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Use of ASTER Images to Study the Outbreak of West Nile Virus and its Relations with Environmental Variables in Indianapolis: Implications for HyspIRI

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West Nile Virus (WNV)

- A mosquito-borne epidemic disease
- Nature cycling:
  - Bird ⇨ mosquito ⇨ bird/human/other mammals
- First appeared in North America in 1999 in New York City
  - then spread prolifically to the rest of USA
- Symptoms
  - headache, fever, disorientation, muscle weakness, and some neurological sicknesses.

Objectives

- Using ASTER and ancillary data to examine the relationship of WNV dissemination and environmental variables.
- To inquiry the potential improvements of HyspIRI data in WNV and other public health studies.

Study Area: Indianapolis, Indiana

- The nation's twelfth largest city in population (0.8 million in Marion County).
- The metro includes 9 counties, comprised of approximately 9100 sq. km. in area and 1.6 million population in 2000, with annual population growth rate above 5%.
- Temperate climate without pronounced wet or dry seasons.
- Topography: flat plain.
- Two major reservoirs and the White River.

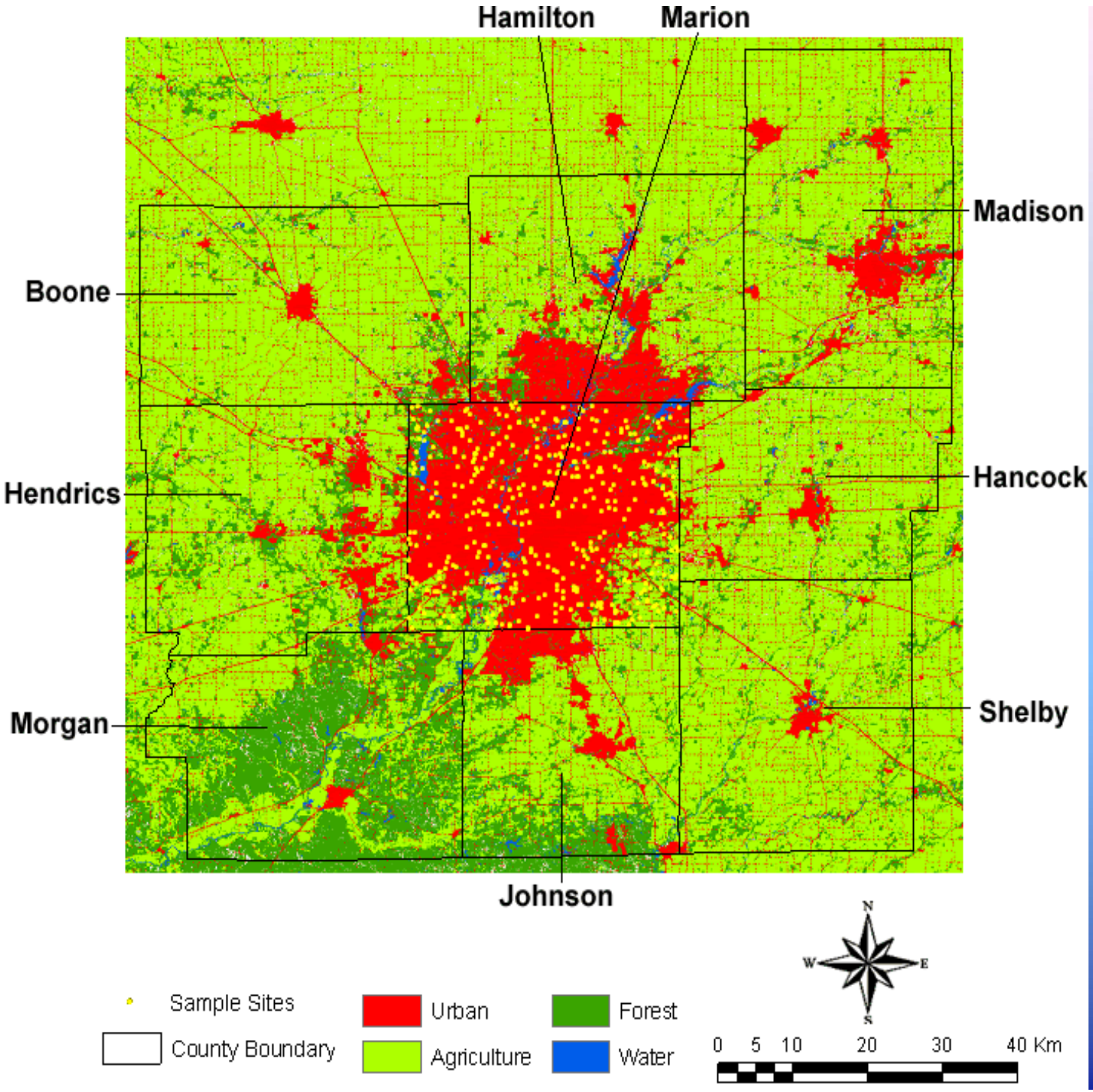


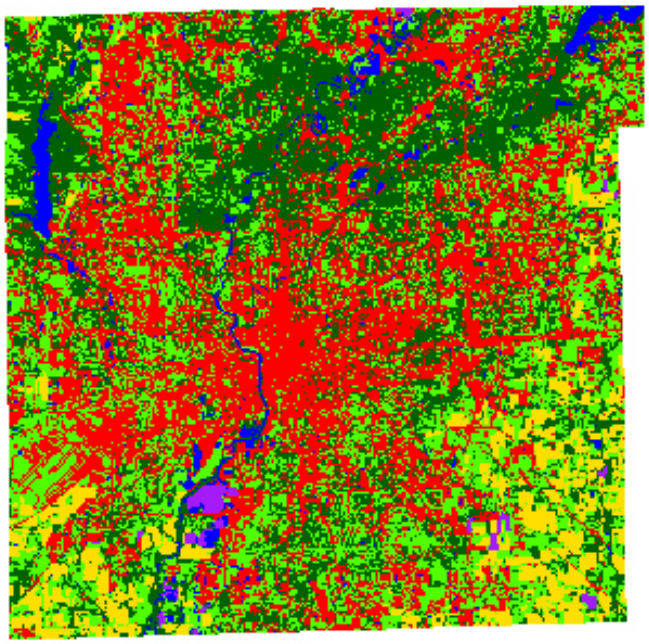
Fig. 1. Land use and land cover map of the metro Indianapolis, derived NLCD 2001. With Dr. Weng's current NSF project, 350 field sites (yellow dots) were visited to collect information on surface cover conditions.

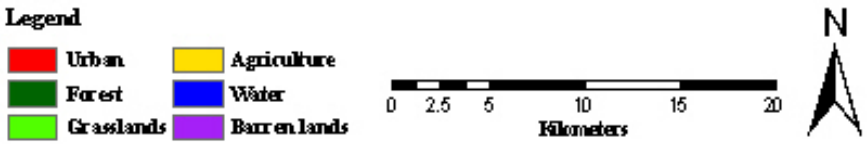
Data Collection and Processing

- WNV data records:
  - Geocoded based on physical addresses of positive mosquito pools.
  - Time period: monthly (April to October) from 2002 to 2007.
  - Provided by Indiana Department of Public Health.

Data Collection and Processing (Cont.)

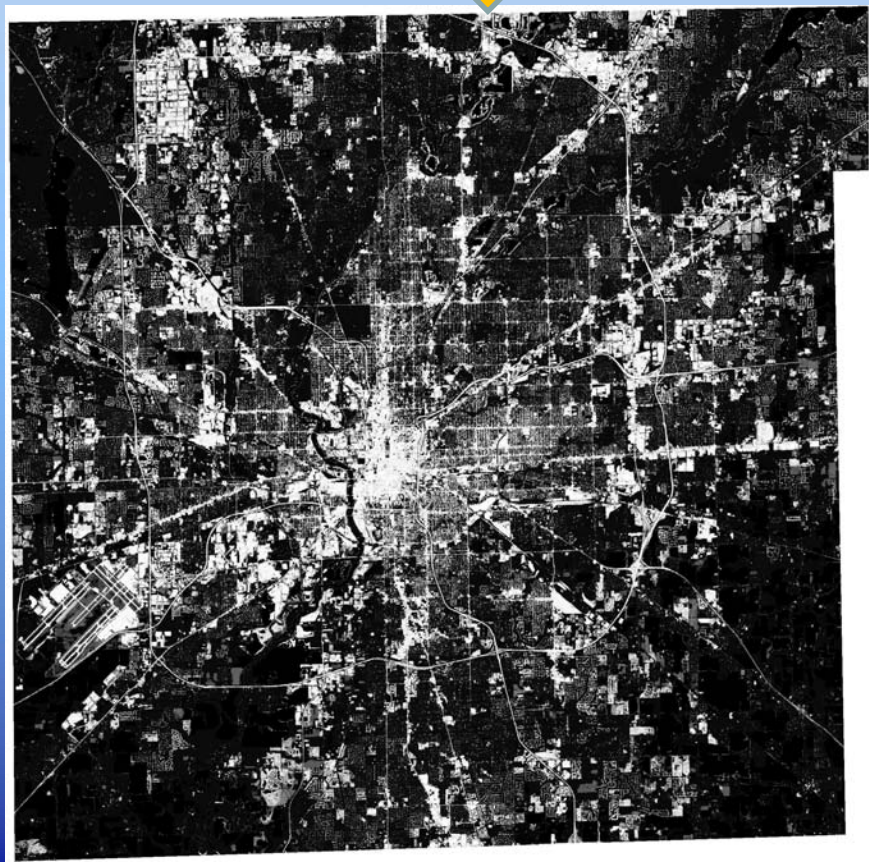
- Environmental variables:
  - Land use and land cover (LULC) types;
  - Impervious surface;
  - Surface heat fluxes;
  - Digital elevation model (DEM);
  - Stream and wetland networks;
  - Pollutants;
  - Sewer pipes;
  - Waste industry sites.





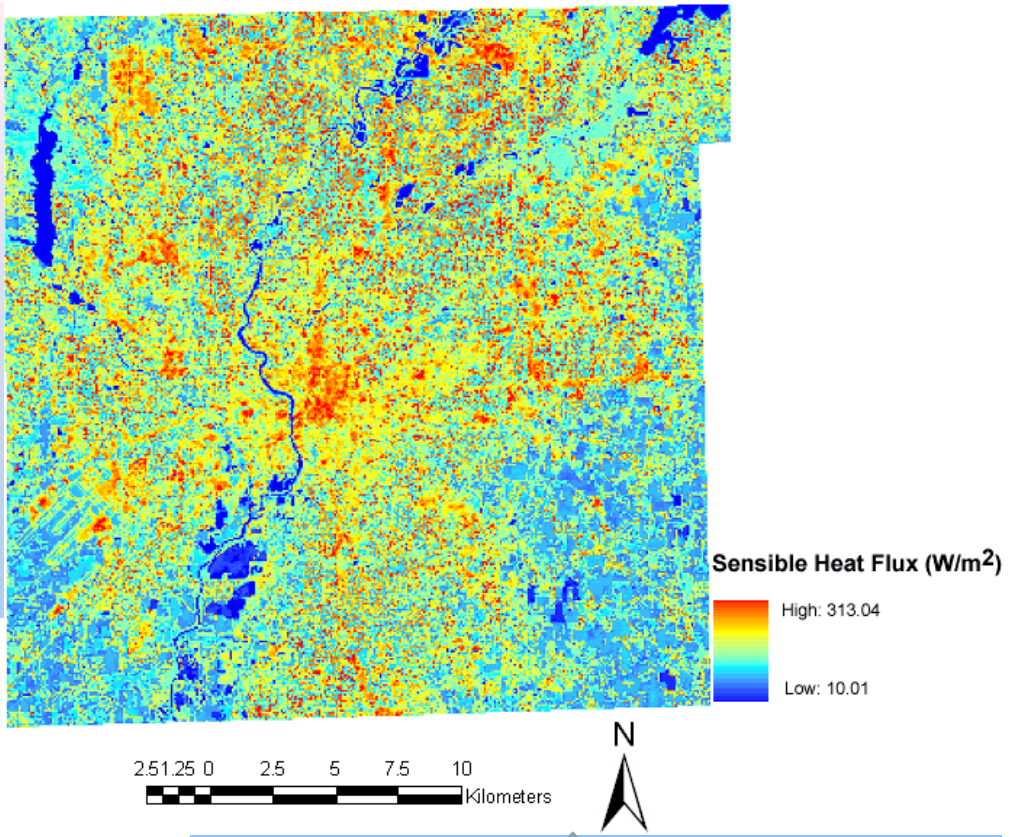
LULC Map of June 16, 2001

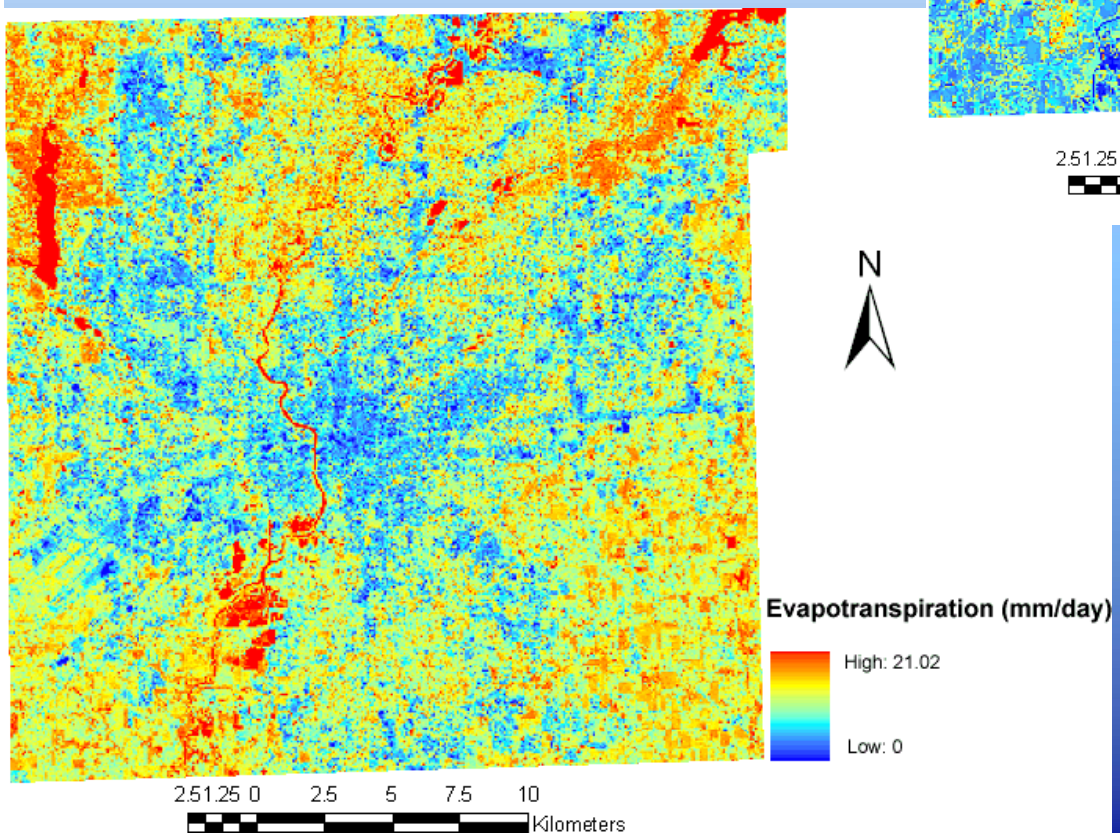
Level 3 Products



Sub-pixel Impervious Surface derived by ANN

Sensible heat flux negatively correlated to WNV, while evapotranspiration (ET) positively correlated to WNV.





Level 3 products

Data Collection and Processing (Cont.)

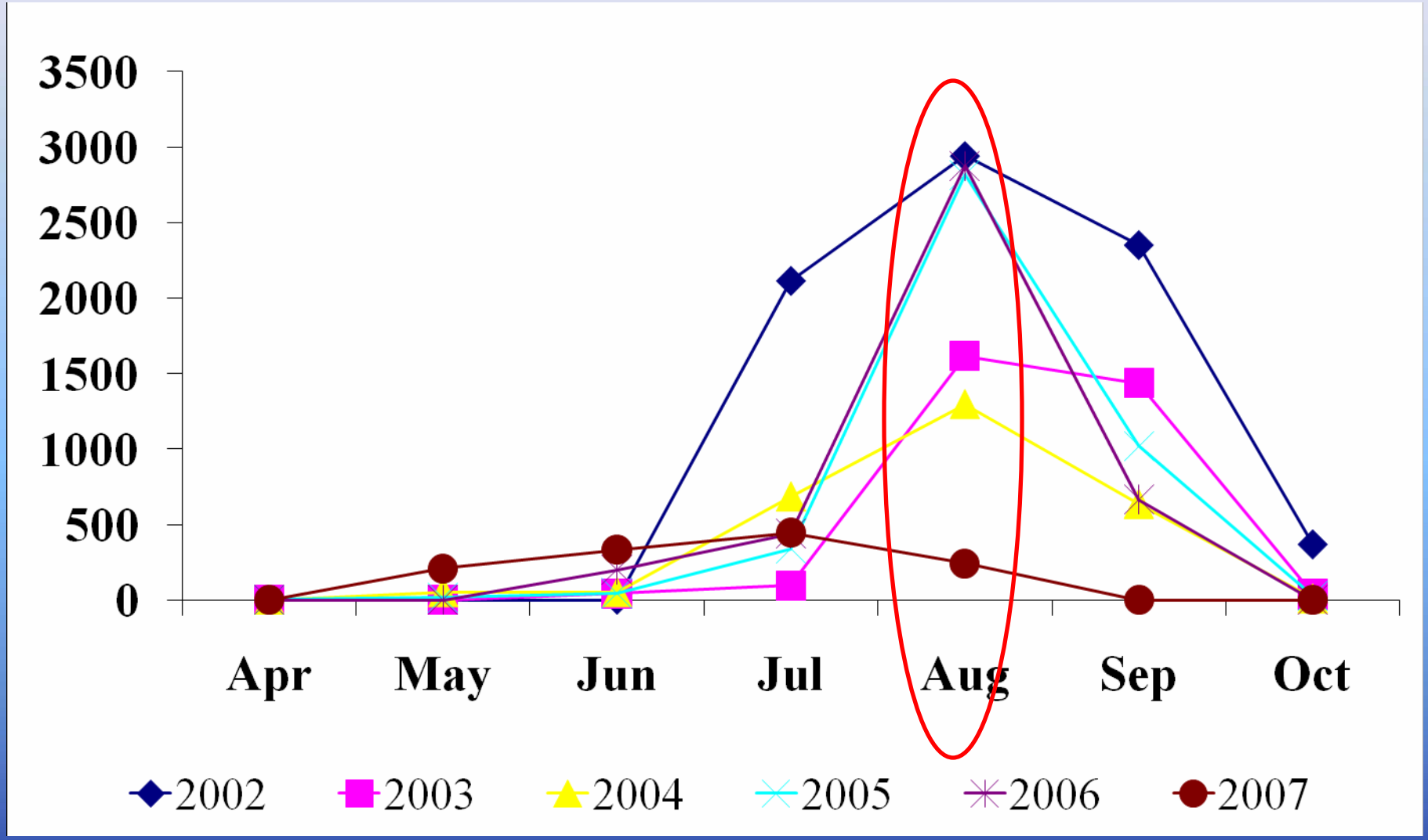
- Population density (U.S. Census 2000)
- Deriving the centroid of each block group.
- Calculating distances from centroids of block groups to:
  - pollutants,
  - sewer pipes, and
  - waste industry sites.
- Deriving total length of stream and total length of wetland in each block group.

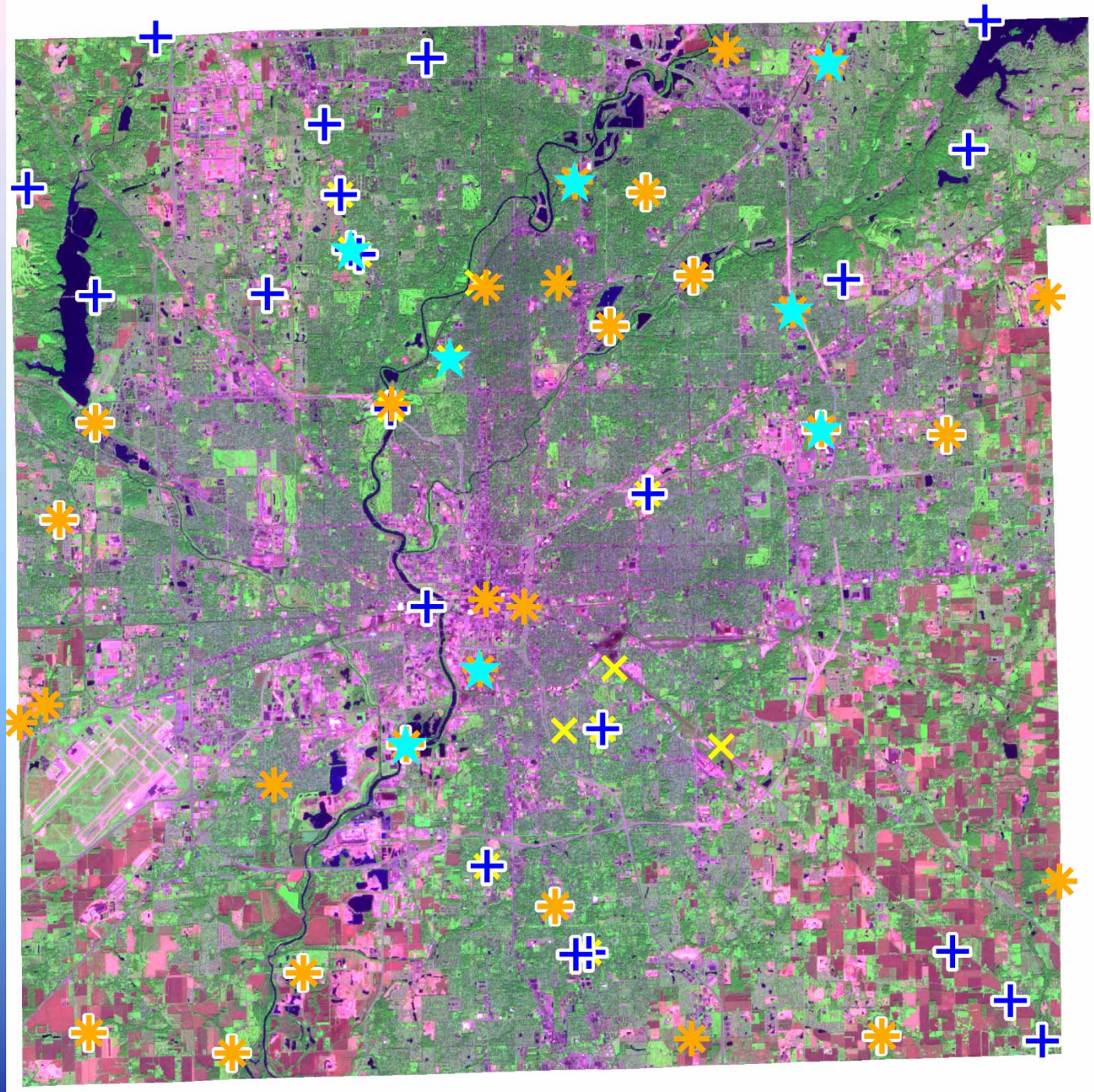
GIS is essential in public health.

Epidemic Curves

- Cumulative epidemic curves were generated to demonstrate the peaks and time trends of WNV outbreaks from year 2002 to 2007.

Epidemic Curves





WNV outbreak in 2002

July
August
September
October
ASTER Band 7
ASTER Band 3
ASTER Band 1

N

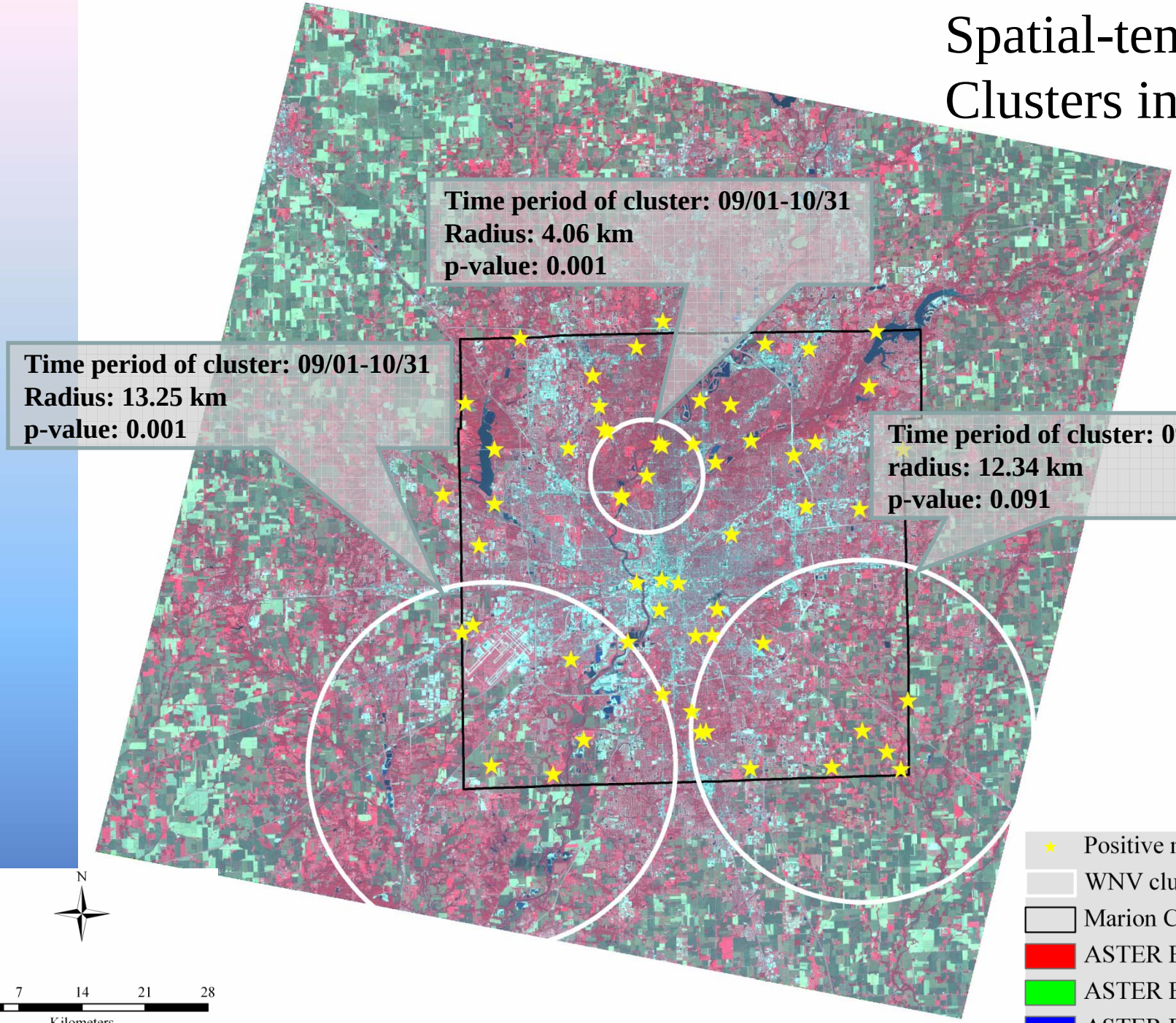
1.5 3 6 9 12

Kilometers

Yearly Spatial Clusters

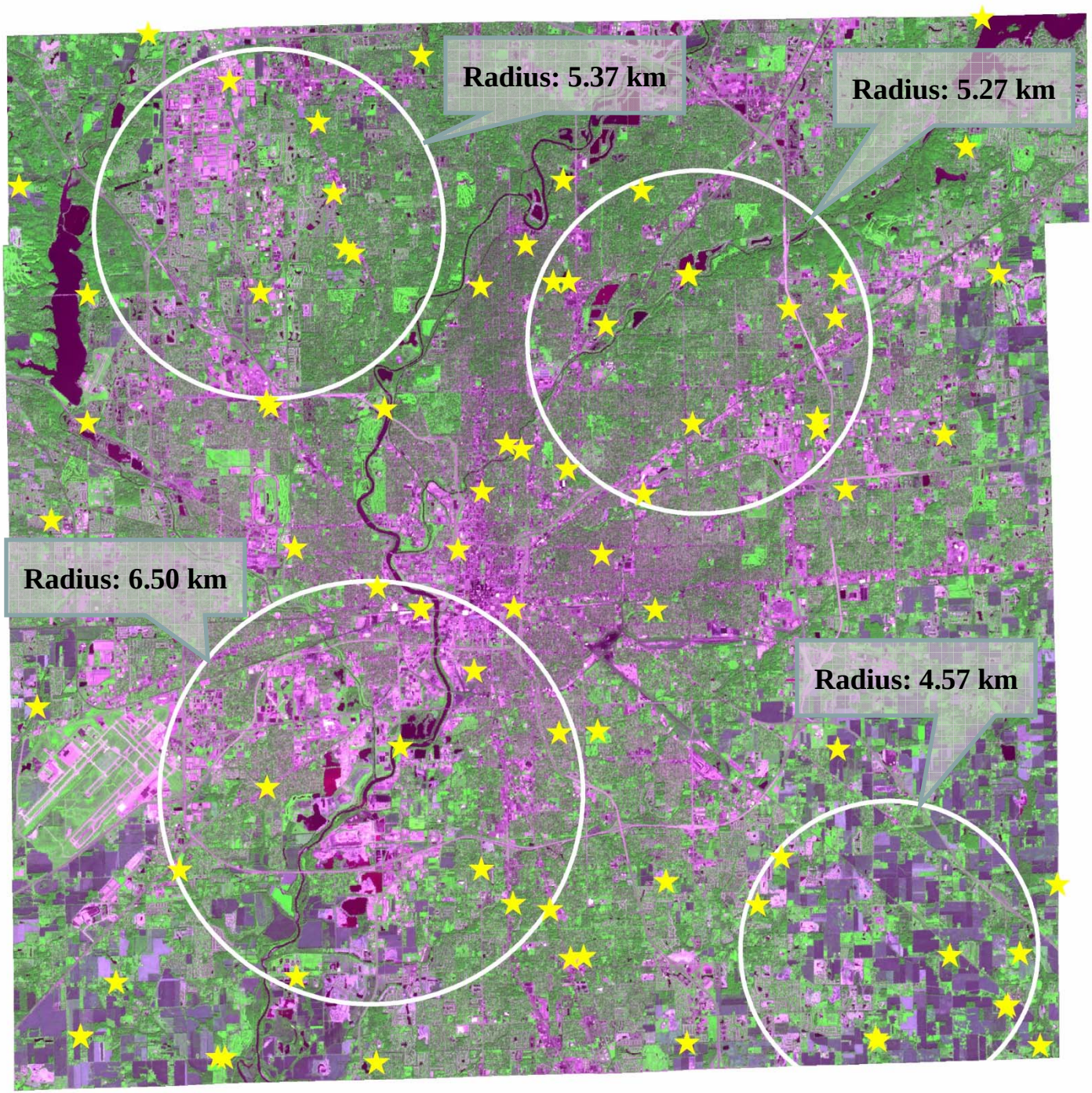
- By using Poisson probability model in SaTScan statistics program, WNV clusters were detected in each year of 2002-2007.

Spatial-temporal Clusters in 2002



Risk Areas

- By using K-means cluster analysis, risk areas in individual months were identified.
- We found:
  - July: two clusters.
  - August: four clusters.
  - September: four clusters.
  - October: two clusters.



Risk areas in August

N

WNV case
Risk area
ASTER Band 1
ASTER Band 3
ASTER Band 2

3.5 7 14 21 28
Kilometers

Discriminant Analysis

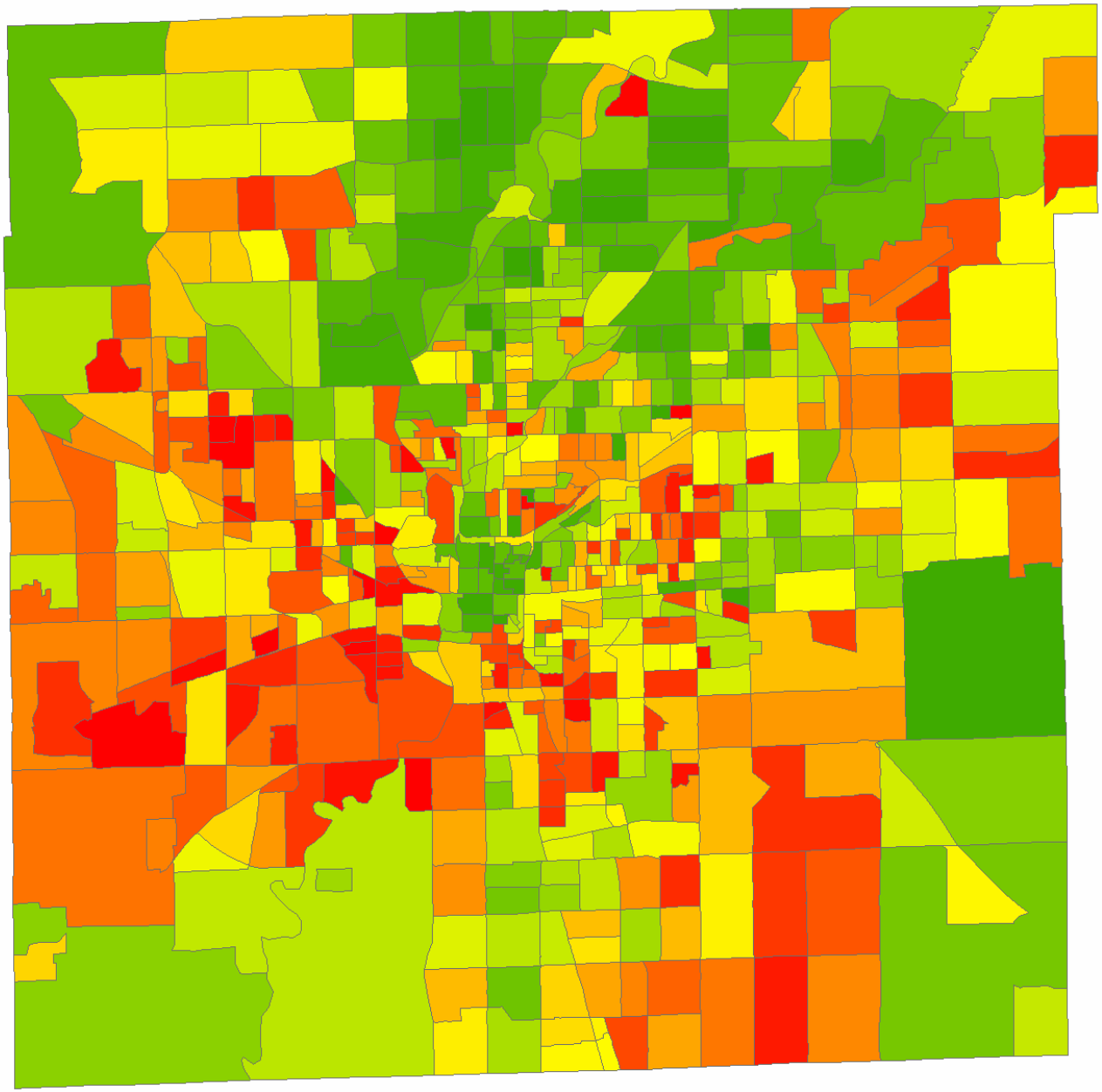
- A stepwise Wilks' lambda discriminant analysis was used to find variables which best separate the block groups with WNV cases to those without any case.
- Factors found to vary by year.

Major Factors in WNV Dissemination, 2002

Variables	Classification function coefficients	Factor structure coefficients	Eigenvalue	BG with/without WNV	Grouping accuracy
Percentage of agriculture	1.371	0.518	0.212	46/612	86.50%
Total length of streams	0.001	0.686			
Total length of wetlands	0.001	0.801			
Mean evapotranspiration	12.223	0.552			
Mean sensible heat flux	1.206	-0.601			
Constant	-141.192				

Mahalanobis Distance Analysis

- Mahalanobis distance
  - a distance index based on correlations between variables by which different patterns can be analyzed
  - used to identify favorable habitats of WNV
  - model inputs:
    - Variables retained by the Discriminant analysis
- Distance values: small – more favorable; large - less favorable.



Health Hazard Risk Map of WNV:

High Risk (in red color) *vs*. Low Risk (in green color) Census Block-Groups in 2002

Level 3 Product

Conclusions

- Based on the study of positive mosquito records in 2002, we found:
  - WNV dissemination started from central longitudinal corridor and spread out to west and east,
  - The infection reaches the peak in August,
  - Factors playing important roles in WNV propagation include:
    - percentages of agricultural land,
    - lengths of streams and wetlands,
    - mean evapotranspiration, and
    - mean sensible heat flux.

Implications of HyspIRI on WNV Studies

- TIR instrument 5-day revisit: Potential one-two observations per epidemic week. → Rapid detection and tracking of events.
- 60-m spatial resolution:
- → better health hazard risk maps of WNV

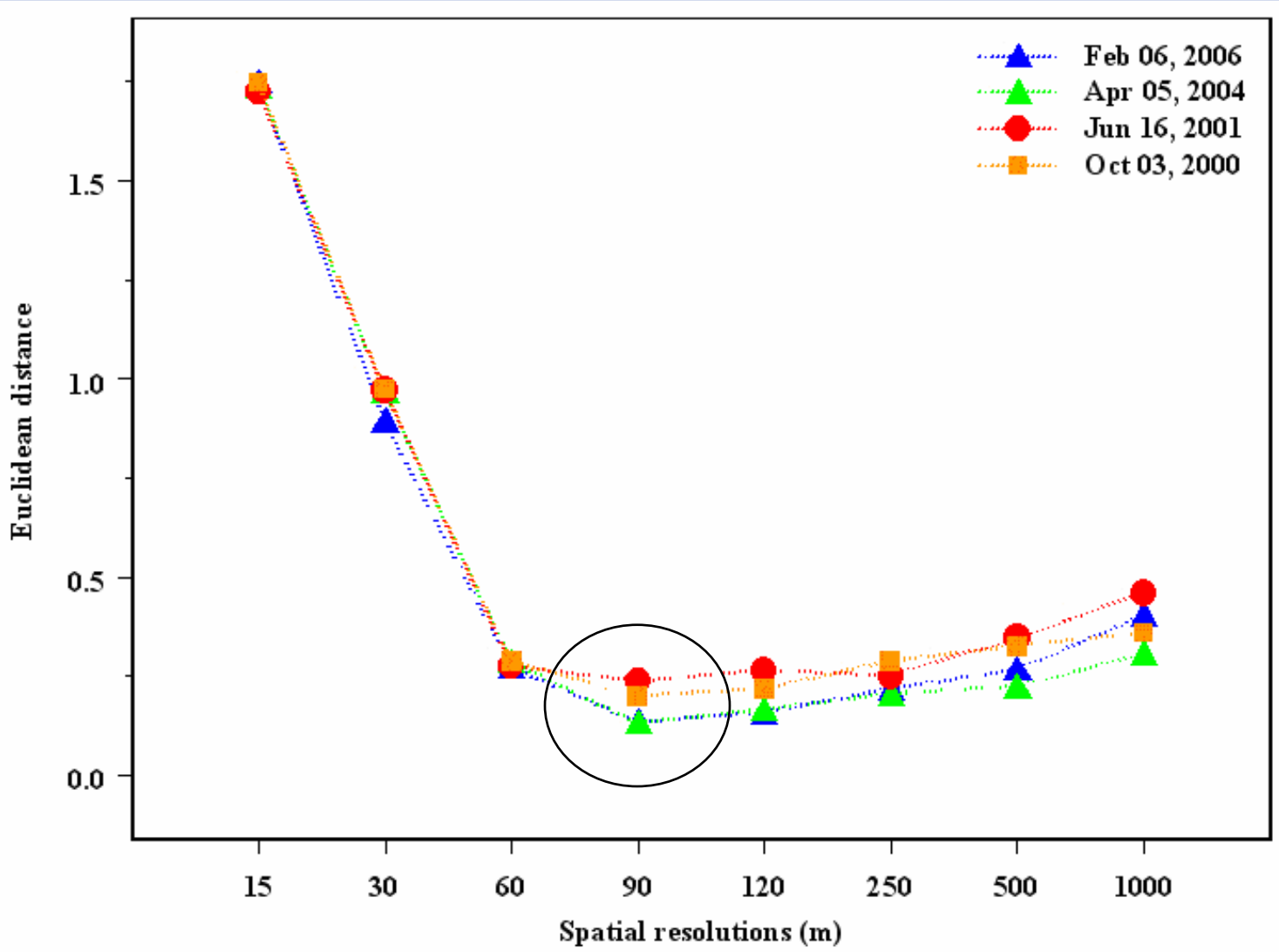
  (Targeted interventions to reduce the vulnerability of humans to health risks.)
- → *Optimal scale* to examine human health-environmental conditions in urban areas.

Optimal Scale for Examining the LST-LULC Relationship

- **Computation of landscape metrics**:
  - Each **ASTER** data layer was re-sampled to the resolutions of 15, 30, 60, 90, 120, 250, 500, and 1000 meters.
  - Landscape metrics were computed for each LULC and LST map at each pixel aggregation level.
  - Landscape metrics used: Patch Density (PD), Landscape Shape Index (LSI), Perimeter- area Fractal Dimension (PFD), Mean Perimeter-area Ratio (MPR), Proximity Index (PI), and Contagion Index (CI).

(Source: Liu and Weng, 2009, *PE&RS*.)

Normalized Euclidean Distances between the LULC and LST Maps across Different Sampling Sizes



Optimal size: ±90m; Seasonal Variability.

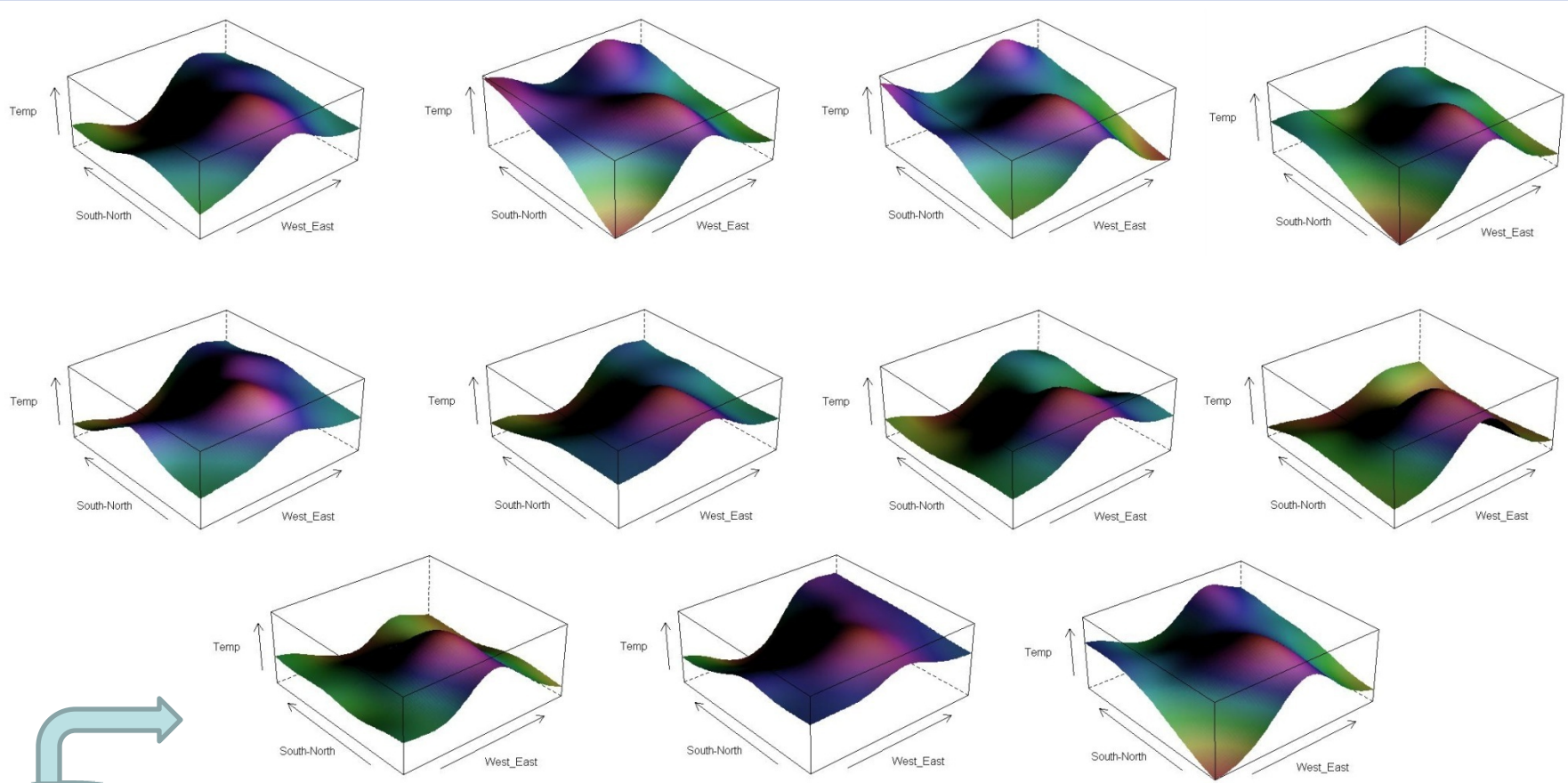
Implications of HyspIRI on WNV Studies

- Higher temporal resolution, spectral (7 bands) and spatial (60-m) resolution:

  ⇒ More precise spatiotemporal variations of environmental parameters.

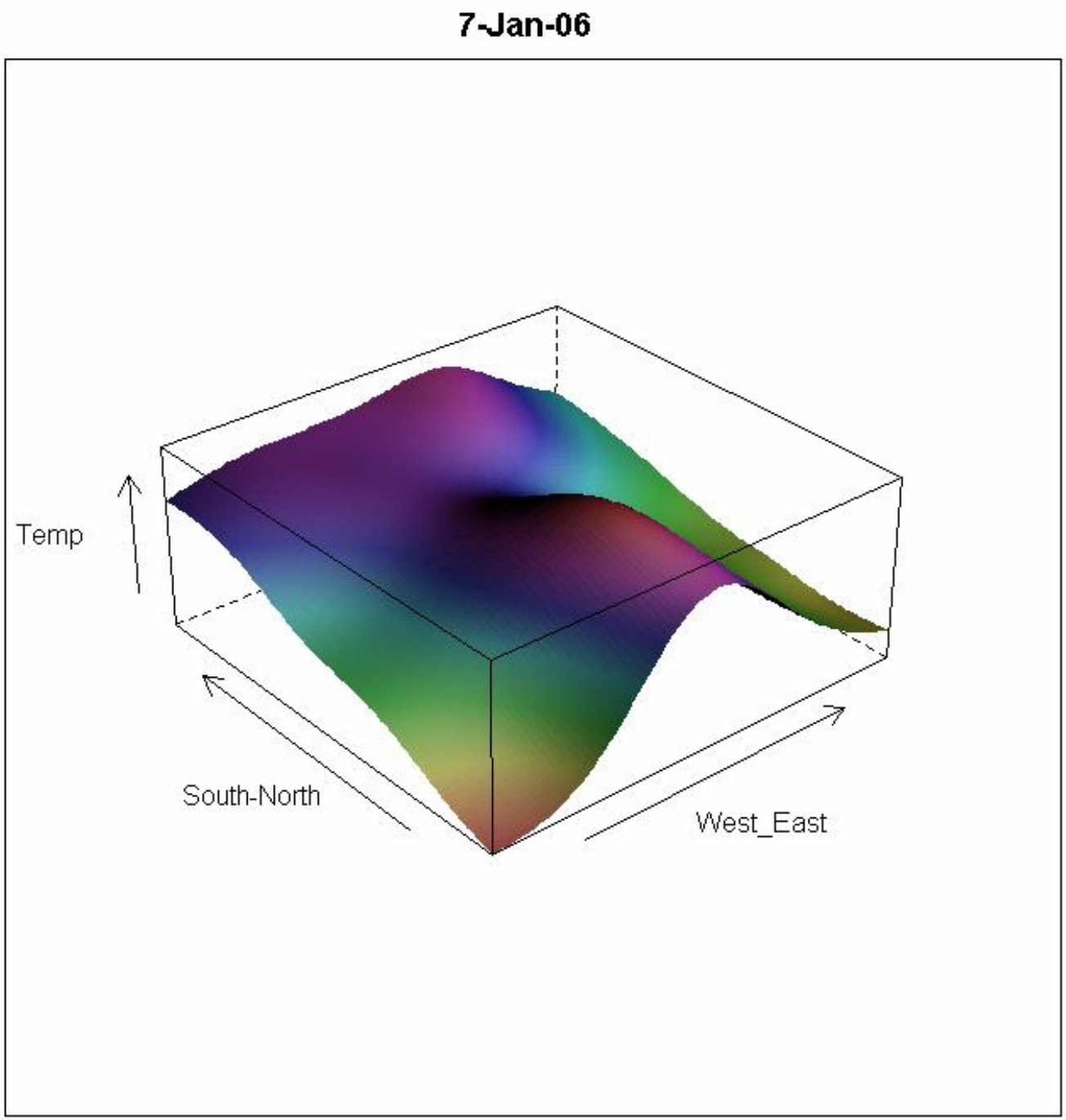
  ⇒ Better prediction of occurrence of disease and disease outbreaks.
- Example 1: modeling urban heat island (UHI) dynamics.
- Example 2: estimation of impervious surfaces.

3-D Models of Daytime UHIs of Indianapolis by Using MODIS LST Data



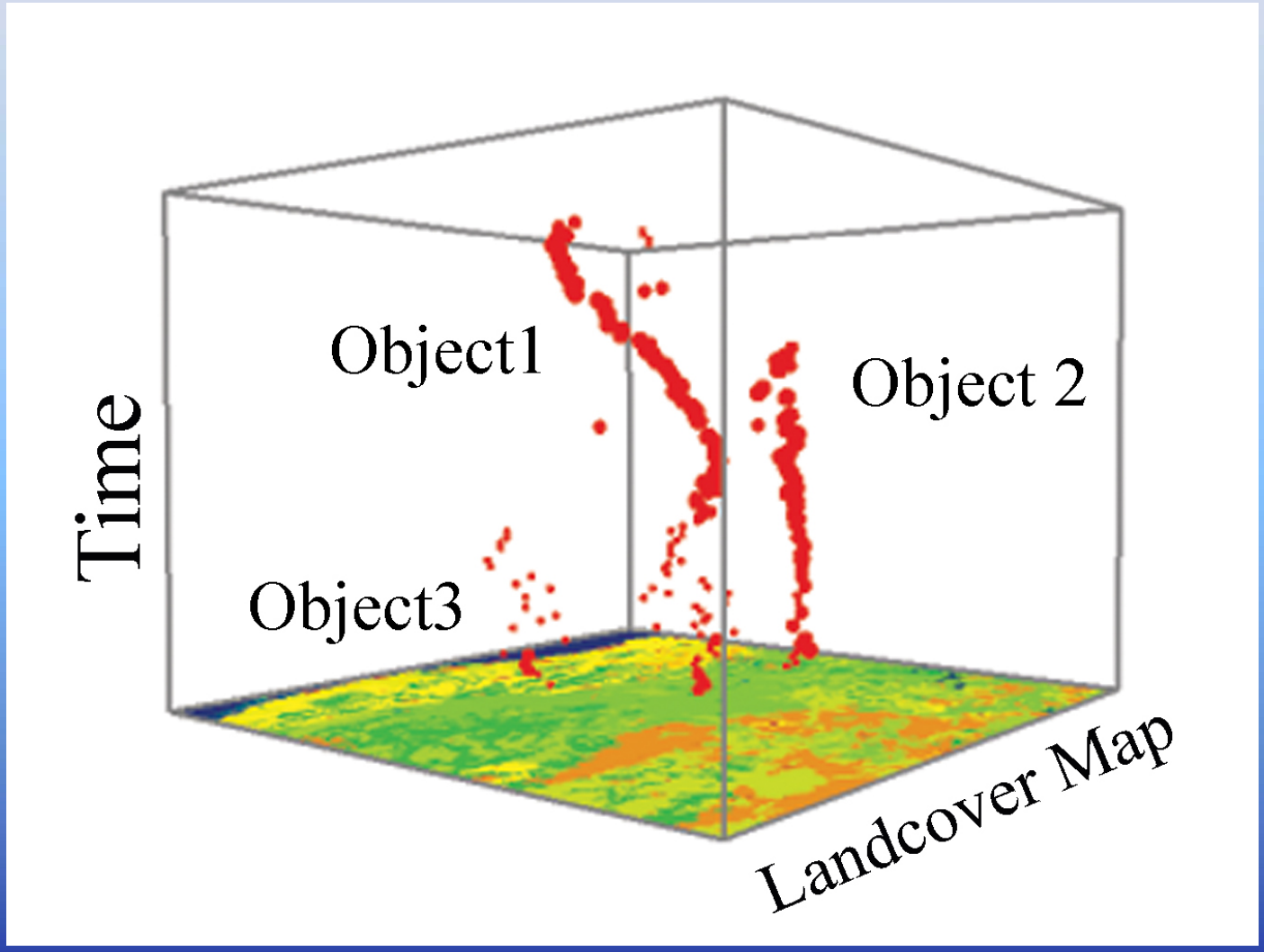
Level 3 Product

(Source: Rajasekar and Weng, 2009, *ISPRS J.*)



MODIS 2006 Day Images

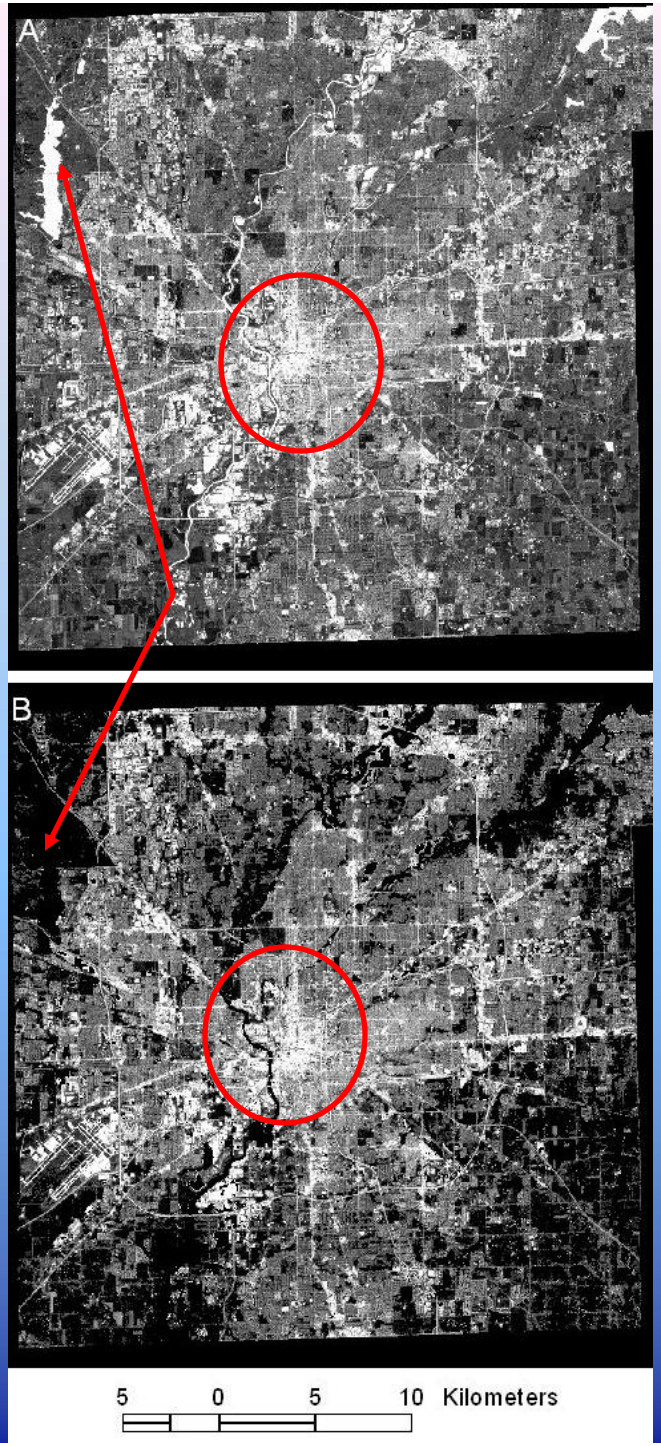
UHI as an Moving Object over the Space and Time



A: Impervious surface estimation based on combination of high-albedo and low-albedo fractions

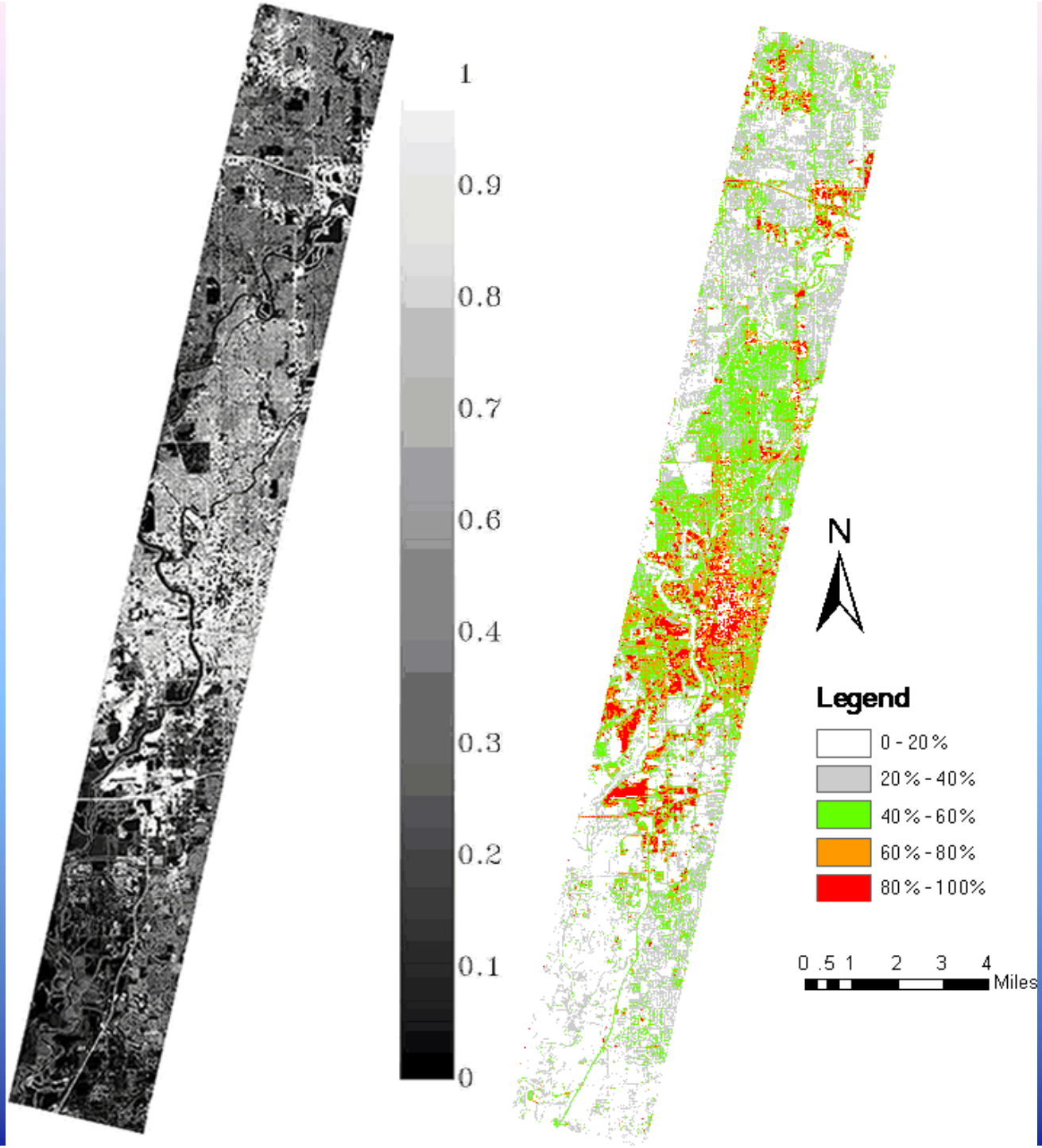
B: Improvement of estimation by combined use TIR data and the fraction images.

(Source: Lu and Weng, 2006, *Remote Sensing of Environment*)



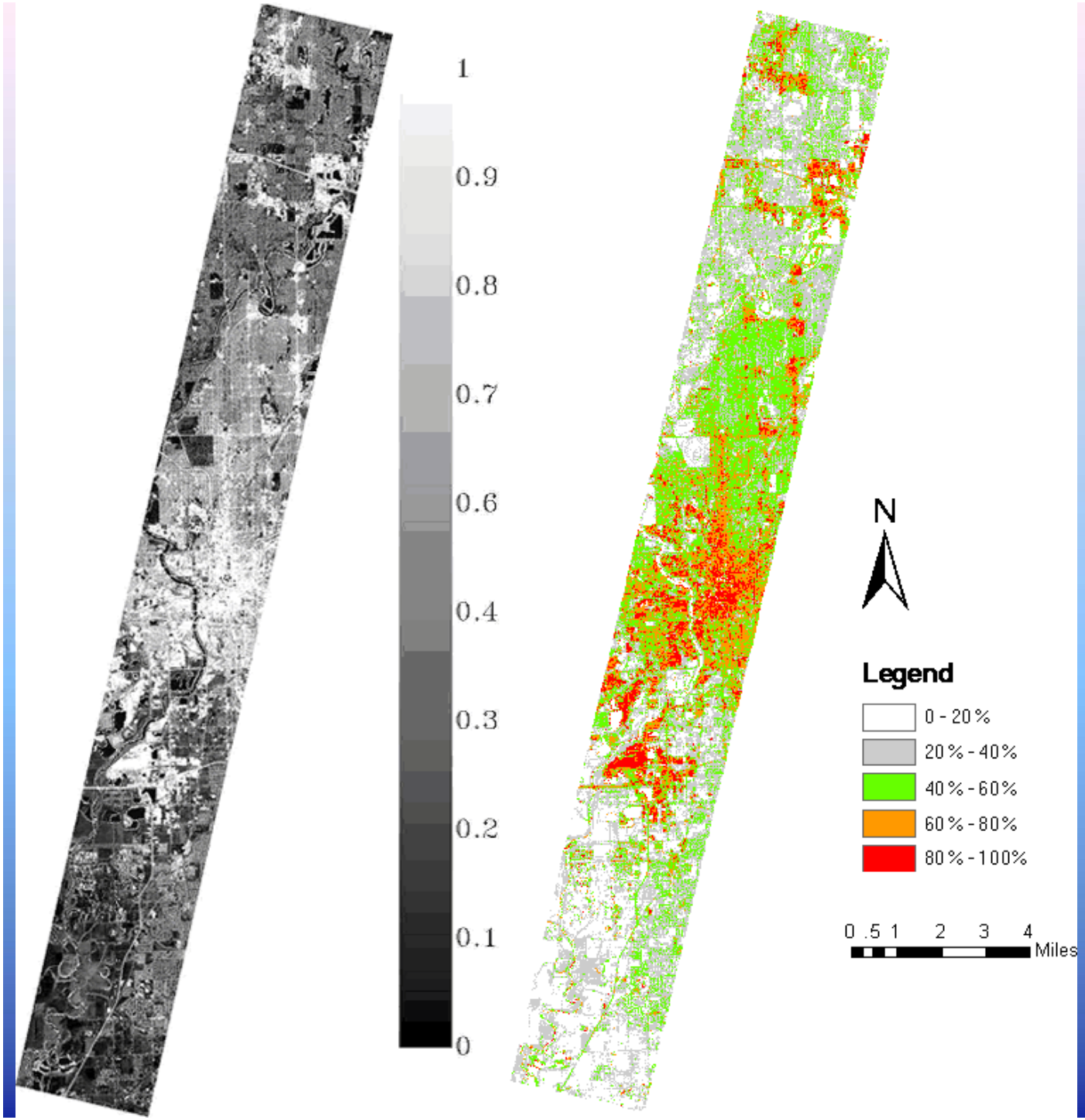
RMSE = 9.22%

76 plots sampled (300m*300m)



Impervious surface map derived from EO-1 ALI image of April 12, 2003

(Source: Weng et al. 2008, IJRS.)



Impervious surface map derived from EO-1 Hyperion image of April 12, 2003

(Source: Weng et al. 2008, IJRS.)

Multispectral *vs.* Hyperspectral Imagery

- Hyperion image was more powerful in discerning low-albedo surface materials.
- The improvement mainly came from additional bands in the mid-infrared region (Bands 7, 8, and 9 of ALI sensor).

- Implications for HyspIRI: Combined use of VNIR, SWIR, and TIR data for impervious surface estimation.

Acknowledgement

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