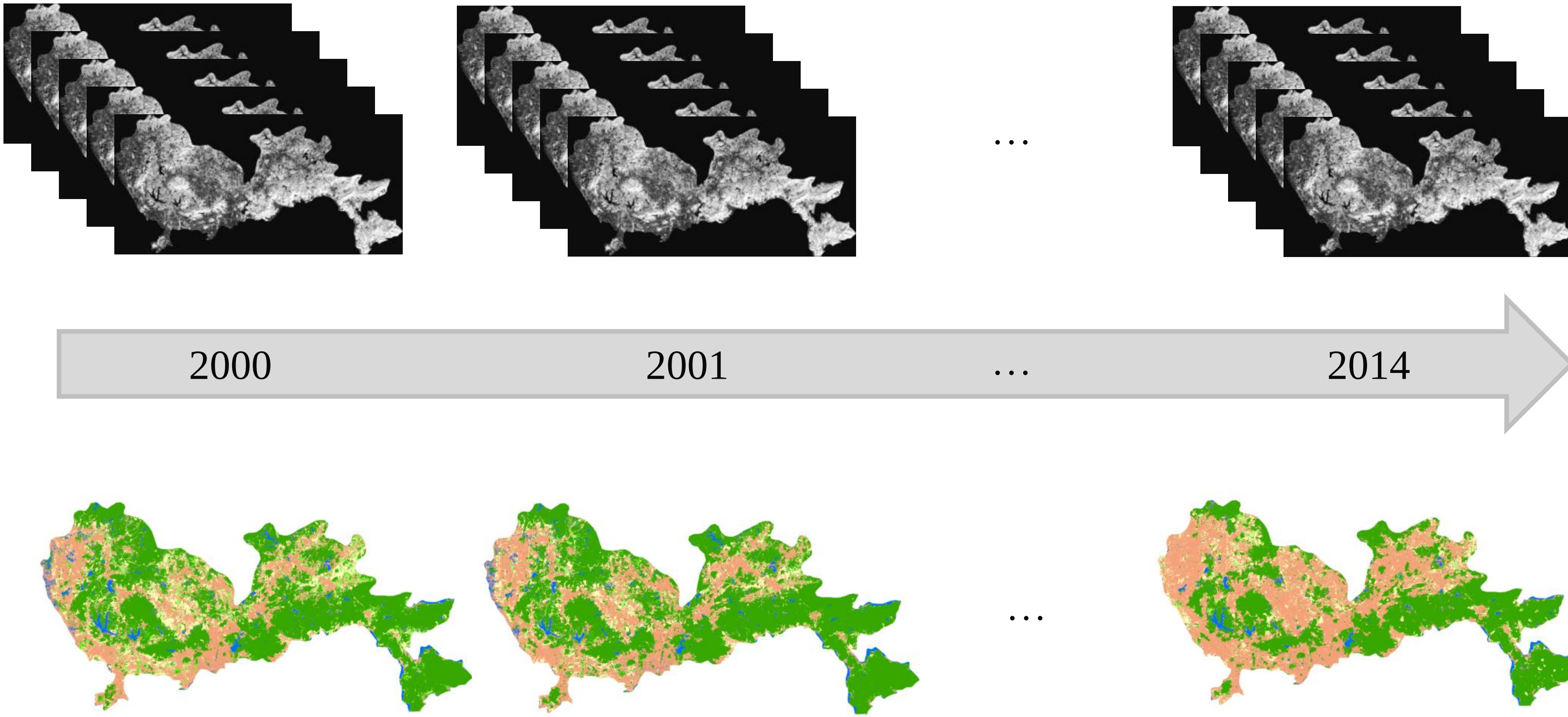
Supervised classification using maximum likelihood/SVMs

Acquired remotely sensed data



15 years data

Continuous Landsat EVI (30 m, 16-day)

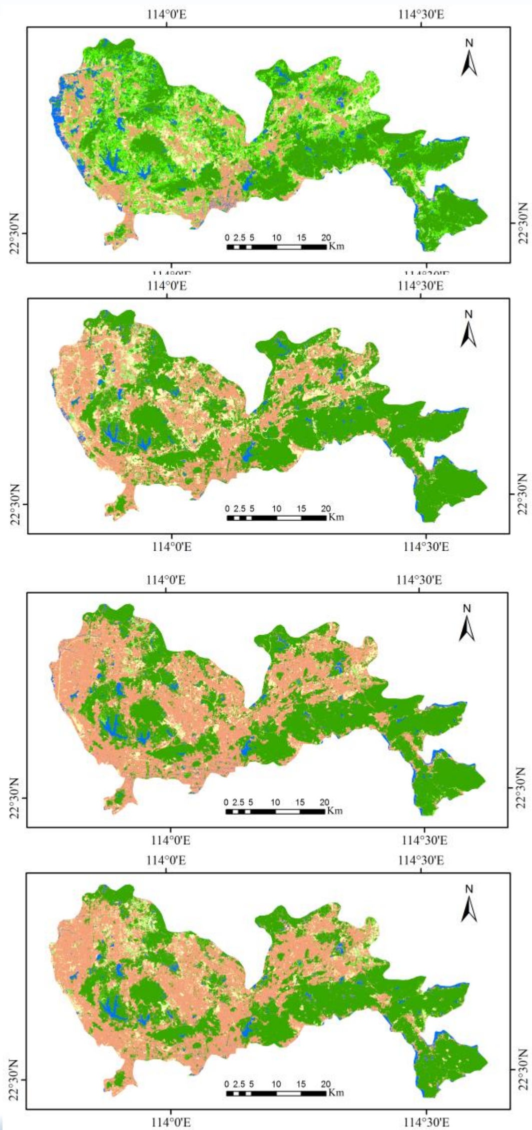


Annual land cover classification map (30 m)

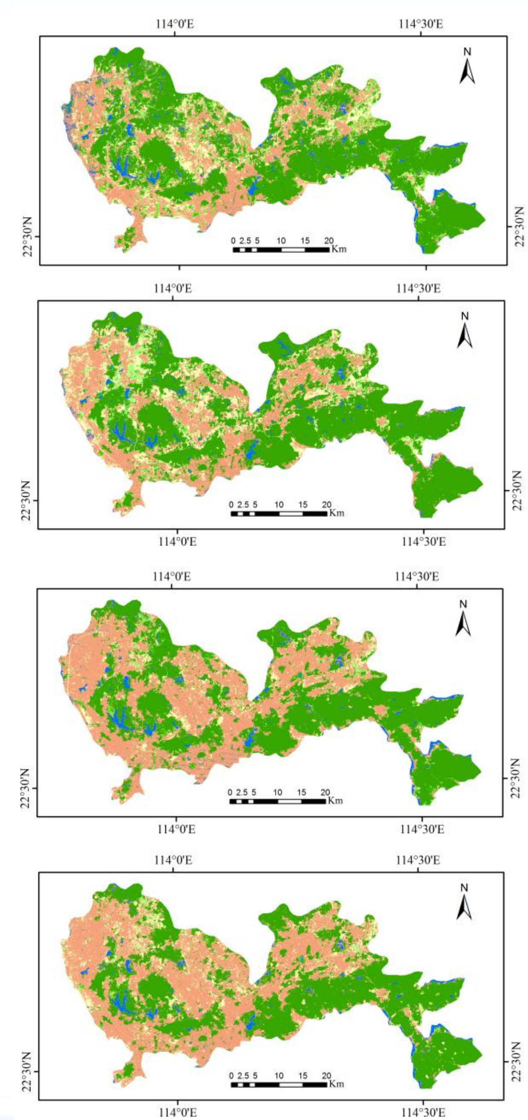
Classification accuracy comparison

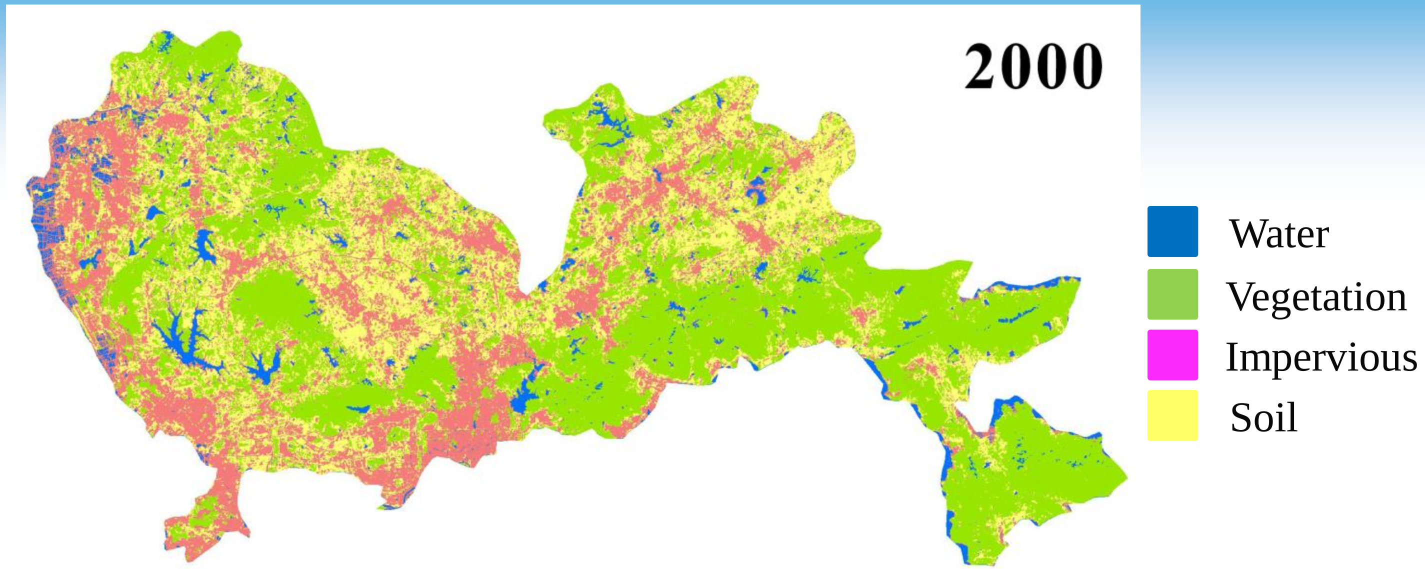
(left) Classification results using Landsat only

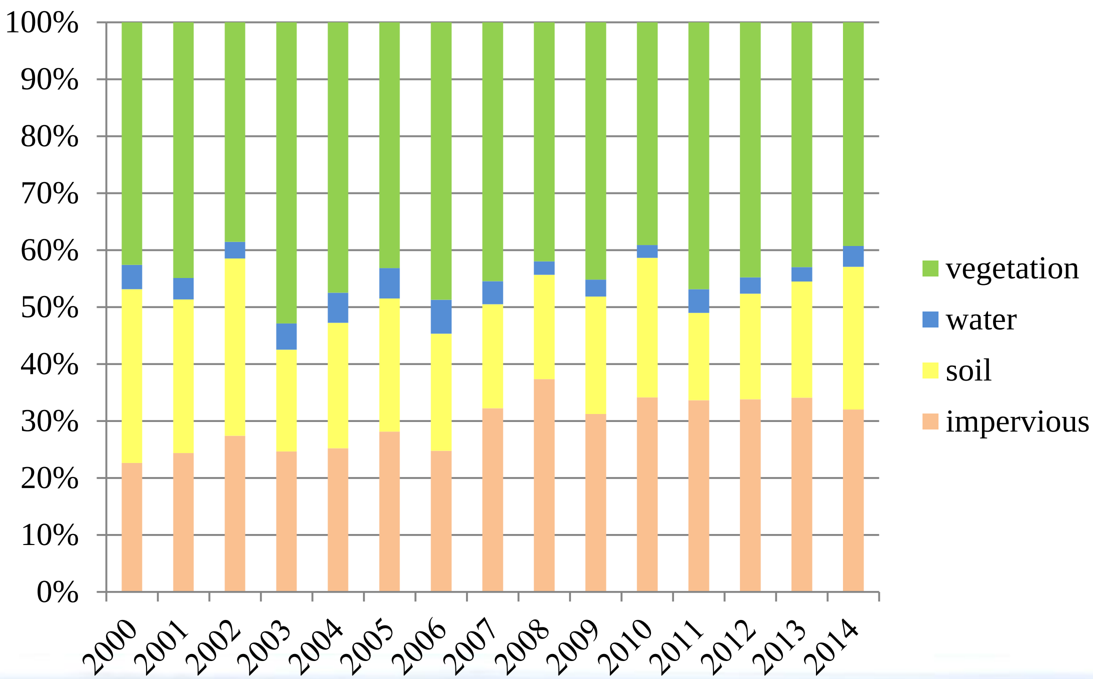
(right) Classification results using fused time-series Landsat data



	Overall accuracy	
2000	**84.2 %**	**91.8 %**
2005	**88.5 %**	**93.6 %**
2010	**86.2 %**	**92.1 %**
2014	**89.5 %**	**94.8 %**







- Impervious urban expands by 10%;
- The fast expansion period is 2000-2002 and 2006-2008;
- Water bodies keep stable;
- The major forest part keeps stable, while other green lands change a lot.

Land Use Change Modeling and Analysis

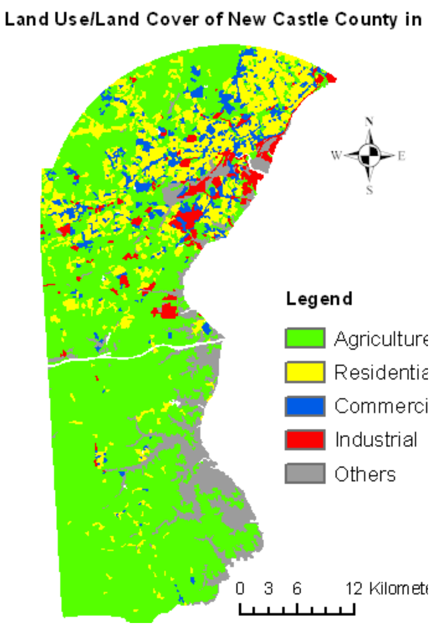
Funded by:
863-Hightech Program of China
Hong Kong Research Grants Council

Change modeling and analysis

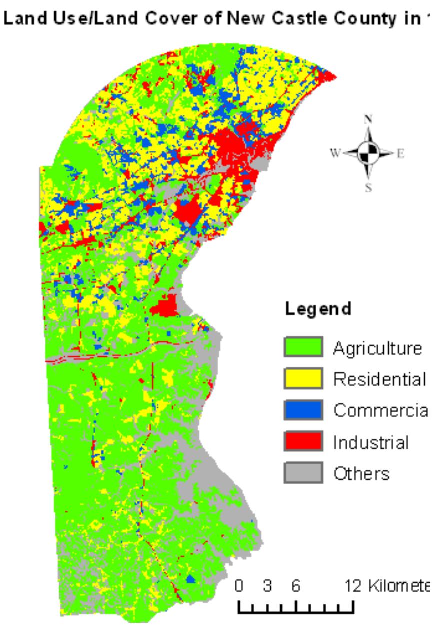
- Seeks to understand the complex spatio-temporal change process

- To identify the factors driving the dynamic processes of change and to explore their relative importance, and to simulate “what-if” decision making under alternative change scenarios

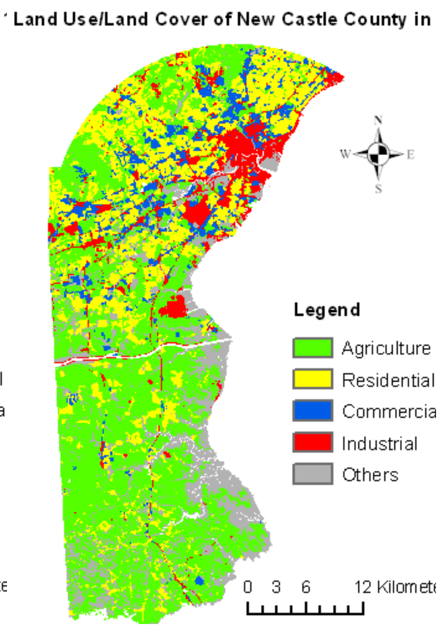
Land Use Change in New Castle County



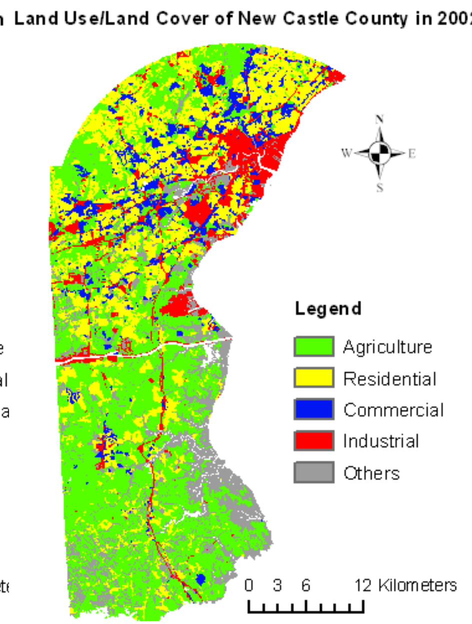
1984



1992

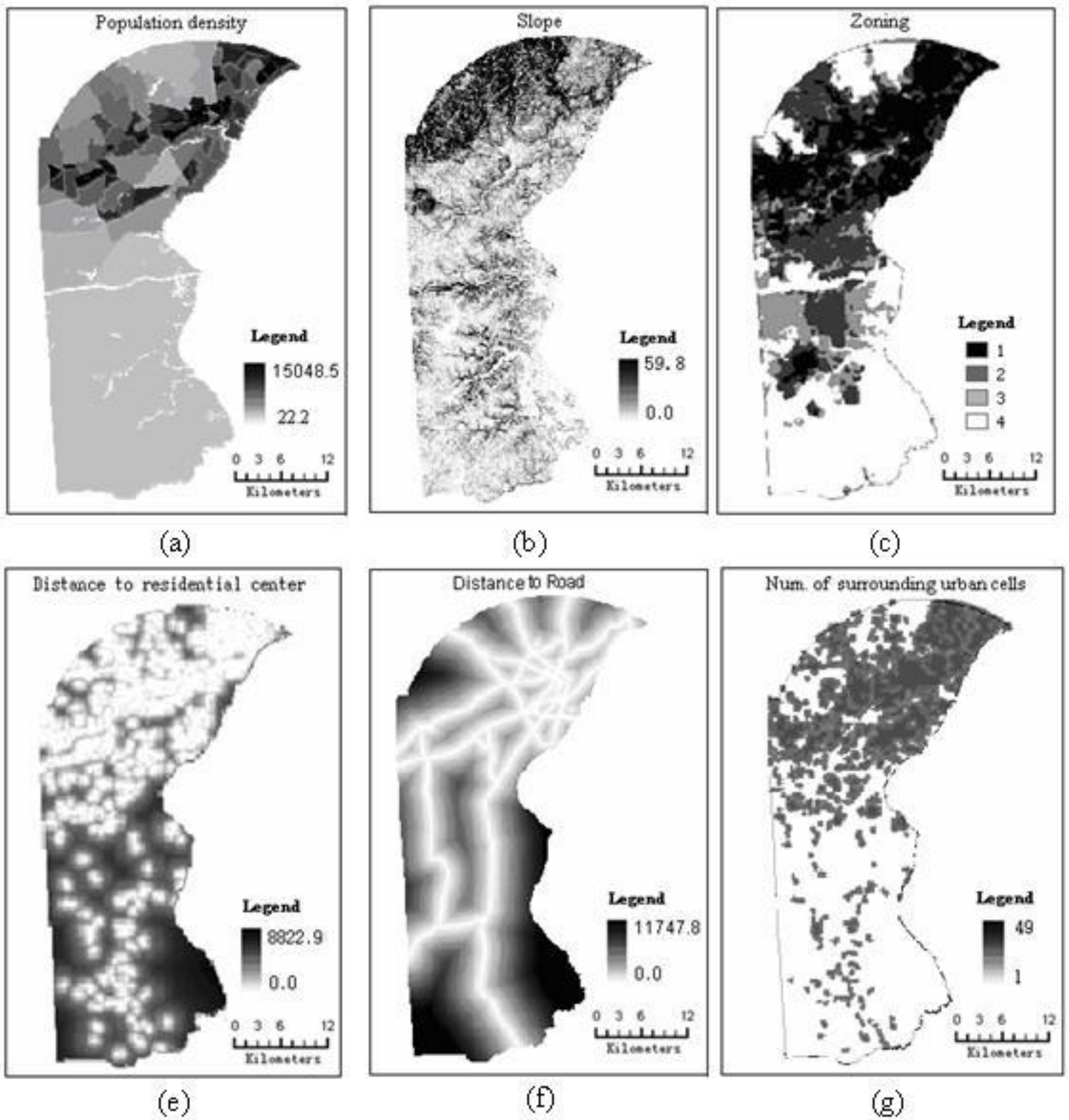


1997



2002

Spatial distribution of predictors



Spatial Logit Model

$$prob(y_{it}^{j}=1)=\frac{\exp(\beta^{j}x_{i,t-1}+\mu_{it}^{j})}{\sum_{j=0}^{J}\exp(\beta^{j}x_{i,t-1}+\mu_{it}^{j})},j=1,\ldots,J;t=1,\ldots.T$$

Category	Variable	Description
Site-specific	Dens_Pop	Population density of the cell
	Slope	Slope of the cell
	Zoning	Zoning plan for development control
Proximity extent	Dist_Com	Distance from the cell to the nearest commercial site
	Dist_Res	Distance from the cell to the nearest residential center
	Dist_Road	Distance from the cell to the nearest road
Neighborhood characteristics	Per_Urb	Percentage of urban land use in the surrounding area

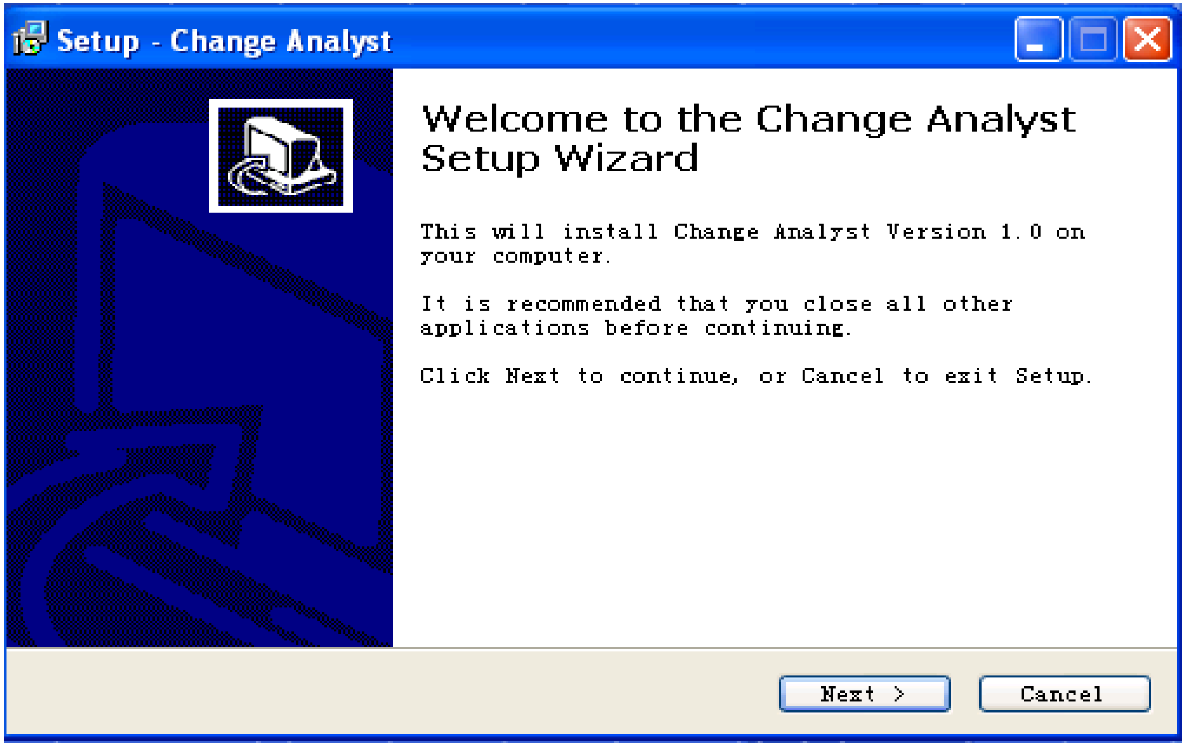
Implementation

- Development of ChangeAnalyst
  - An ArcGIS extension for change analysis and prediction
- Help files
- Friendly user interface
- Available at

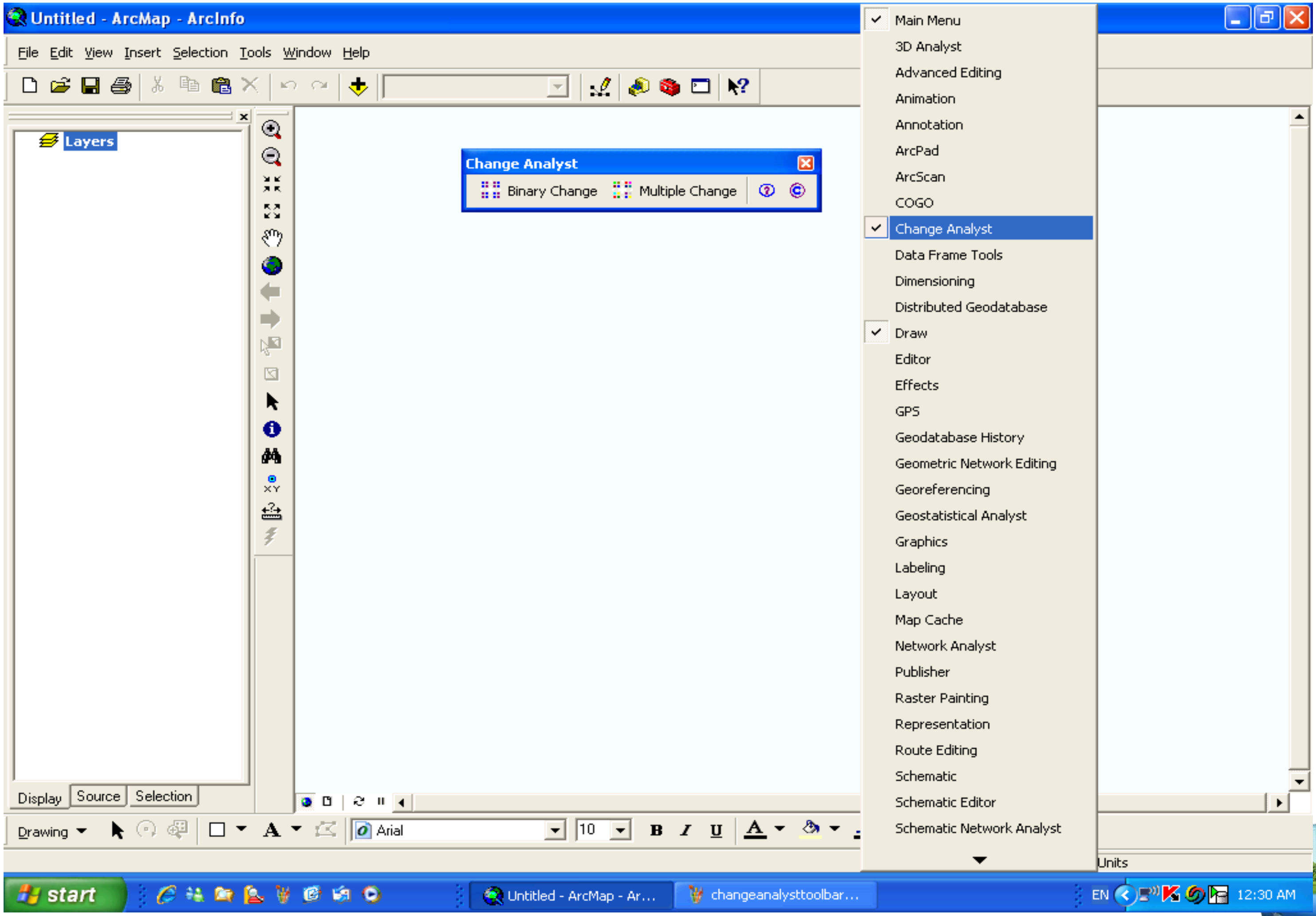
Huang, Bo, Zhang, Li and Wu, Bo (2009) 'Spatiotemporal analysis of rural-urban land conversion', *International Journal of Geographical Information Science*, 23:3,379 — 398

http://www.grm.cuhk.edu.hk/~huang/ChangeAnalyst_setup.exe

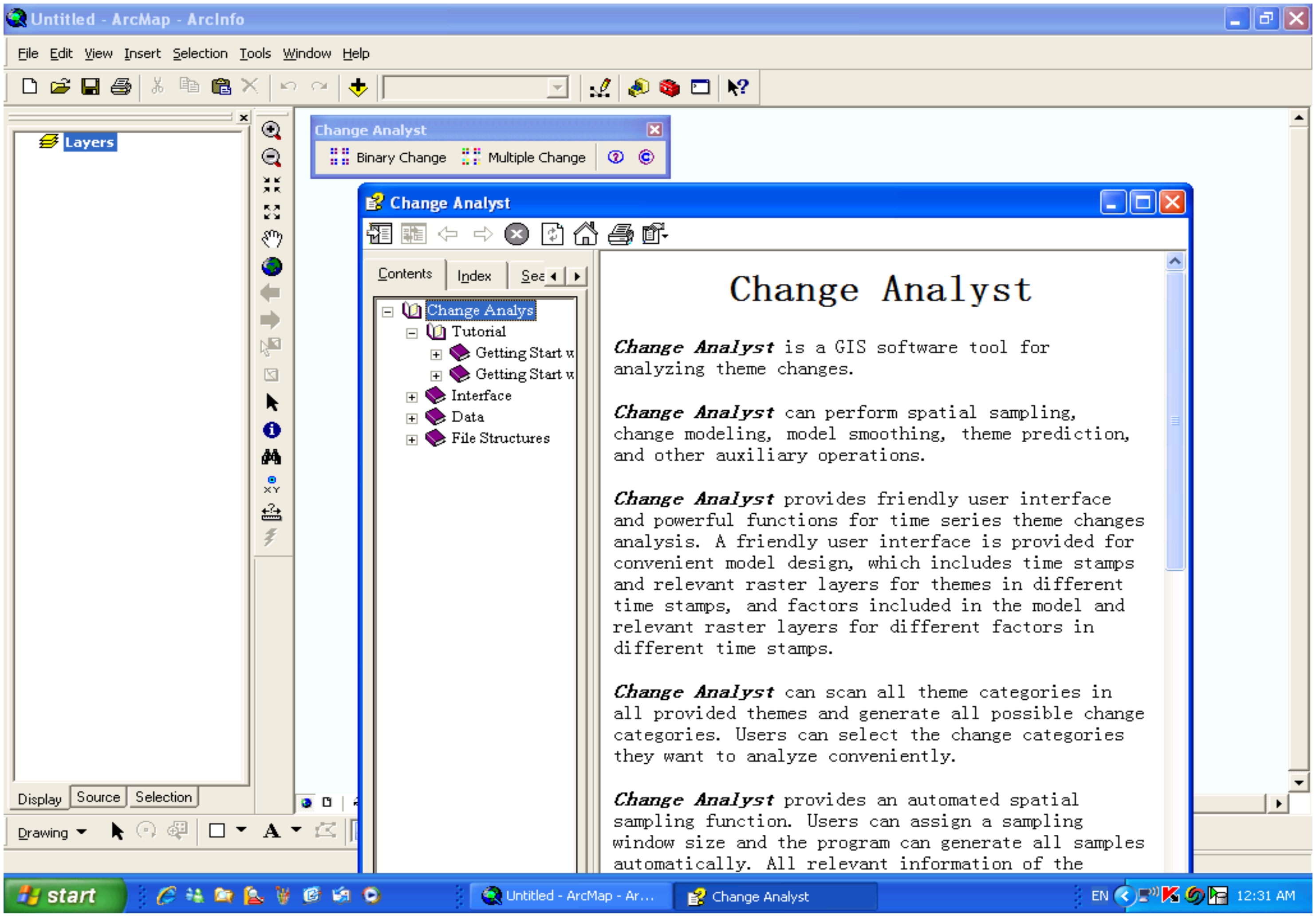
Easy installation (ChangeAnalyst 1.0)



Launching ChangeAnalyst



Help file



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Layers
Change Analyst
Binary Change
Multiple Change
Change Analyst
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Change Analys
Tutorial
Getting Start w
Getting Start w
Interface
Data
File Structures
Change Analyst
Change Analyst is a GIS software tool for analyzing theme changes.
Change Analyst can perform spatial sampling, change modeling, model smoothing, theme prediction, and other auxiliary operations.
Change Analyst provides friendly user interface and powerful functions for time series theme changes analysis. A friendly user interface is provided for convenient model design, which includes time stamps and relevant raster layers for themes in different time stamps, and factors included in the model and relevant raster layers for different factors in different time stamps.
Change Analyst can scan all theme categories in all provided themes and generate all possible change categories. Users can select the change categories they want to analyze conveniently.
Change Analyst provides an automated spatial sampling function. Users can assign a sampling window size and the program can generate all samples automatically. All relevant information of the
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Change Analyst
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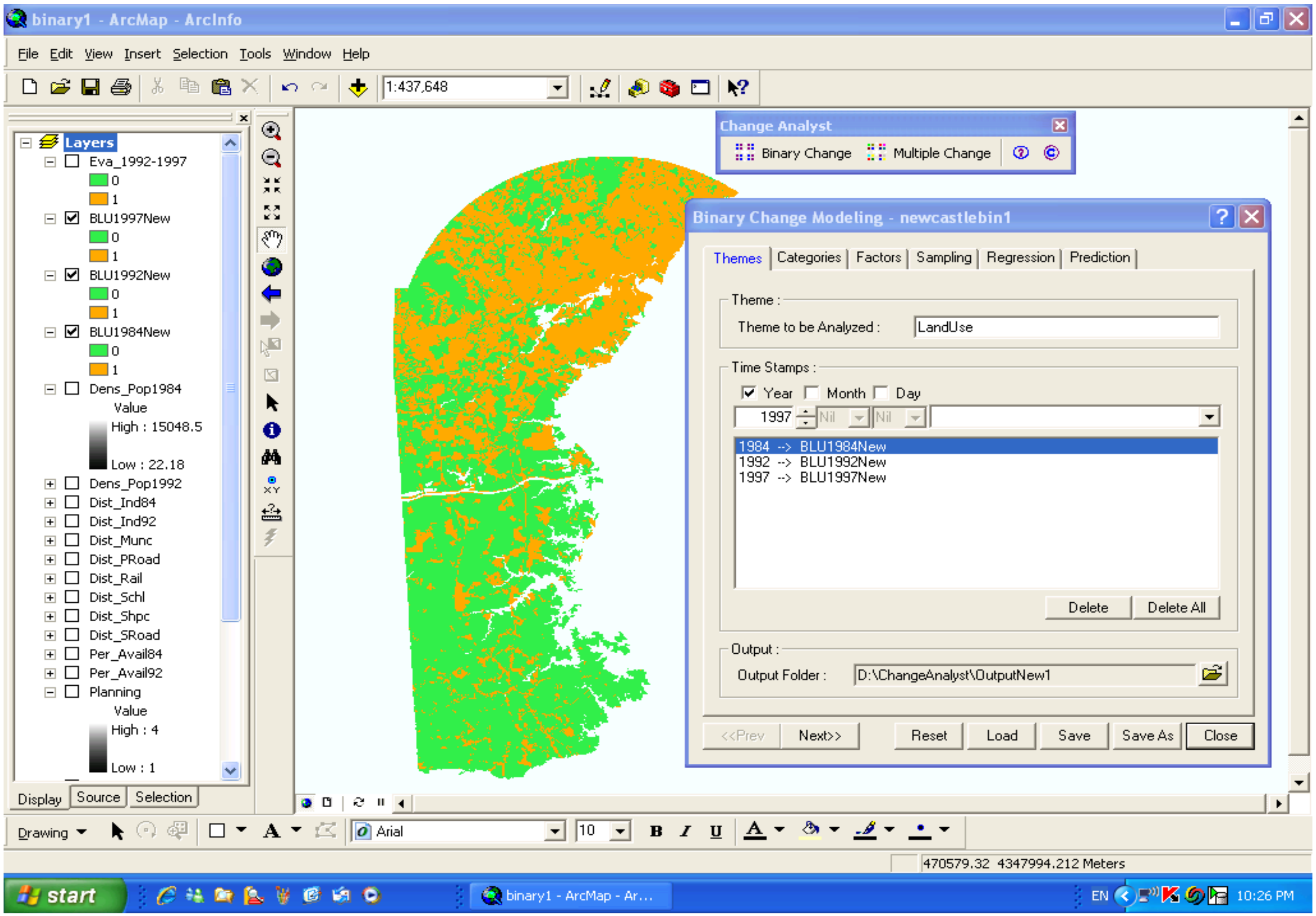
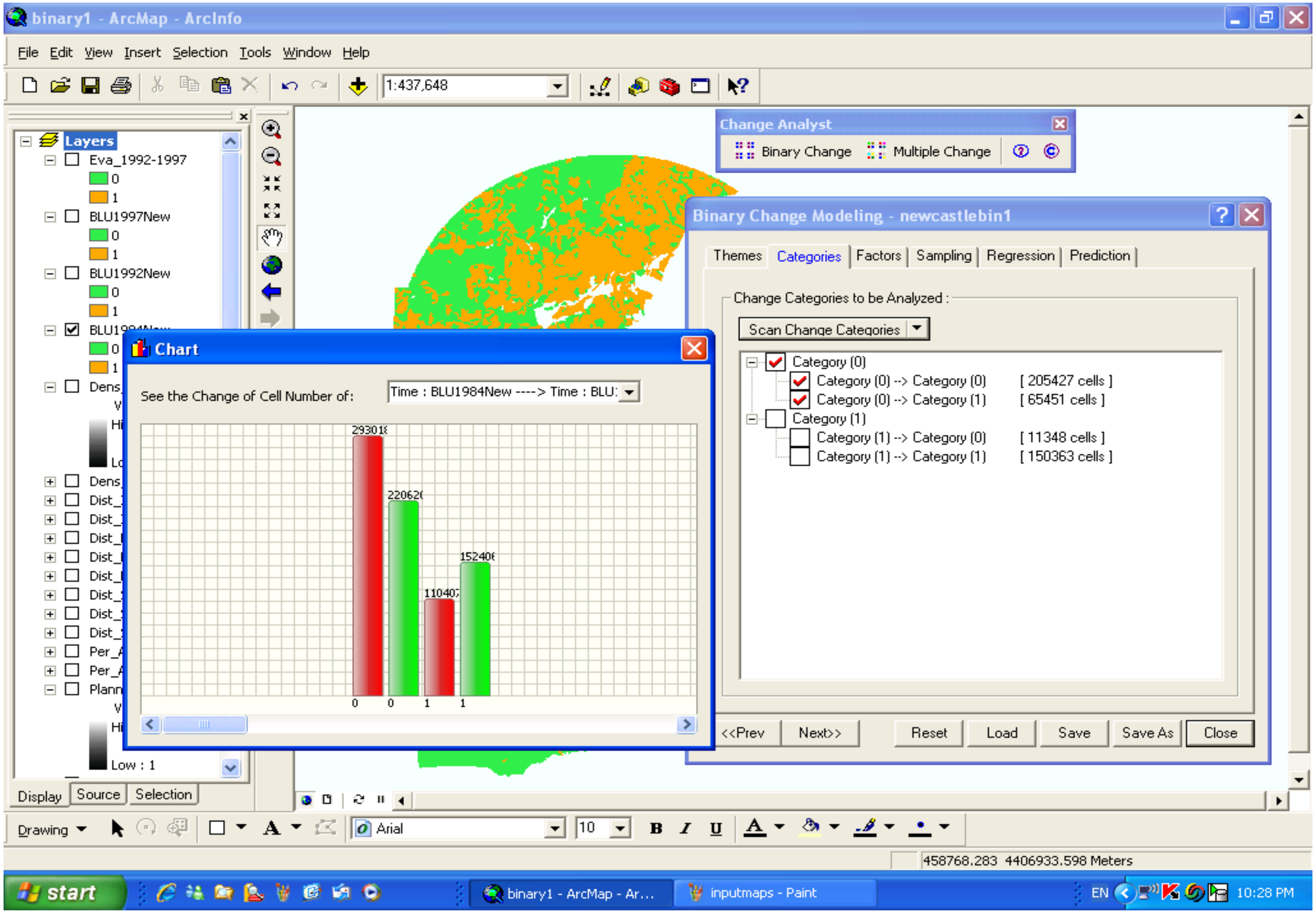
A binary change application
- Urban sprawl in Newcastle County

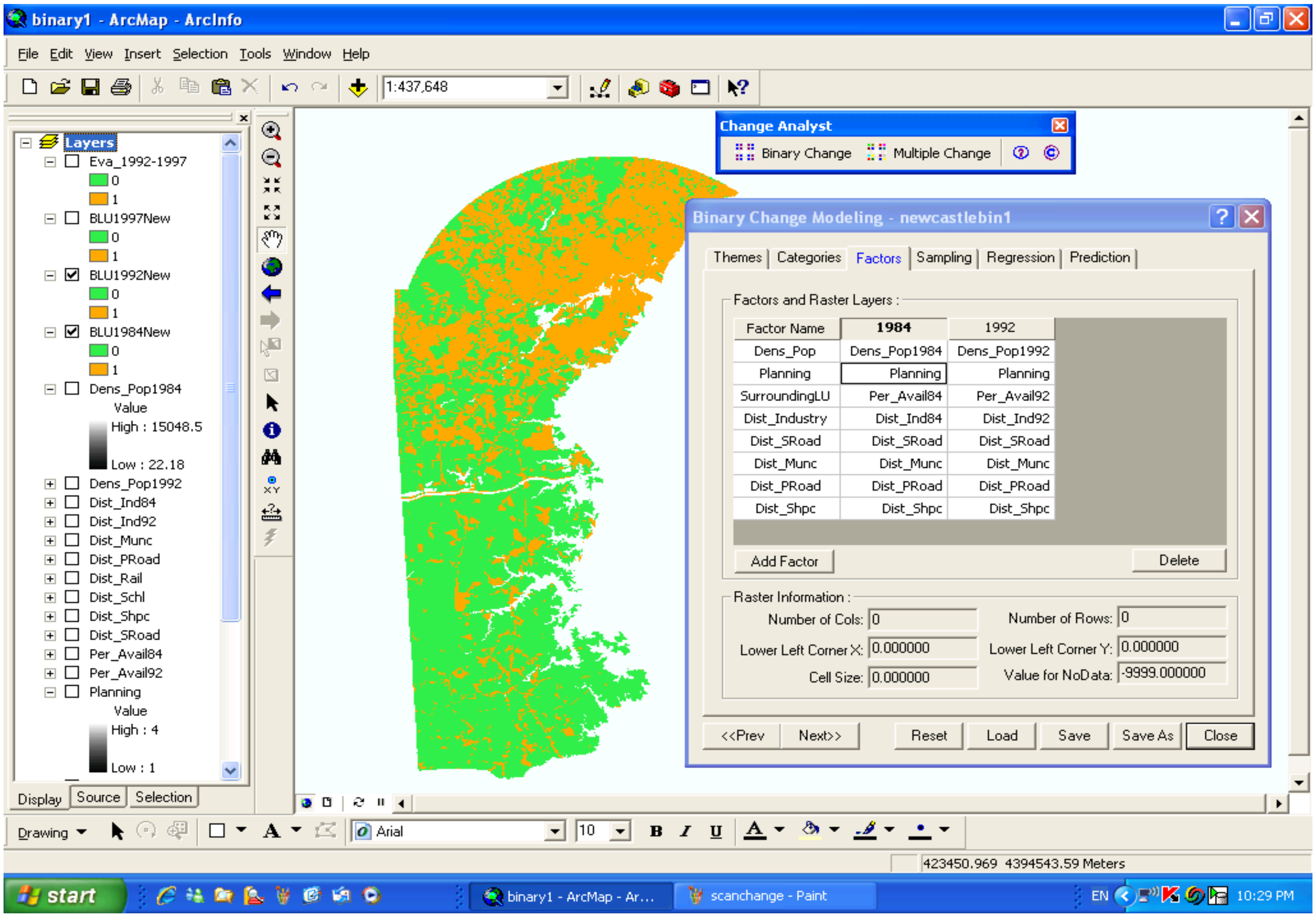
Input time-series maps



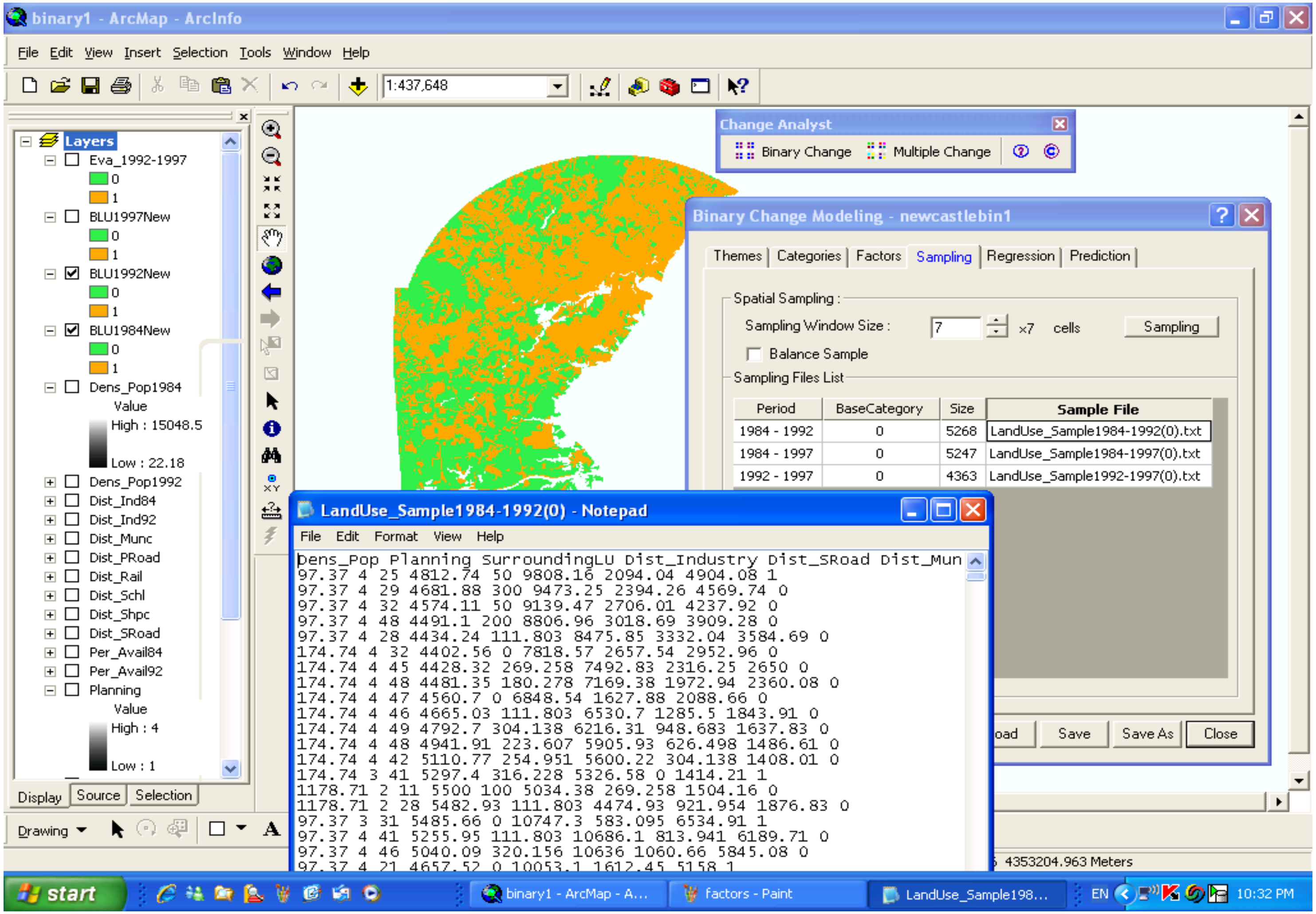
Scanning of changes



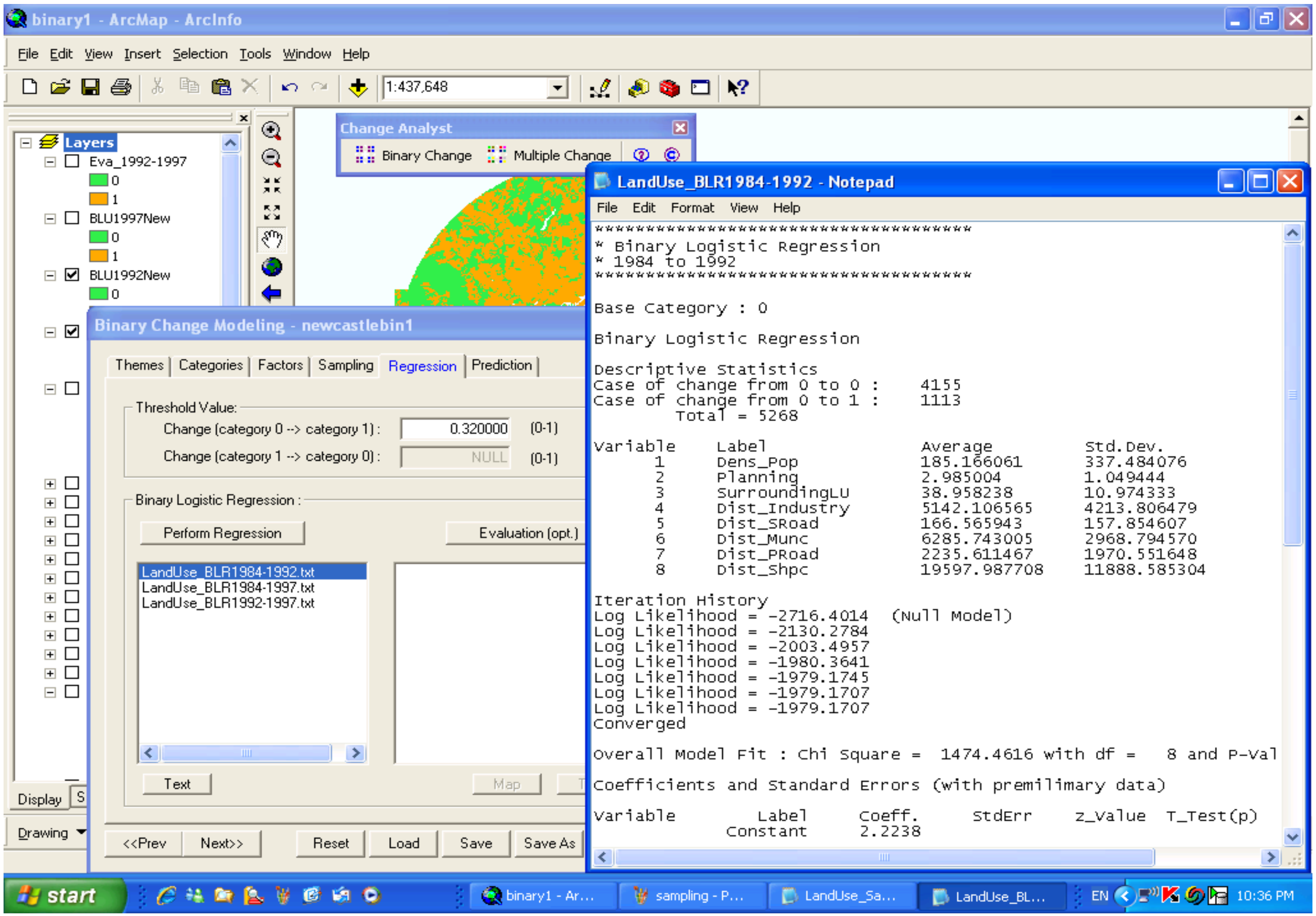
Input causal factors



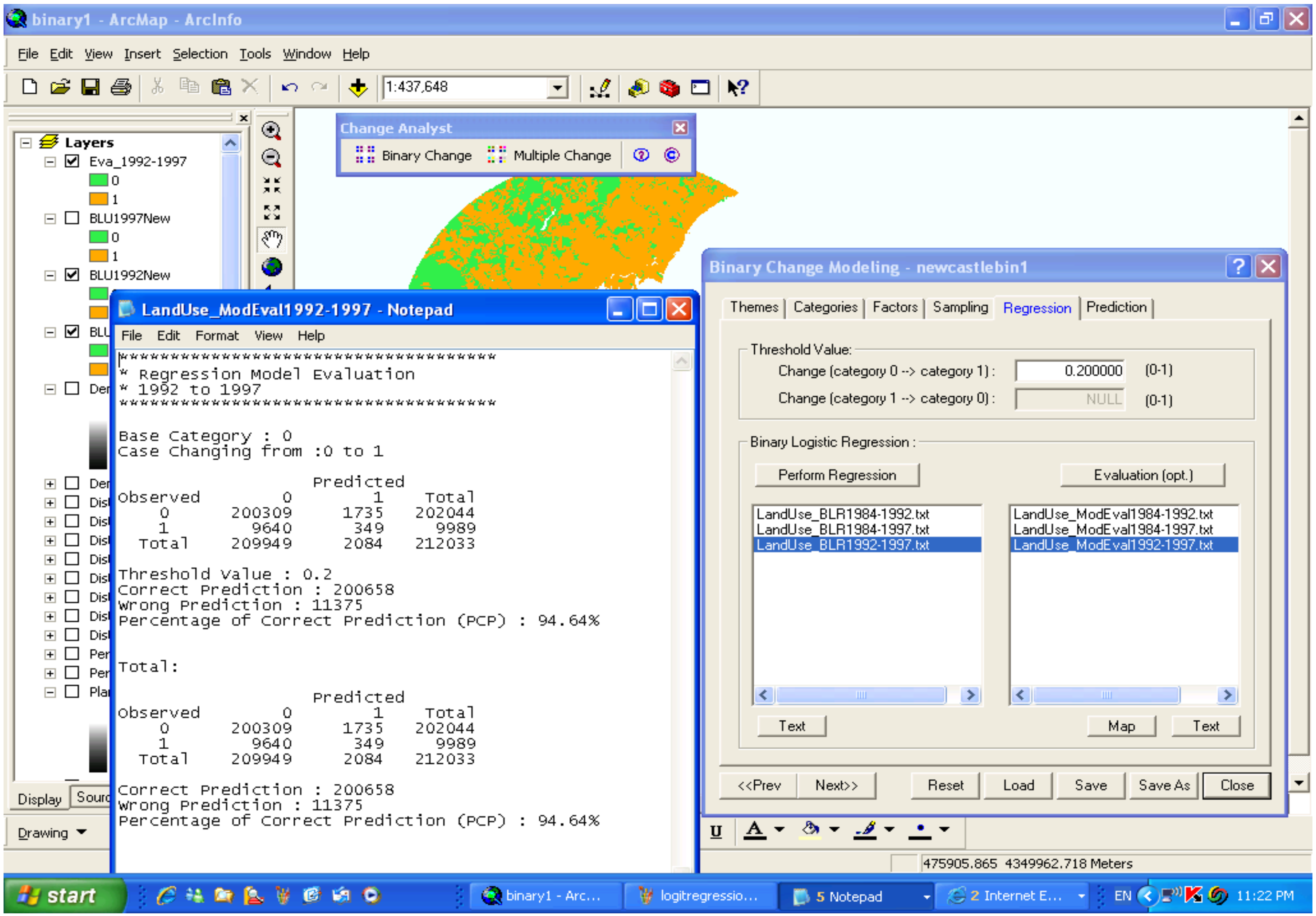
Spatial sampling



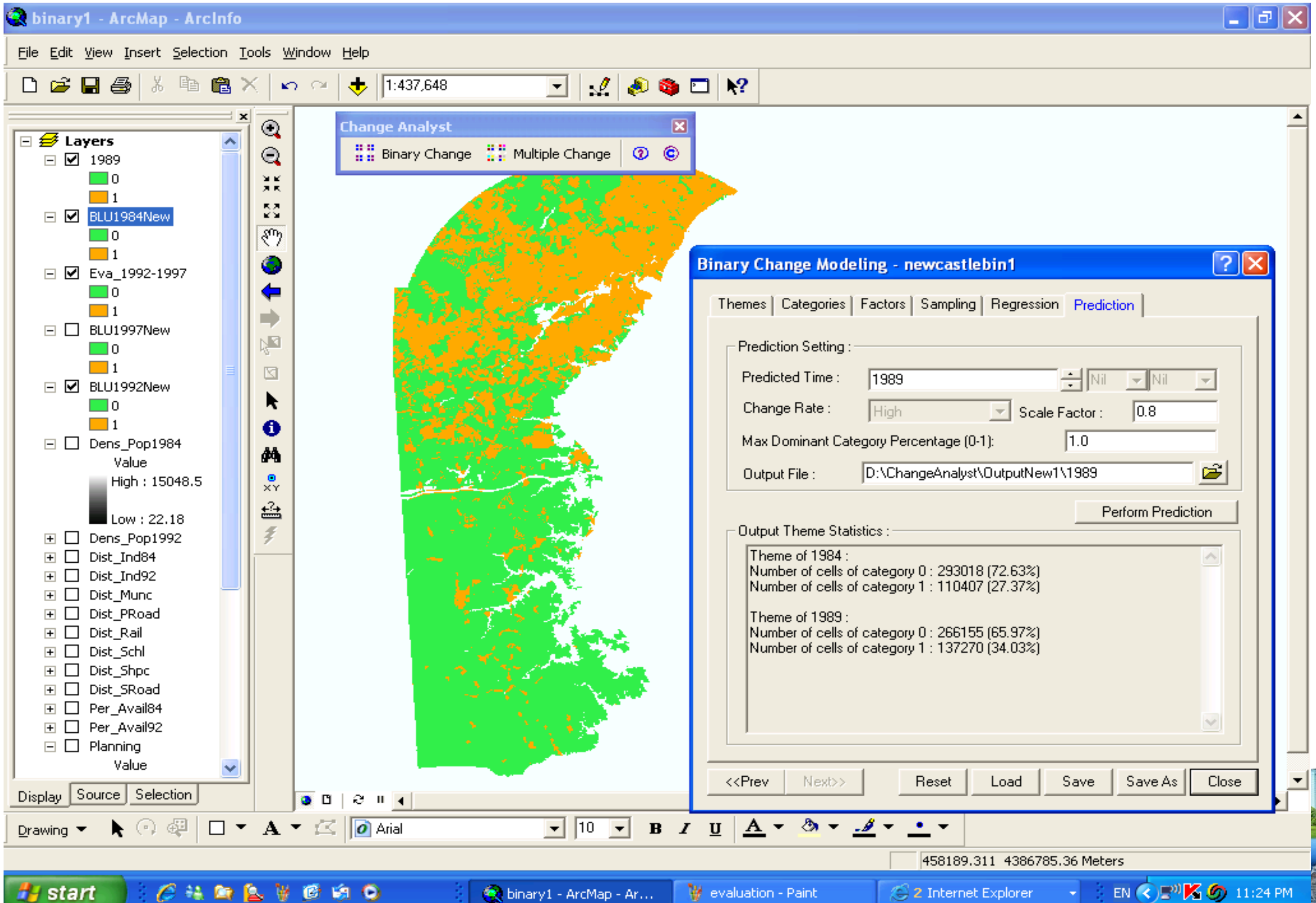
Regression modeling of changes



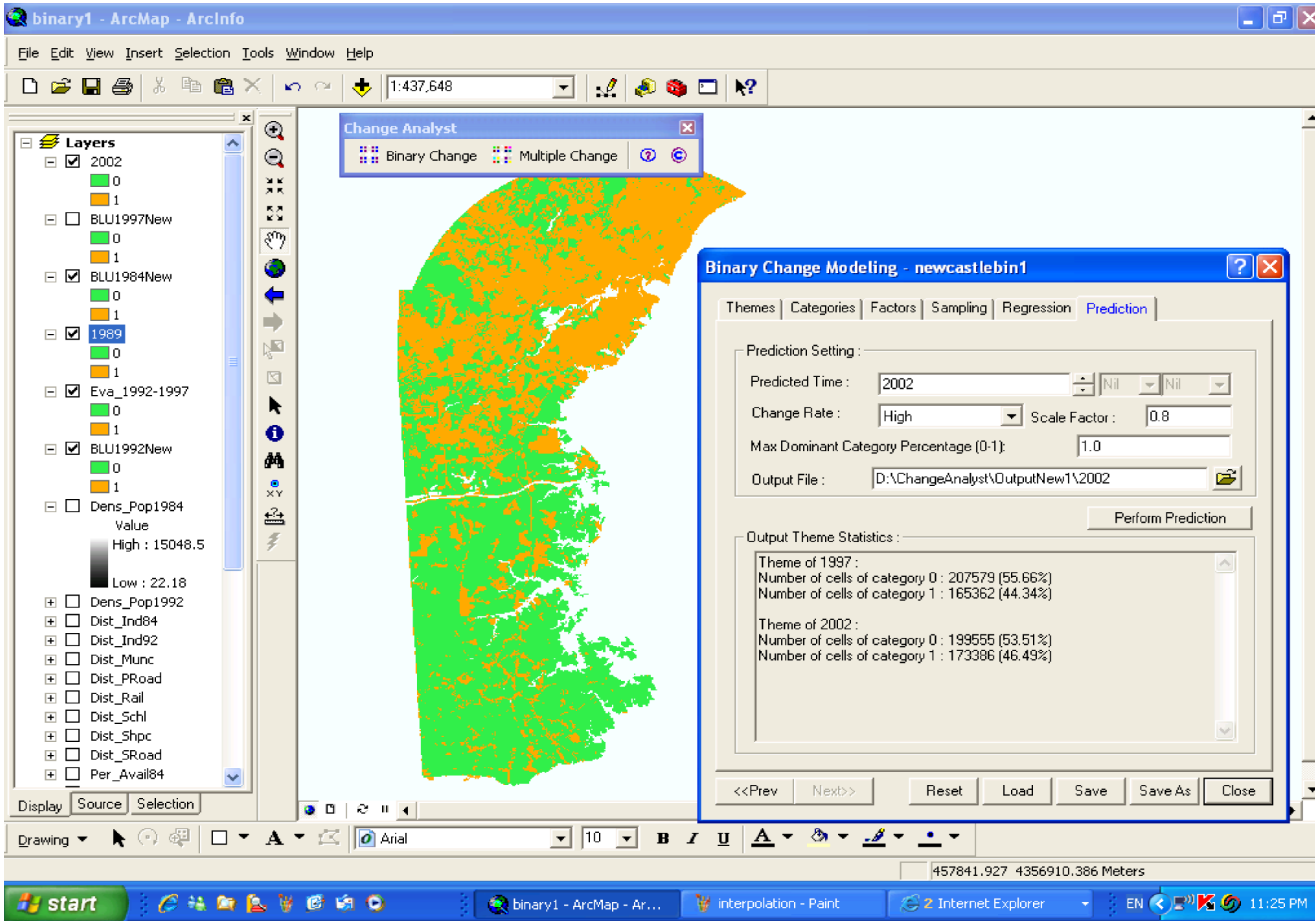
Evaluation of regression models



Interpolation of a theme
(time in between input times)



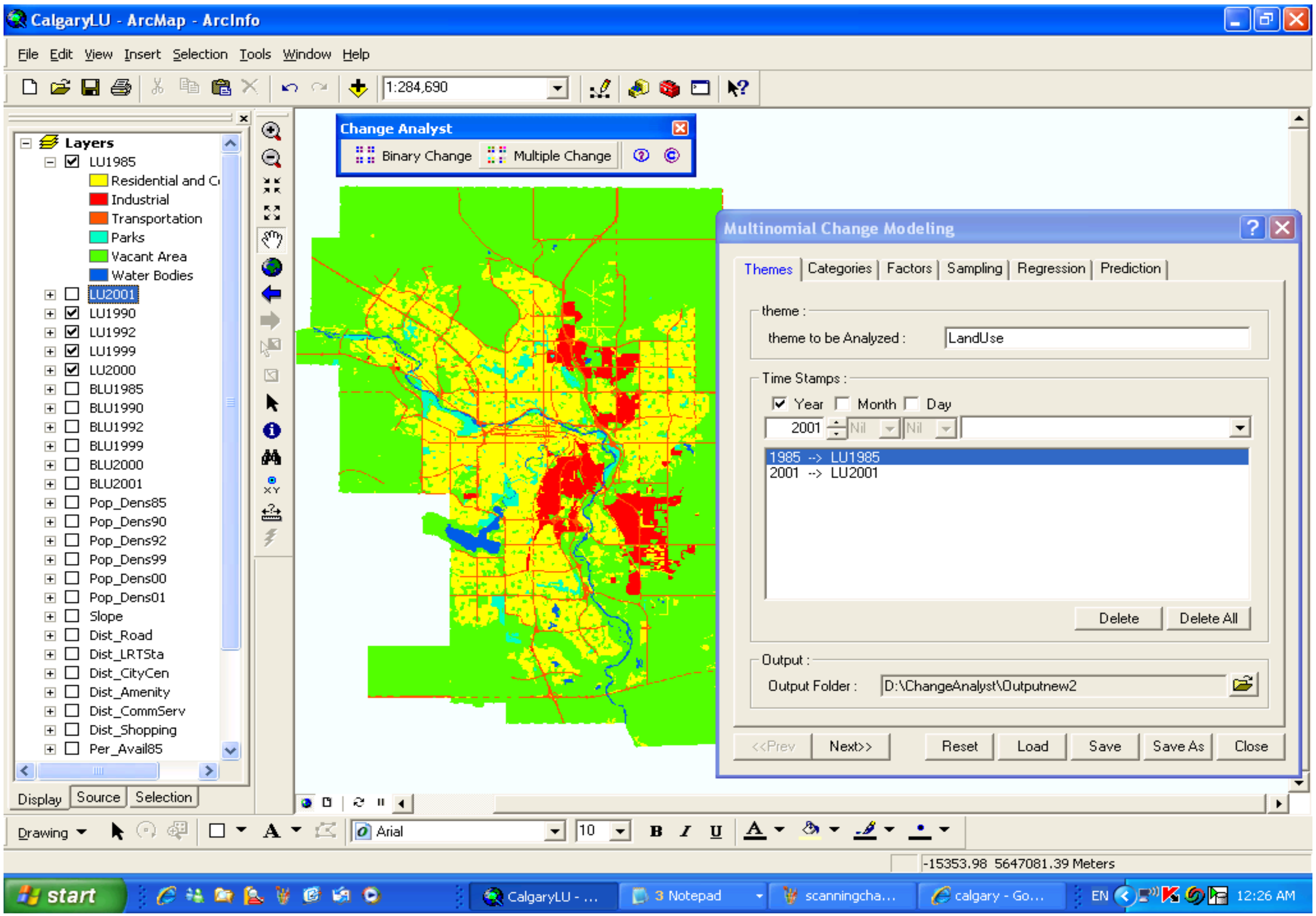
Forecasting a future theme



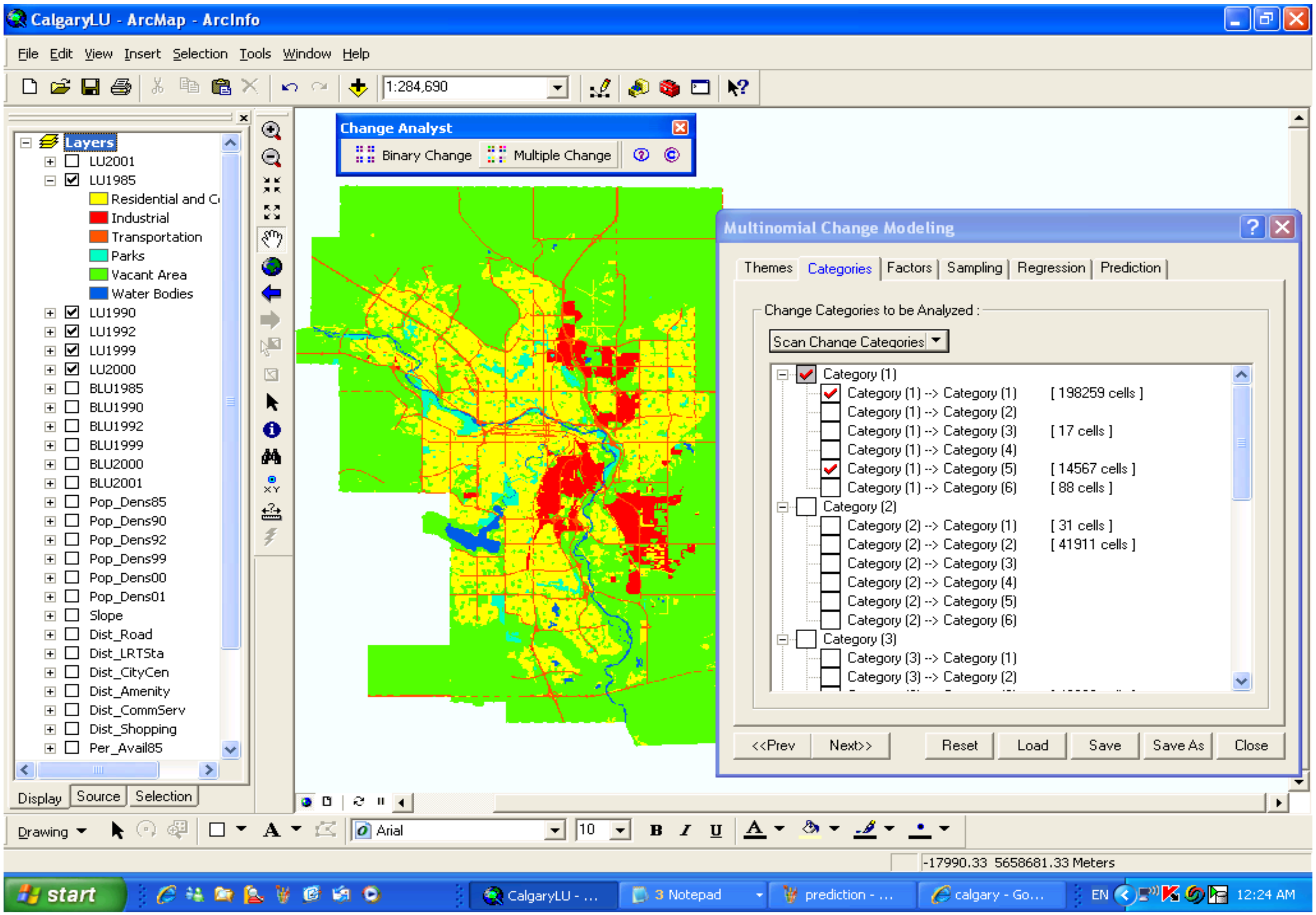
A multinomial change application

- Land use change in Calgary

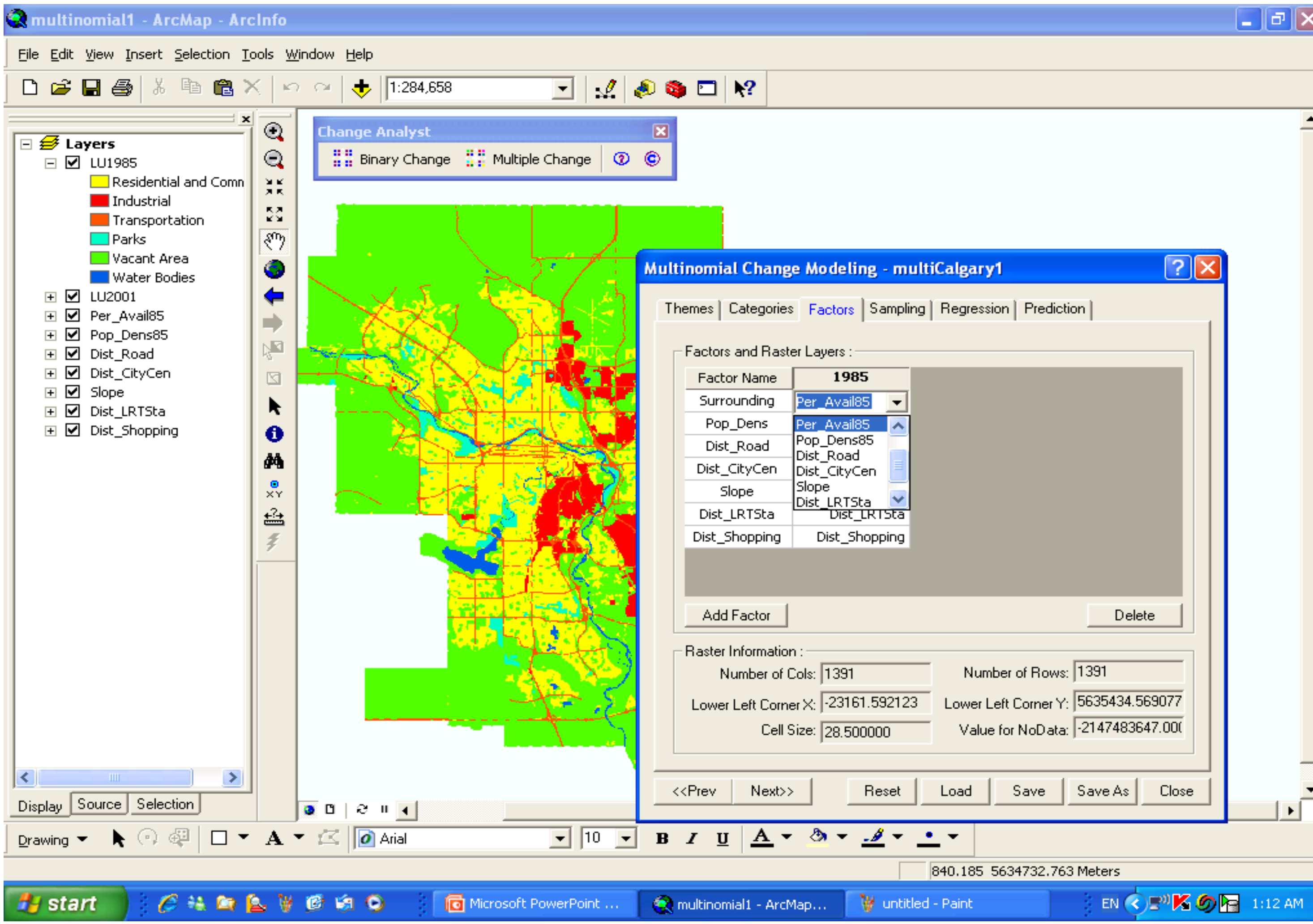
Input of multi-temporal multinomial themes



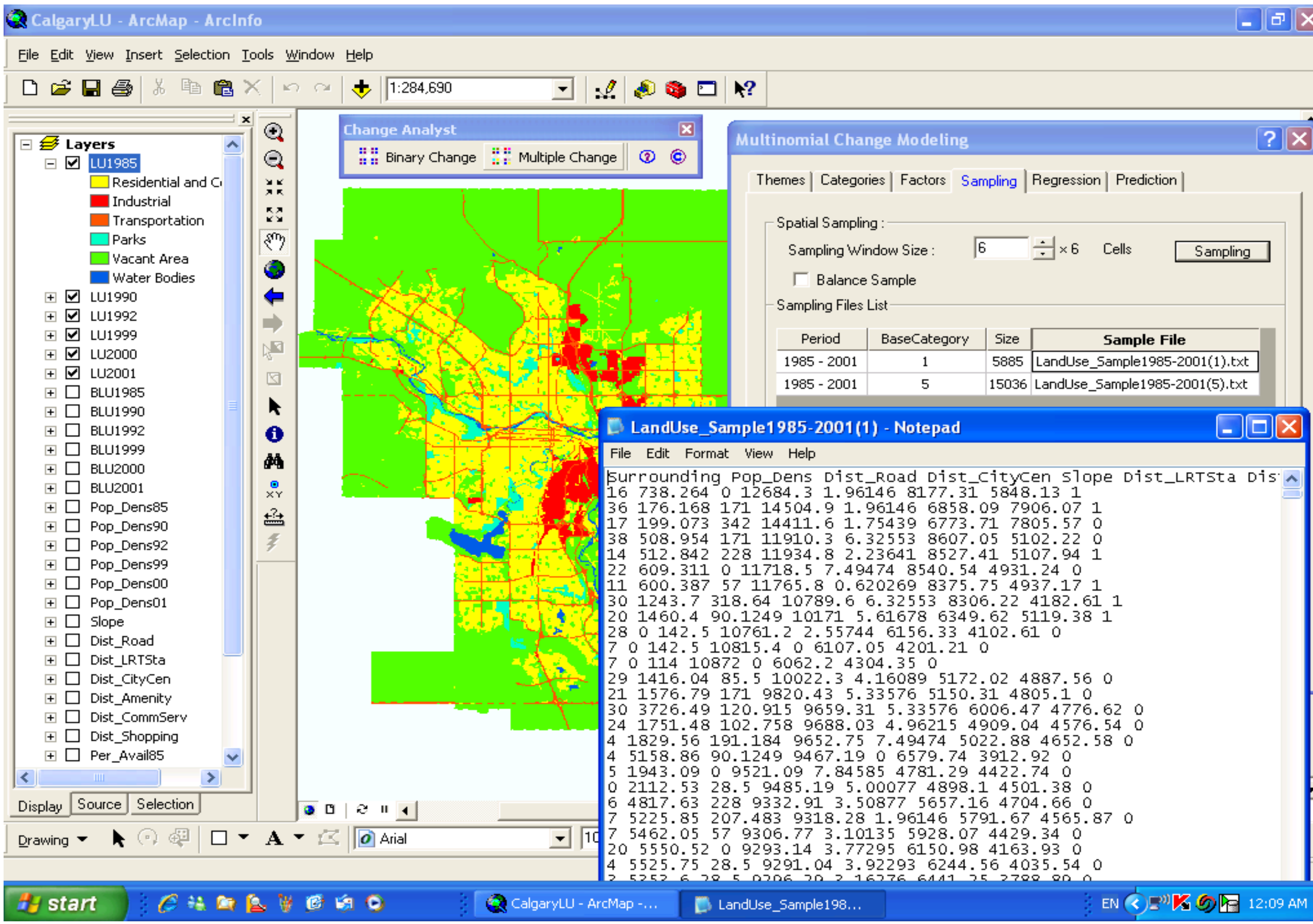
Scanning of multinomial change



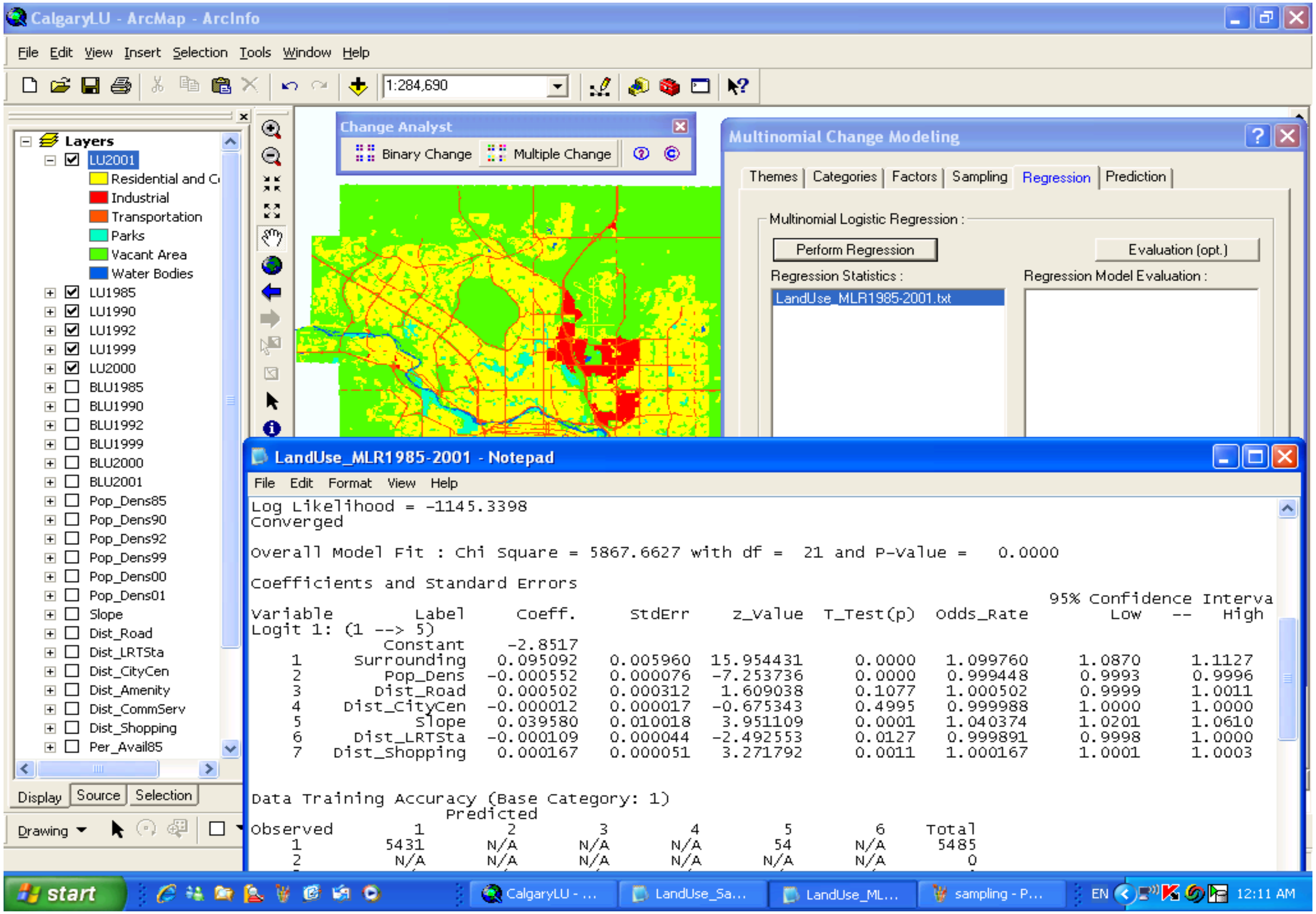
Selection of factors



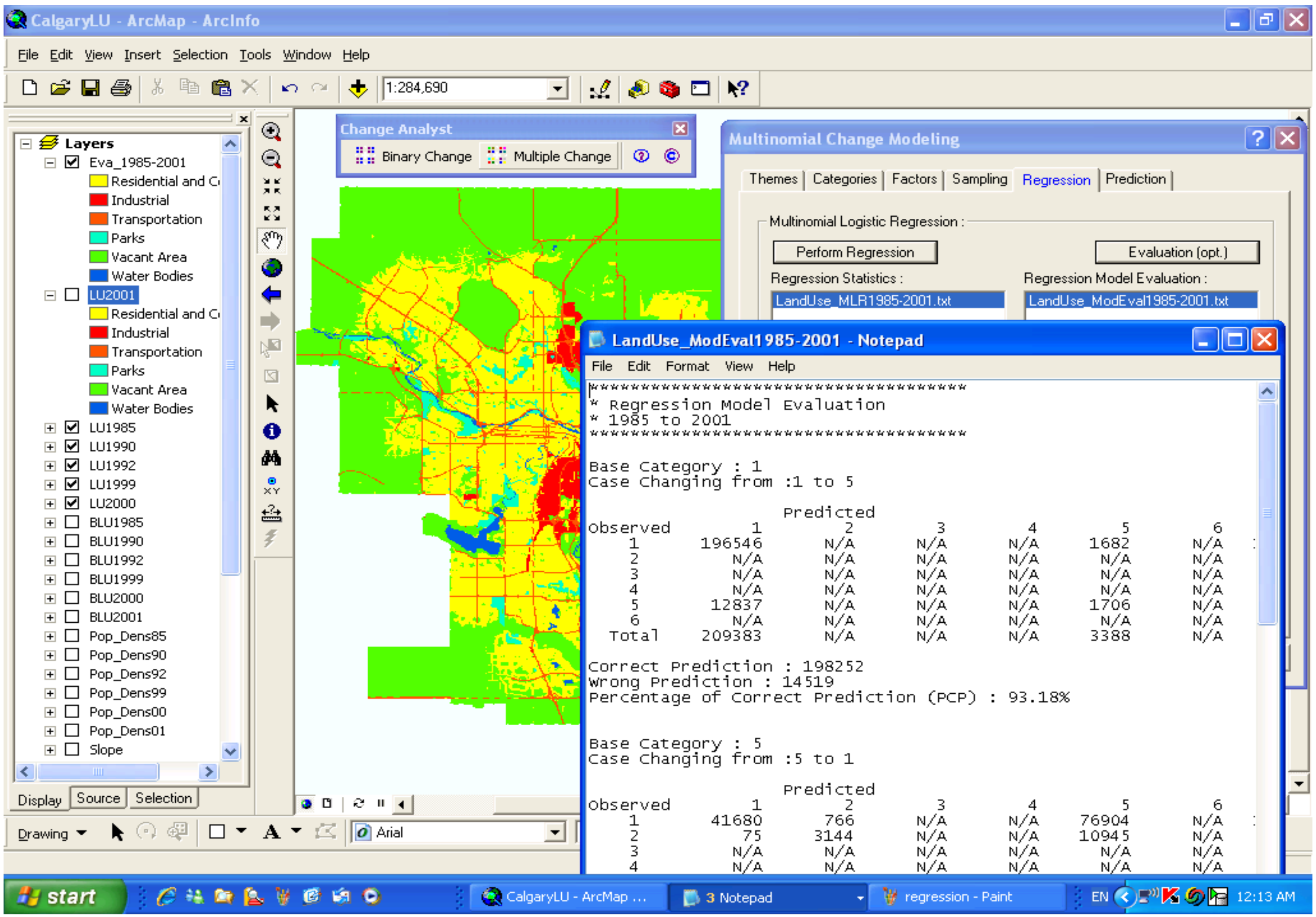
Multinomial change sampling



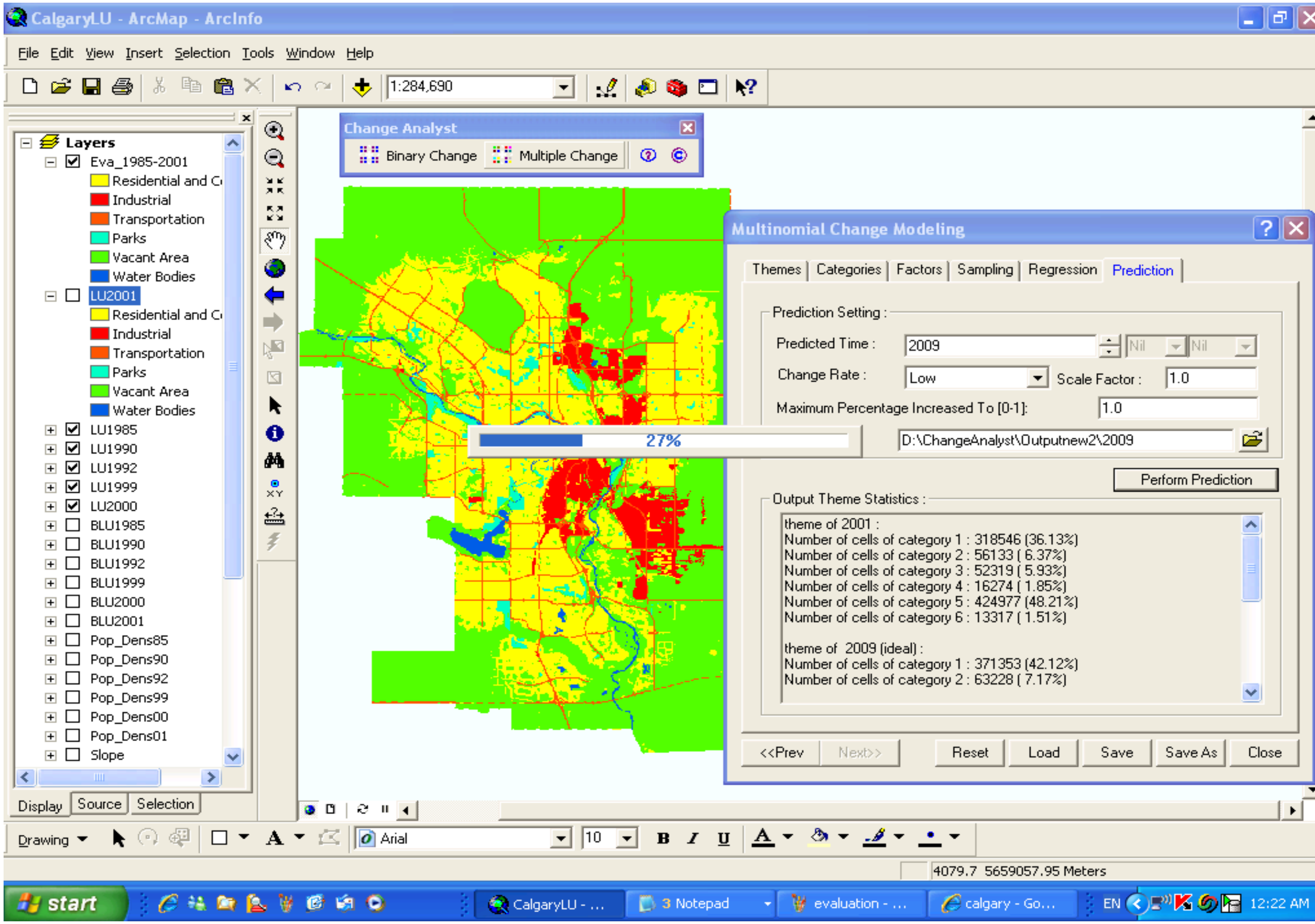
Multinomial regression modeling



Evaluation of regression model



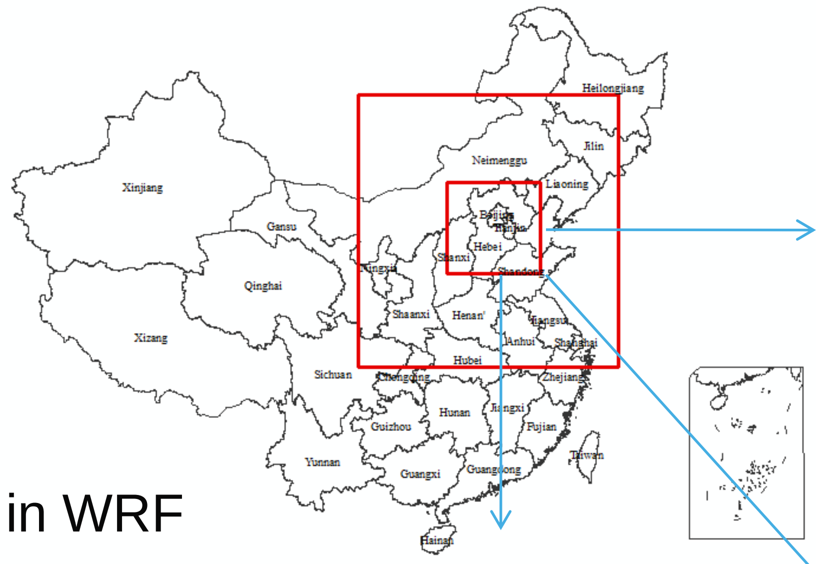
Prediction of a future theme

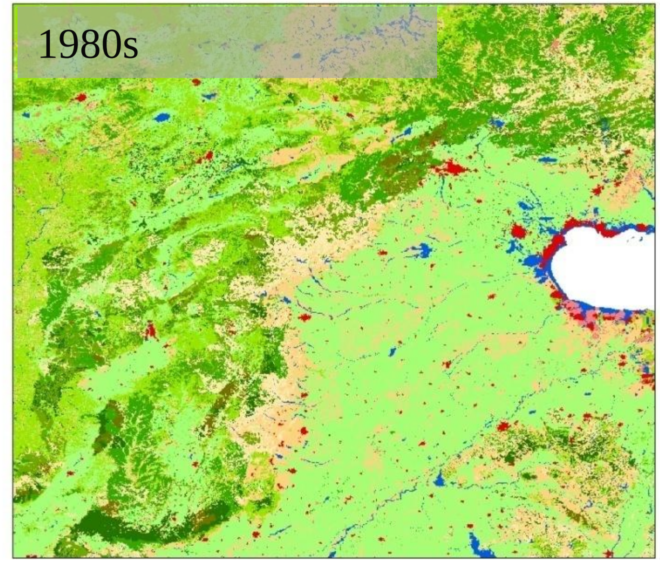


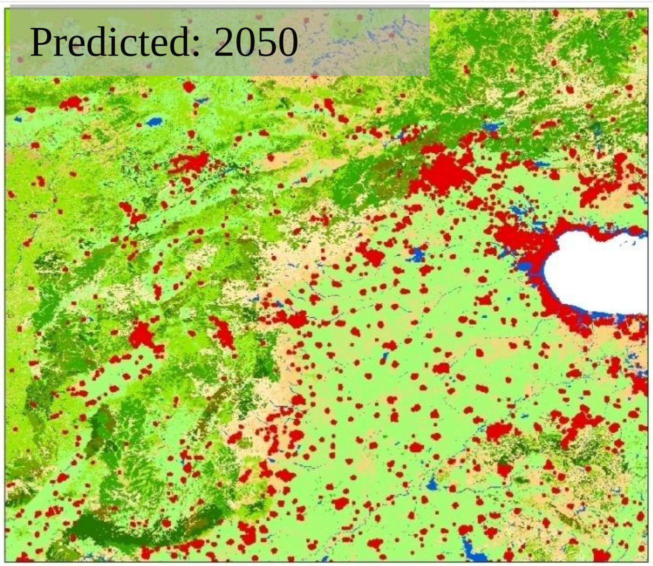
Land Use Change Impact Analysis

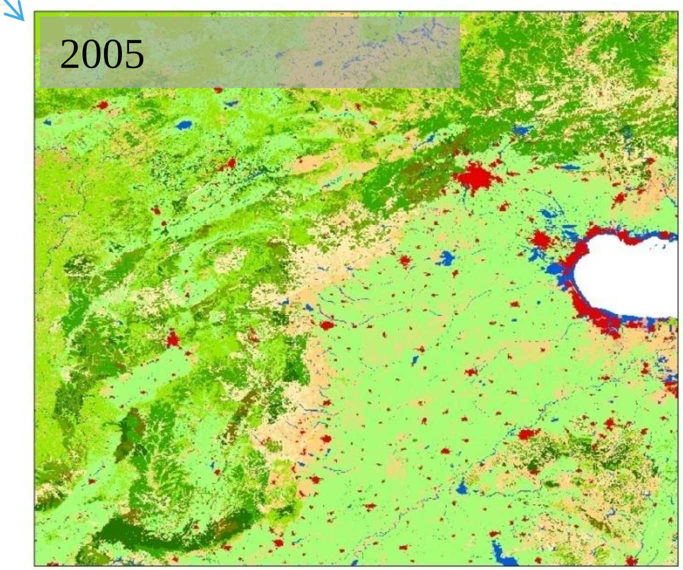
Wang, J., Huang, B., Zhang, X. Z., Fu, D. J. and Atkinson, P. M., 2016. Response of urban heat island to future urban expansion over the Beijing-Tianjin-Hebei metropolitan area. Accepted for publication in *Applied Geography*.

Nested design in WRF







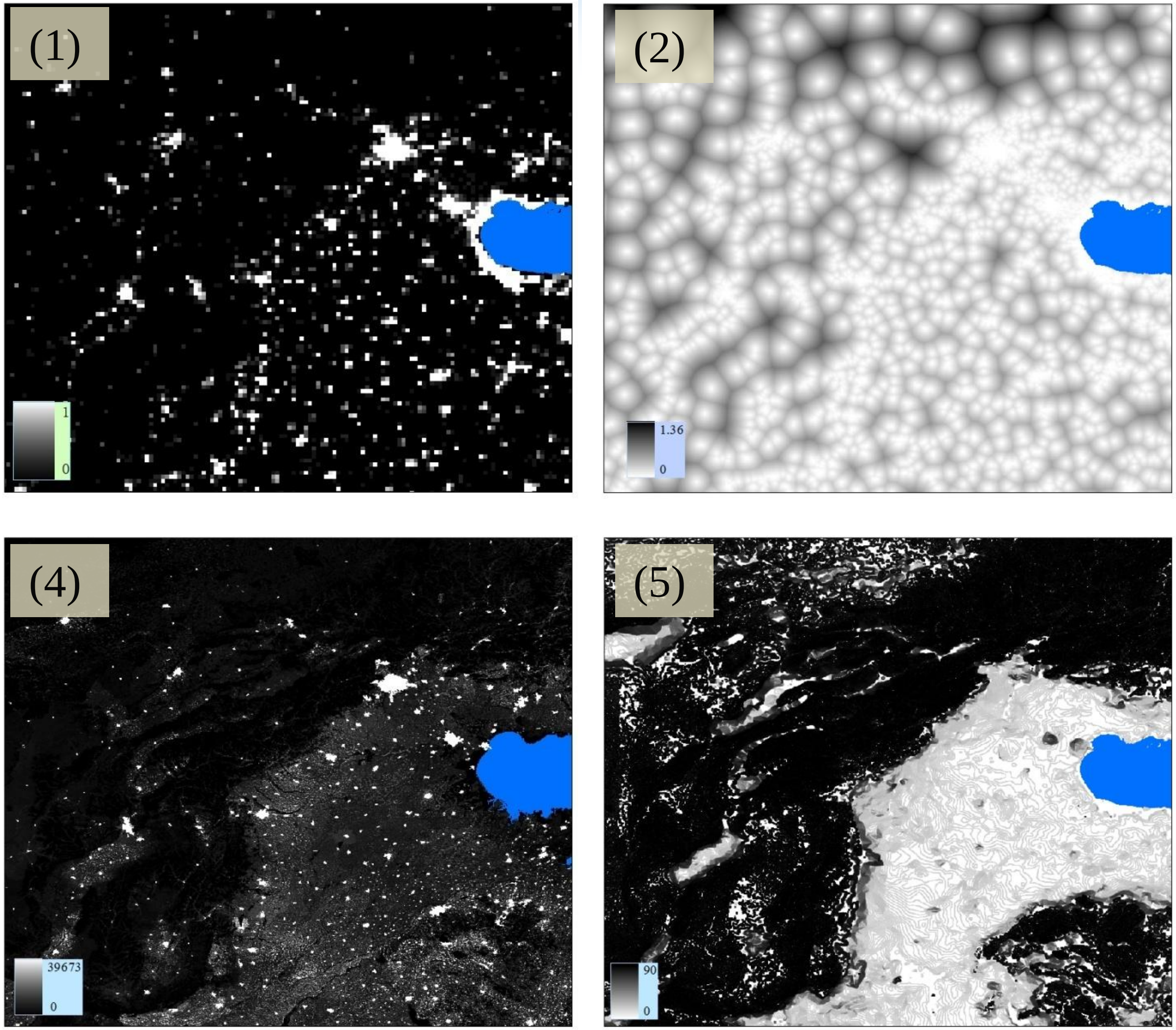


Urban and Built-up Land
Dryland Cropland and Pasture
Irrigated Cropland and Pasture
Cropland/Grassland Mosaic
Cropland/Woodland Mosaic
Grassland
Shrubland
Savanna
Deciduous Broadleaf Forest
Deciduous Needleleaf Forest
Evergreen Broadleaf
Evergreen Needleleaf
Mixed Forest
Water Bodies
Herbaceous Wetland
Barren or Sparsely Vegetated
Wooded Tundra
Mixed Tundra

LULC Source:

1980s/2005: IGSNRR,CAS

2050: Change Analyst Model (Huang, 2009)



Factors for predicting LULC in 2050 using Change AnalysisTools (Huang, 2009)

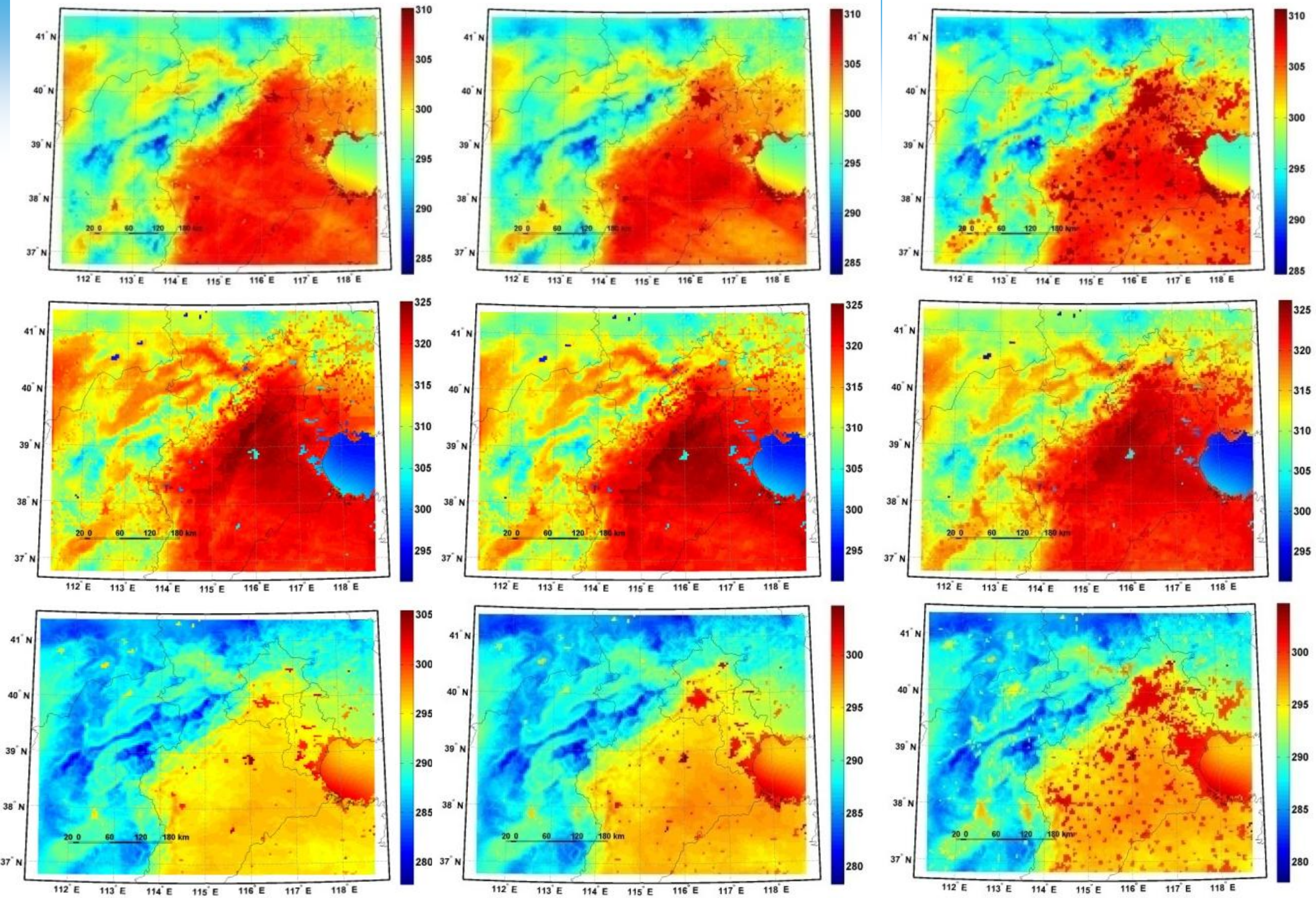
(1): Percentage of urban area

(2): Euclidian distance to urban

(3): Euclidian distance to road

(4): Population (person/km^2)

(5): Slope



LST for non-rainy days, July in 1980s (left), 2005 (middle), 2050 (right). 1) Above: daily mean temperature; 2) Middle: daily maximum temperature;3) below: daily minimum temperature

Multiobjective Spatial Optimization for Sustainable Land Use Planning

Funded by:
Hong Kong Research Grants Council
Shenzhen Municipal Government
Nansha New District Government

Multiobjective Optimization-based Planning Process

Objectives Identification
- Max/Min
- Suitability

→

Constraints Identification
- Change Matrix
- Land-use Proportion

→

Optimization
- GA

→

Result Analysis
- Pareto Front

Sustainable development

Objectives

- Economic Gain
- Social Equity
- Environmental Impact

General Objectives

- GDP
- Energy Consumption
- Urban Pattern (Compactness)
- Compatibility
- Ecological Protection
- Resilience
- Environmental Impact
- Accessibility
- Conversion Cost/Defensible Development/Infill development
- More and better located public area
- …

Specific Objectives

Genetic Algorithm (GA) representation

1st gene

1	1	0	5	5	6	3	3	6	8	8	8	8	2	2	…	…	5	4	4
1	1	0	5	5	6	3	3	6	8	8	8	8	2	2	…	…	5	4	4

……

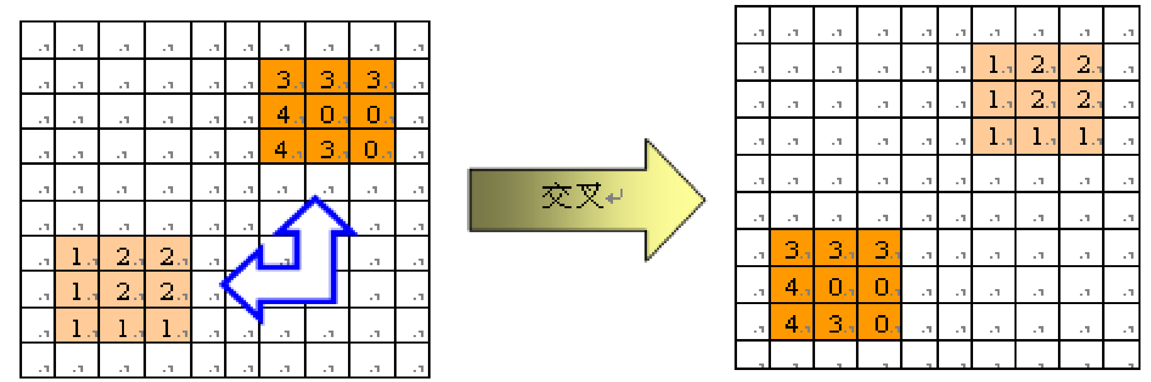
0	0	0	8	8	8	6	2	2	8	8	8	8	2	2	…	…	3	0	0

Last gene

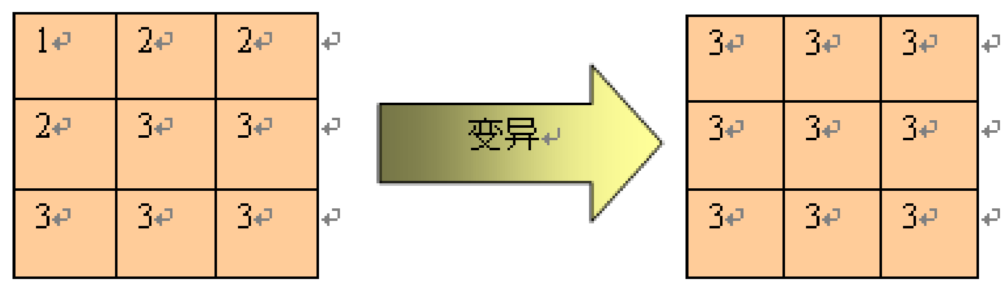
Representation of a chromosome

GA – Crossover and Mutation

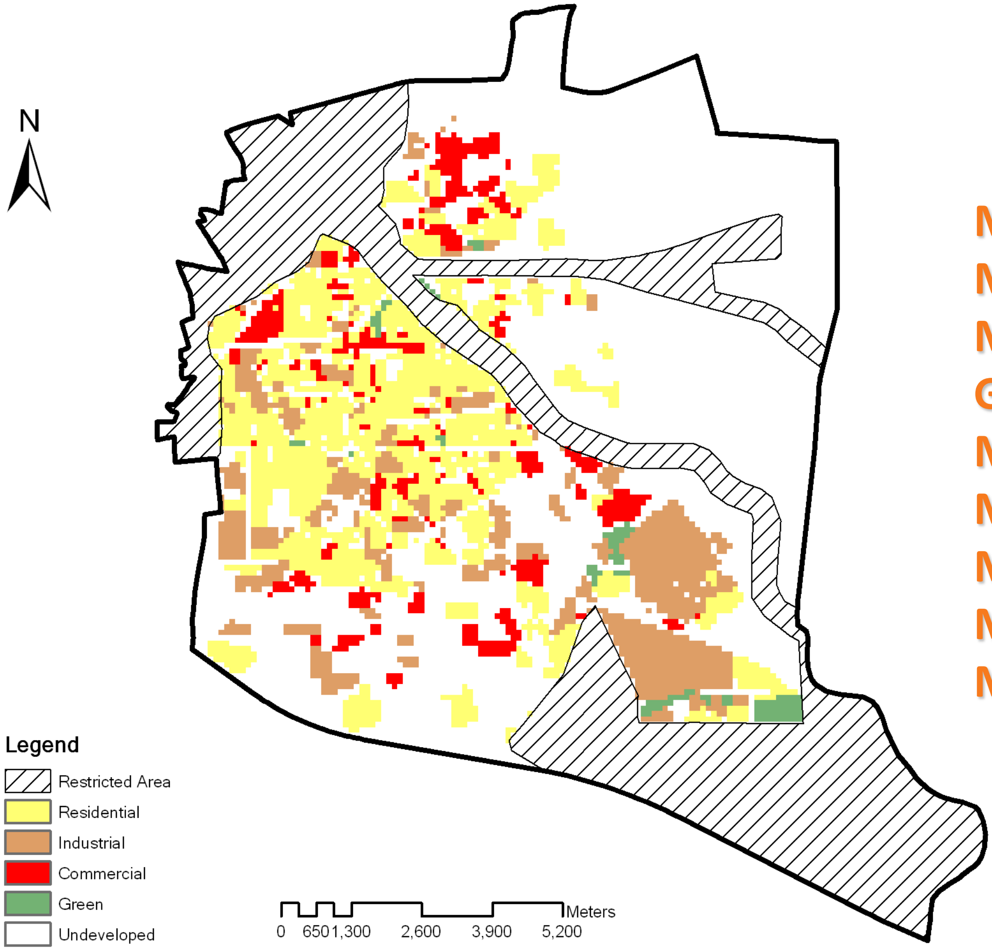
Cross-over



Mutation



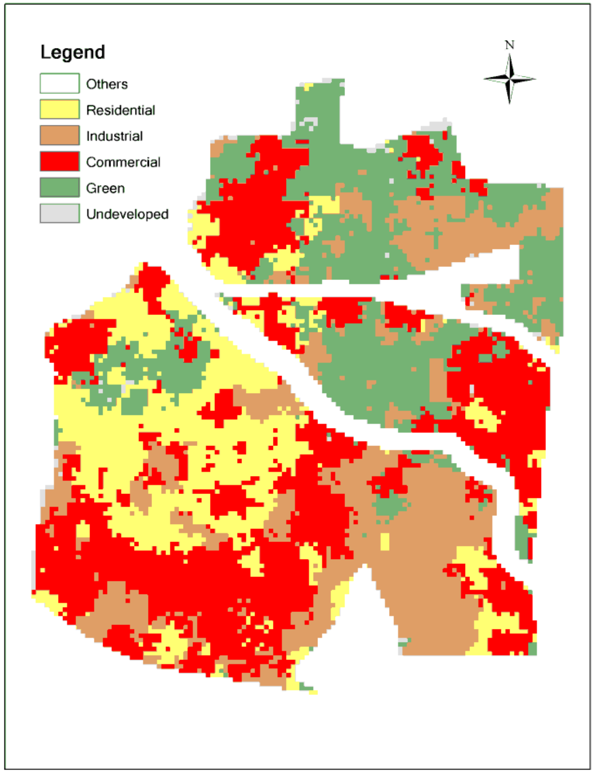
Planning for Tongzhou Newtown

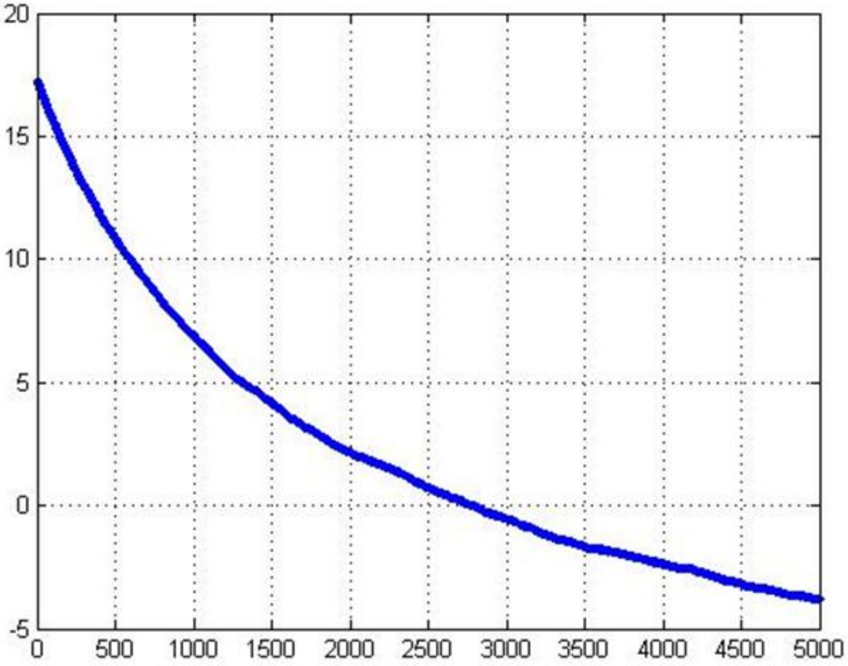


141*119 cells

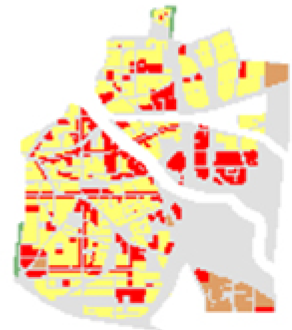
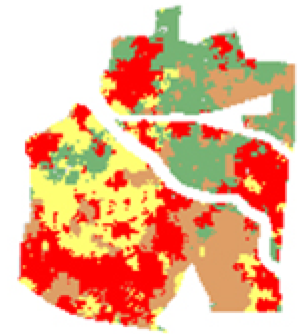
Maximization of GDP *(obj-1)*
Minimization of Conversion *(obj-2)*
Maximization of Geomorphology and Geological Suitability *(obj-3)*
Maximization of Ecological Suitability *(obj-4)*
Maximization of Accessibility *(obj-5)*
Minimization of NIMBY Influence *(obj-6)*
Maximization of Compactness *(obj-7)*
Maximization of Compatibility *(obj-8)*

Planned Land Use





Comparison of Optimal and Planned Scenarios

		Planned Scenario	Optimal Scenario	
Figures				
Objectives	Obj-1	815497	2011753	146.69%
	Obj-2	1425	2741	92.35%
	Obj-3	47762	57529	20.45%
	Obj-4	7352	13791	87.58%
	Obj-5	509218	718059	41.01%
	Obj-6	563381	547028	-2.90%
	Obj-7	61392	68519	11.61%
	Obj-8	37600	41208	9.60%

Nansha New District

- Location:

  Guangzhou, Guangdong Province, China

- Area:

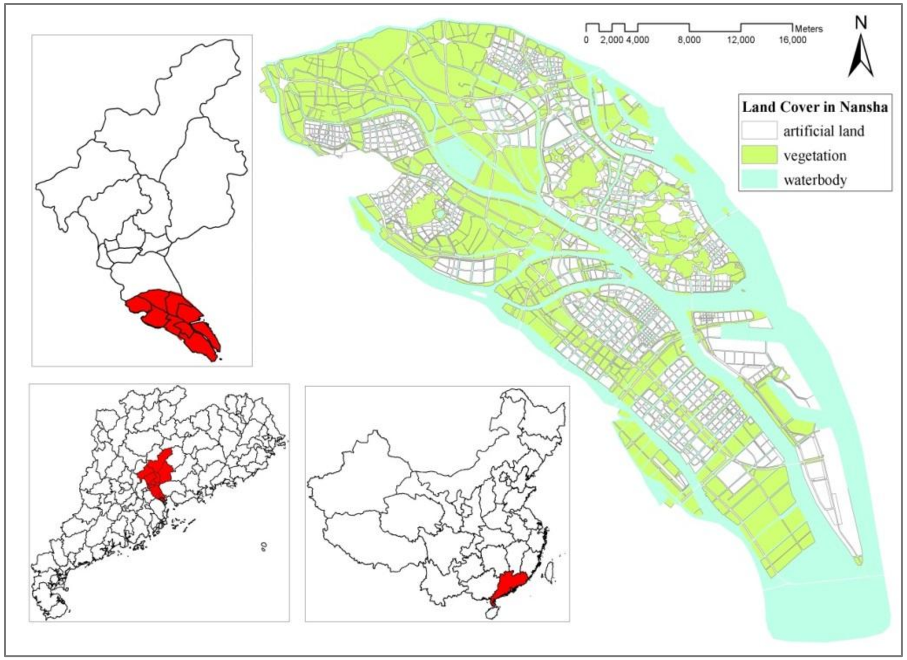
  803 km^2

- Population:

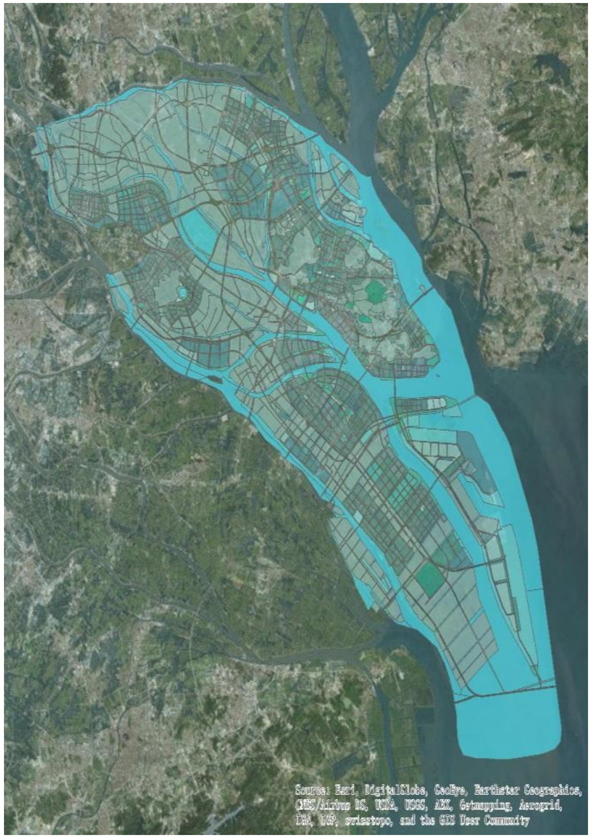
  2.40 million

- Climate:

  Subtropical Monsoon Climate



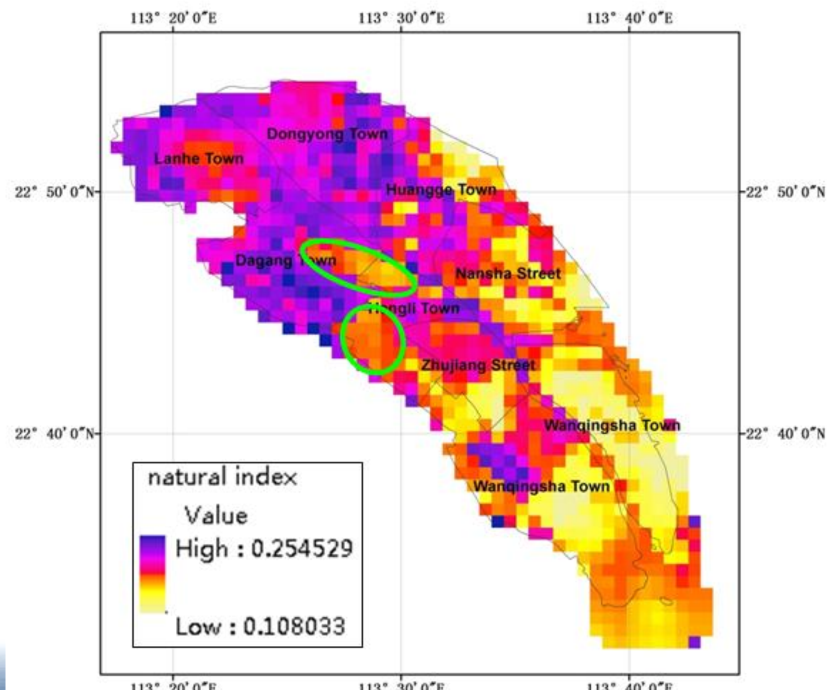
Objectives

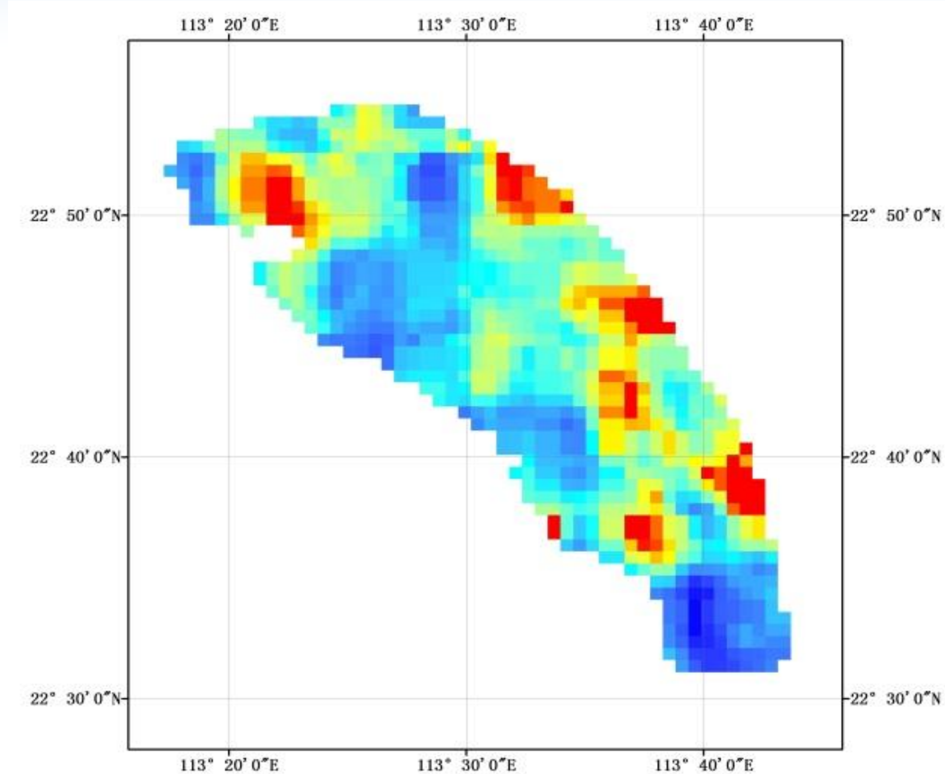


- Land suitability
- Resilience to flooding
- Air pollution
- Plot ratio/Population
- Accessibility to Public Services
- Accessibility to Greenbelts
- Contiguity
- Compactness
- …

Evaluation of Resilience

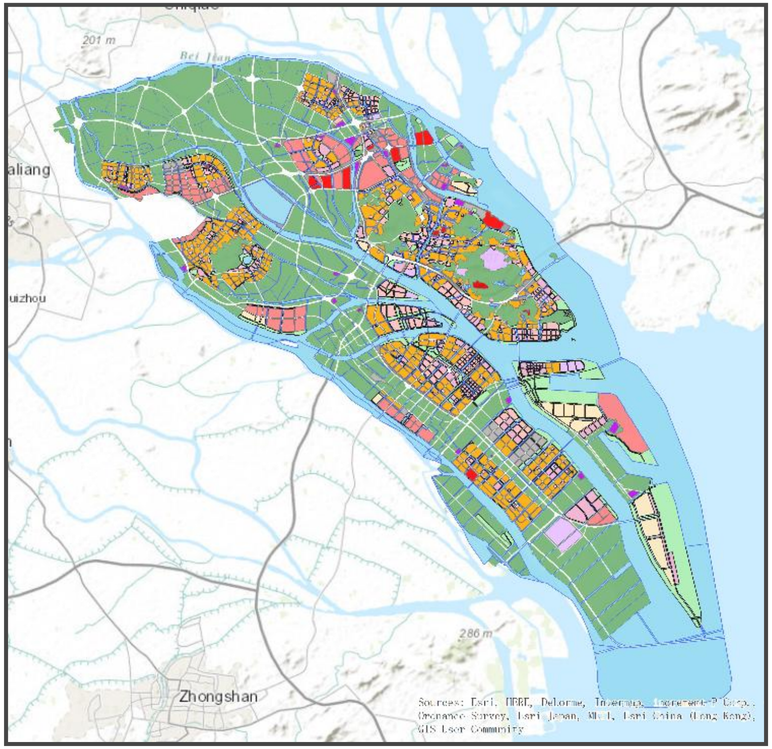
- Exposure
- Damage
- Recovery

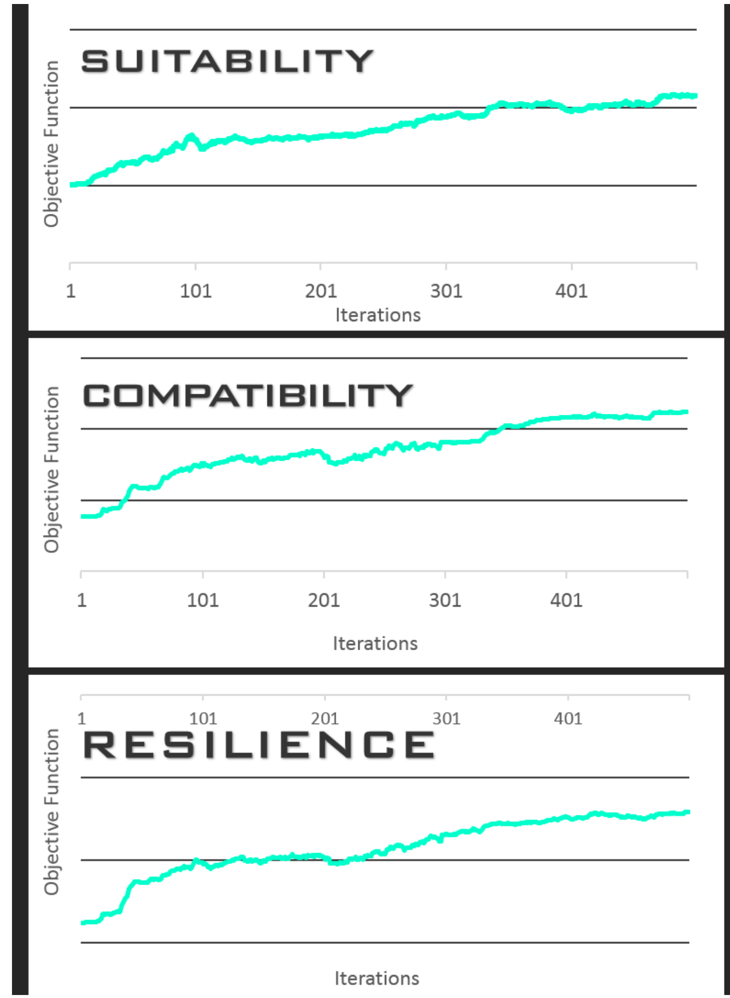




Precipitation at 100-year return level

Optimized Plan





Summary

- Land use planning provides an effective means to urban resilience to natural disasters.
- Multiobjective optimization provides an open and effective framework to incorporate the resilience objective.
- Relationship between objectives and spatial patterns should be established before optimization.

Thank you!