2010 HyspIRI Science Workshop, JPL, August 24-26

Climate Change, Urban Heat Island, and Human Health: Needs for HyspIRI-like Data Products in Urban Climate/Environmental Studies

Qihao Weng, Mahesh Rajasekar, Indiana State University
Dale A. Quattrochi, NASA MSFC, Huntsville, AL
Hua Liu, Old Dominion University, Norfolk, VA
Xuefei Hu, Emory University, Atlanta, GA

Contact: qweng@indstate.edu

Urbanization and Global Change

- The extent and rate of global changes largely driven by rapid population growth.
- Half world population living in urban areas. First “Urban Century”. 100 megacities by 2025 as compared to 20 today.
- Urbanization is one of the most profound examples of human modification of the Earth’s surface.
  - Impacts on local energy, water and carbon exchanges; affect climate, ecosystems, human health, and human systems.
  - The impacts may be of local, regional, or global scale, depending on the size of the area affected.

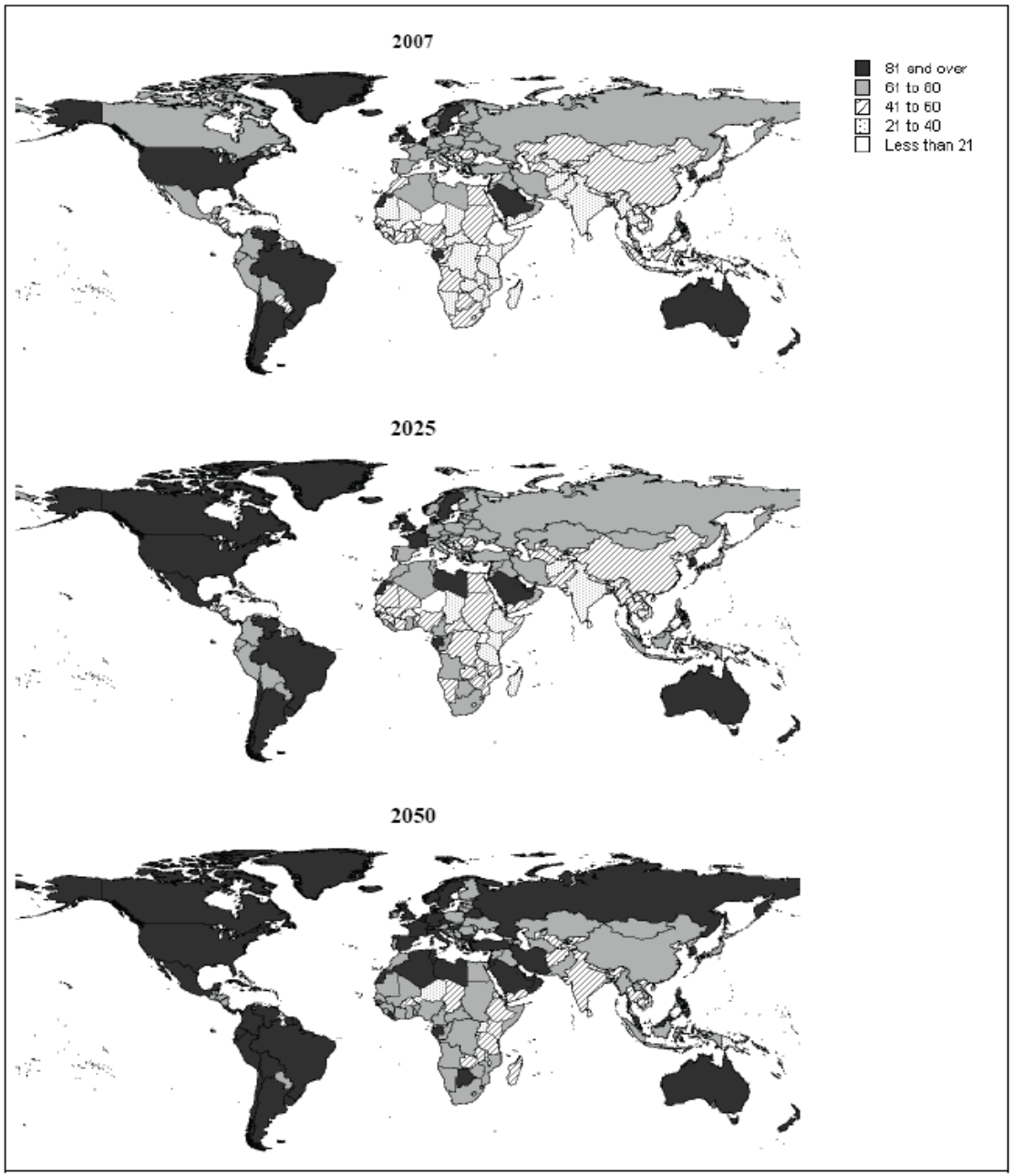

Los Angeles


Hong Kong


Bird’s Nest, Beijing, before Olympia

Most impact are invisible.

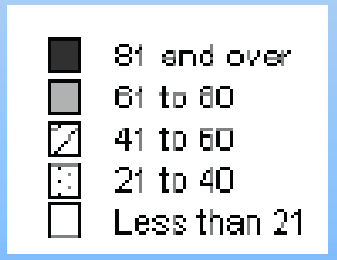
Figure I.3. Percentage of the population in urban areas, 2007, 2025 and 2050



Source: United Nations, Department of Economic and Social Affairs, Population Division: World Population Prospects DEMOBASE extract. 2007.

NOTE: The boundaries shown on the present map do not imply official endorsement or acceptance by the United Nations.

Urban Population Percentage



UN Department of Economics and Social Affairs, 2007

HyspIRI Urban Imaging
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Urbanization and Global Change

- Urbanization research is uniquely suited to answer some key science questions in addressing global change, including:

- *How does urbanization affect the local, regional, and global environment?*
- *How do changes in land cover and land use from urbanization affect the sustainability and productivity of natural and human ecosystems?*
- *How do the patterns of human environmental and infectious diseases respond to urban growth and associated impacts?*
- *Can we characterize this effect to help mitigate its impacts?*

REGI

Region
Metro NE
Larger NE
Mid-Atlantic
Coastal SE
Inland SE
Upper Midwest
Inner Midwest
Appalachians
Great Plains
Mountain West
Arid Southwest
California
Northwest
Alaska
Hawaii

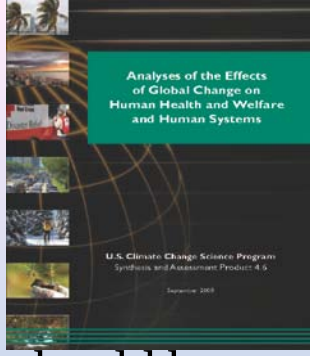
Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems

U.S. Climate Change Science Program
Synthesis and Assessment Product 4.6

September 2008

HyspIRI Urban Imaging
Weng et al. 2010

Some Recommendations Based on the Preliminary Assessment



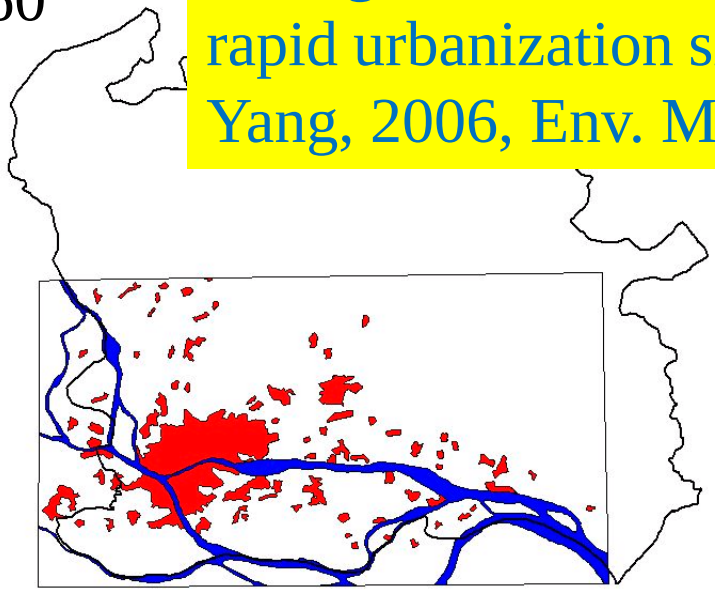
1. Research on climate change effects on human settlements in the U.S should be given a much higher priority in order to provide better metropolitan-area scale decision-making
2. In-depth case studies of selected urban area impacts and responses should be performed as soon as possible, especially for:
   - ►coastal areas in the Southeast
   - ►arid areas of the Southwest
   - ►coastal areas of the Northwest
   - ►Great Lakes region of the Midwest
6. A structure and process needs to be established for informing U.S. decision-makers about climate change effects, how to integrate climate change considerations into what they do with building codes, zoning, etc.

Climate Change and Urban Heat Island

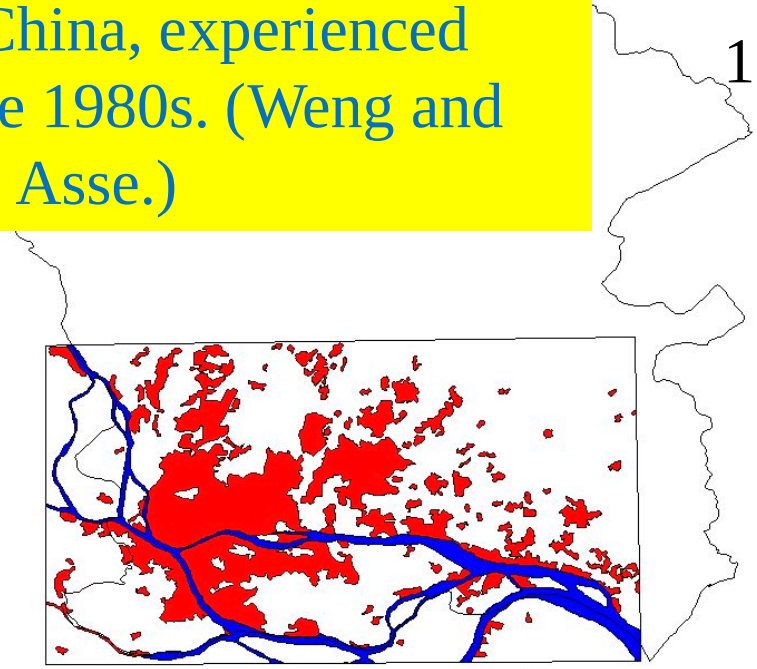
- The UHI phenomenon is an analog of global climate change. Useful for studies on the responses of urban ecosystems and human systems to warming.
- The UHI effect: more than heat, air quality (pollution and ozone), health, and energy consumption.
- Emerging research trend includes:
  - (1) the impact of UHI on urban biogeochemical cycles and CO_2 dome;
  - (2) the dynamic interactions among UHI, earth system science, and global climate change; and
  - (3) global and regional mitigation simulation, negative radiative forcing, and GHG offset.

Guangzhou, southern China, experienced rapid urbanization since 1980s. (Weng and Yang, 2006, Env. Mon. Asse.)

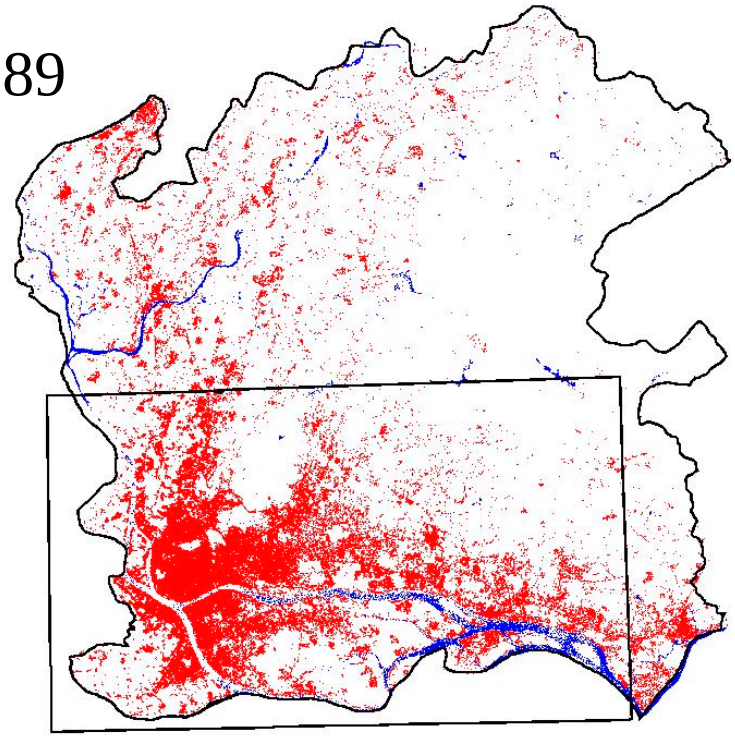
1960



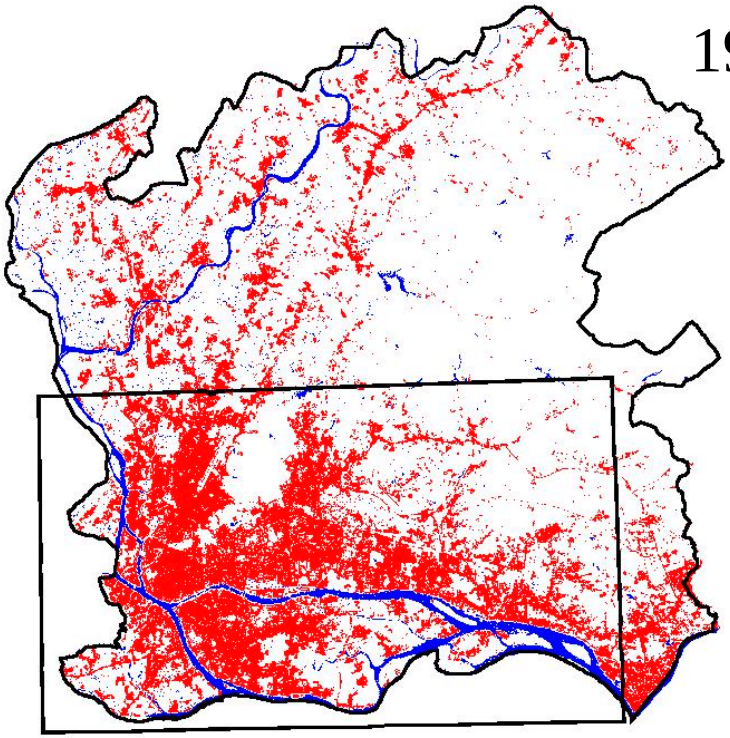
1984



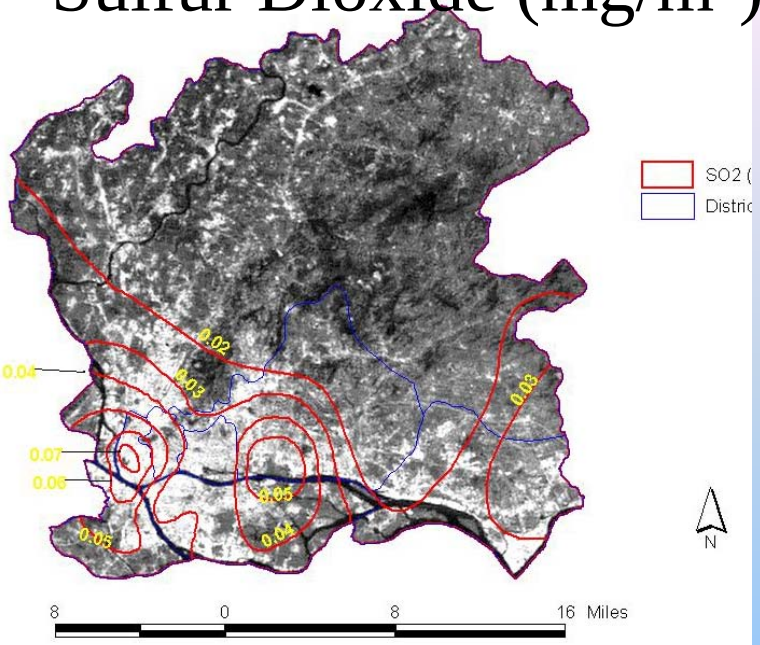
1989



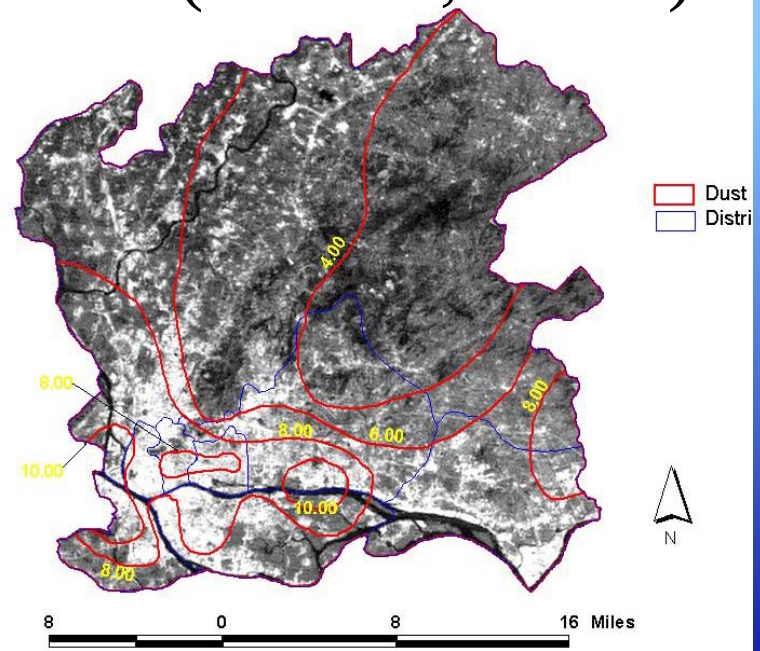
1997



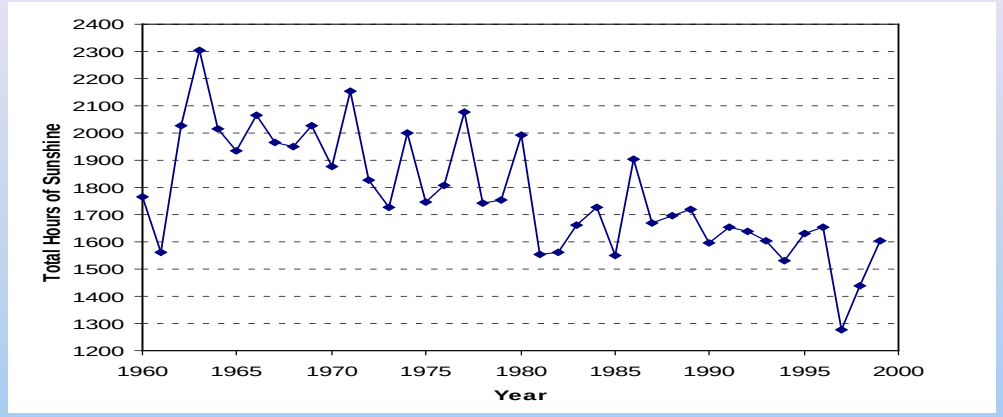
Sulfur Dioxide (mg/m^3)



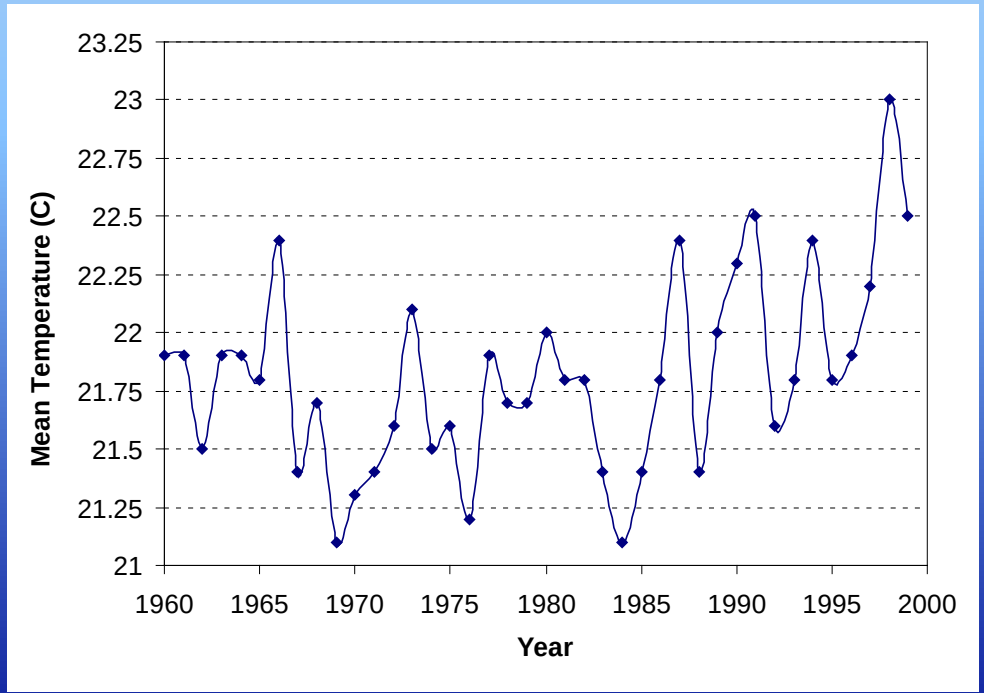
Dust (ton/km^2, month)



Annual Total Hours of Sunshine, 1960-1999



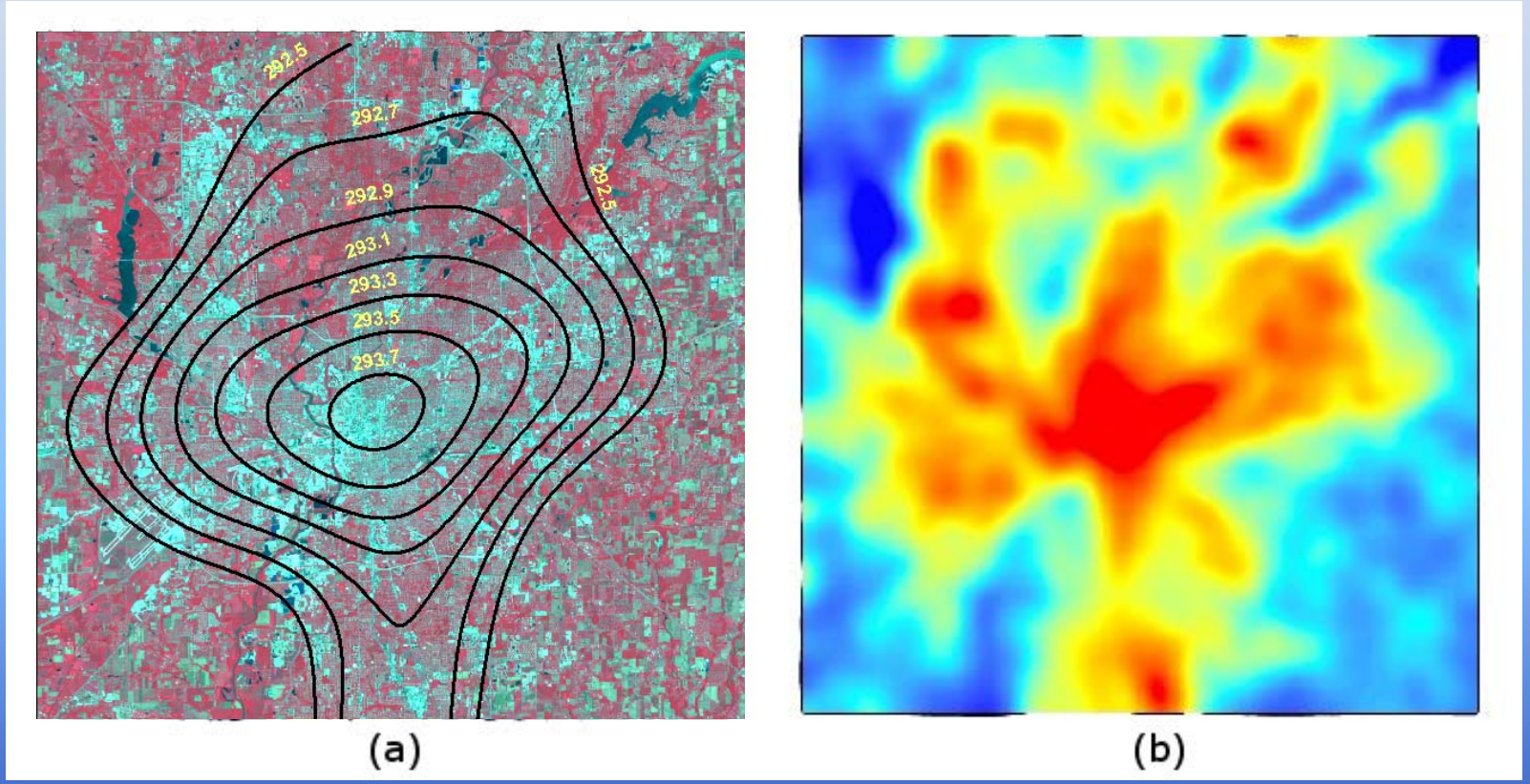
Annual Mean Air Temperature



Why HyspIRI-like TIR Data Needed in UHI Studies?

- No system currently provides data combining both high spatial resolution and revisit capabilities.
  - High revisit/low resolution (AVHRR, MODIS, Meteosat, GOES)
  - High resolution/low revisit (ASTER, Landsat ETM+).
- HyspIRI will enhance resolutions and revisit simultaneously: 60-m resolution, 7 spectral bands, 5-day revisit, day and night imaging.
- HyspIRI data, in conjunction with other NASA data such as MODIS, will help provide further information on urban heat, air quality, ozone, and CO_2 “domes”.

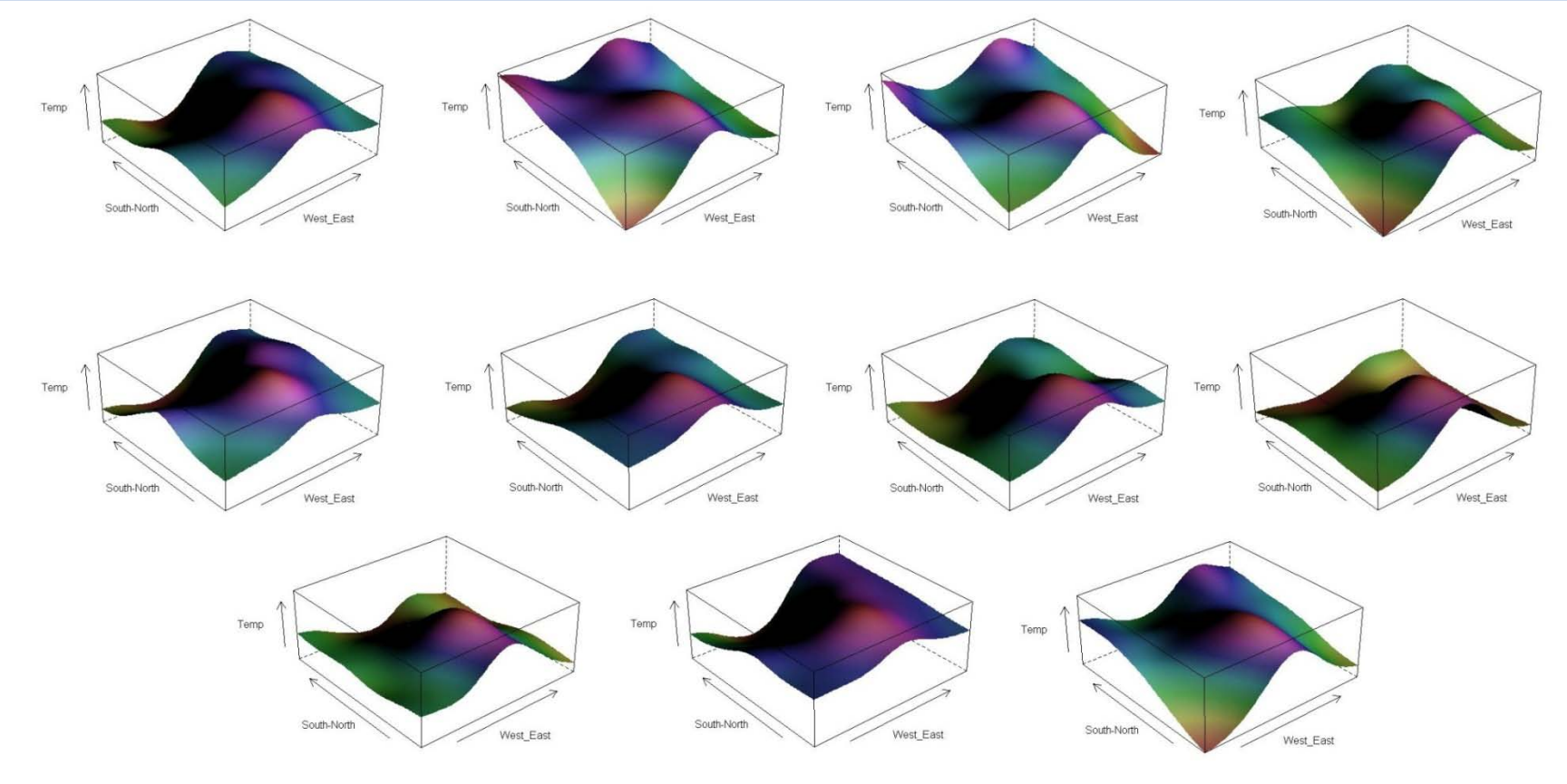
UHI of Indianapolis as detected by Landsat ETM+, June 22, 2000



(a) FCC overlaid with temperature contour; (b) UHIs detected by Gaussian process model

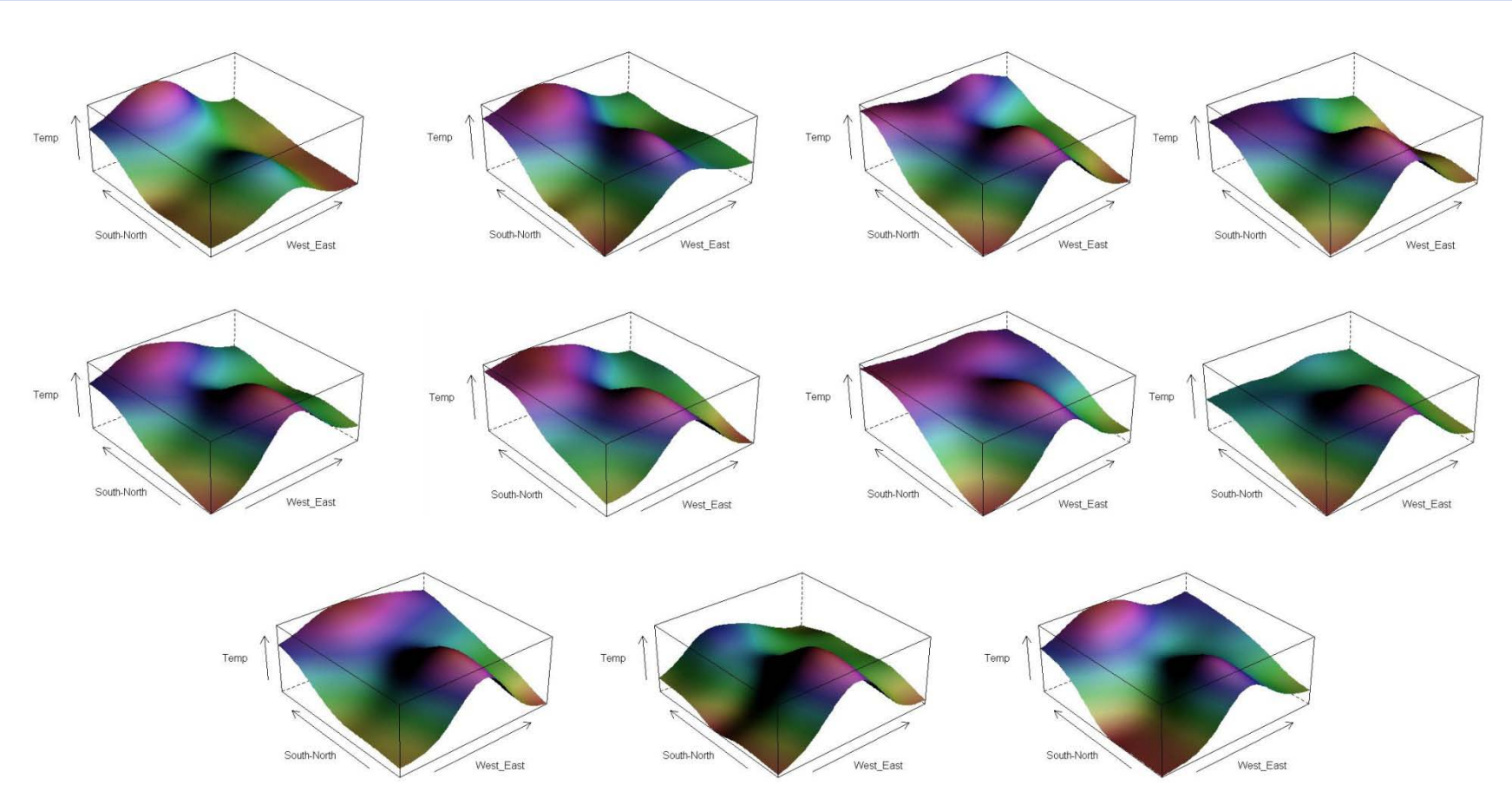
(Rajasekar and Weng, 2009, *IJRS*)

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



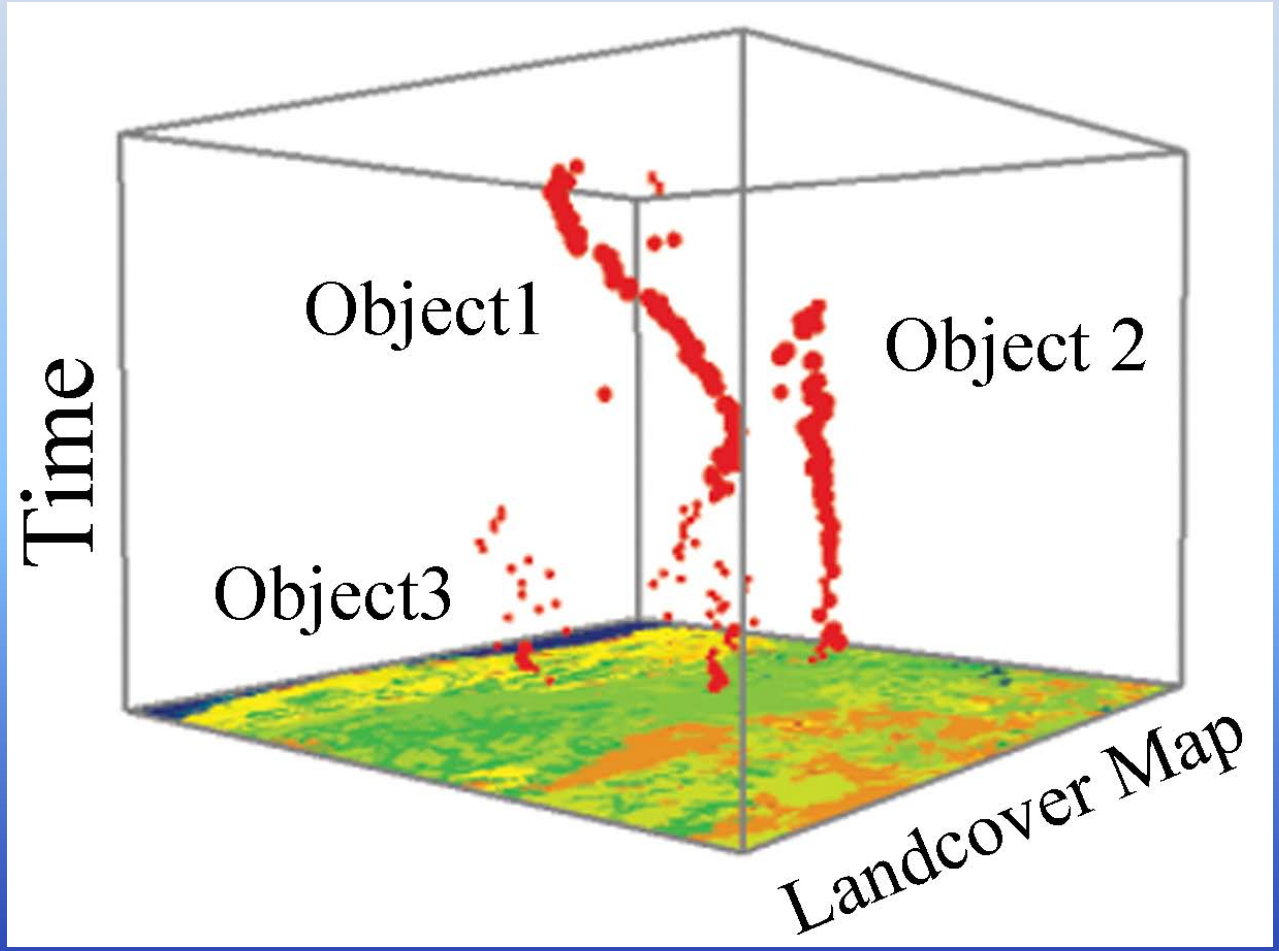
(Rajasekar and Weng, 2009, *ISPRS J.*)

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



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

UHI as an Moving Object over the Space and Time



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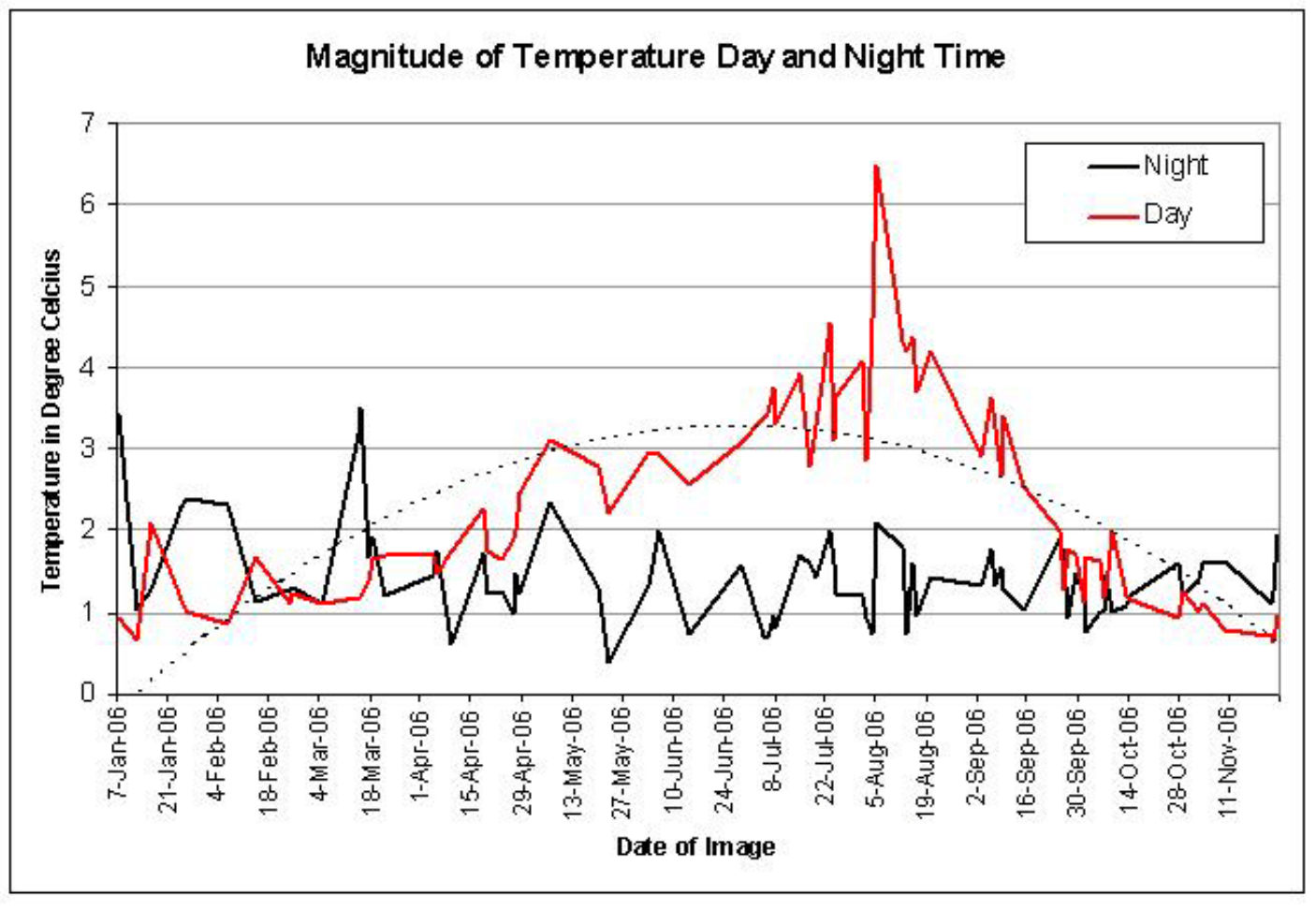
UHI Magnitude/Intensity in 2006



Day Mean: 2.28C (Std Dev: 1.22); Night Mean: 1.47C (Std Dev: 0.59)

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

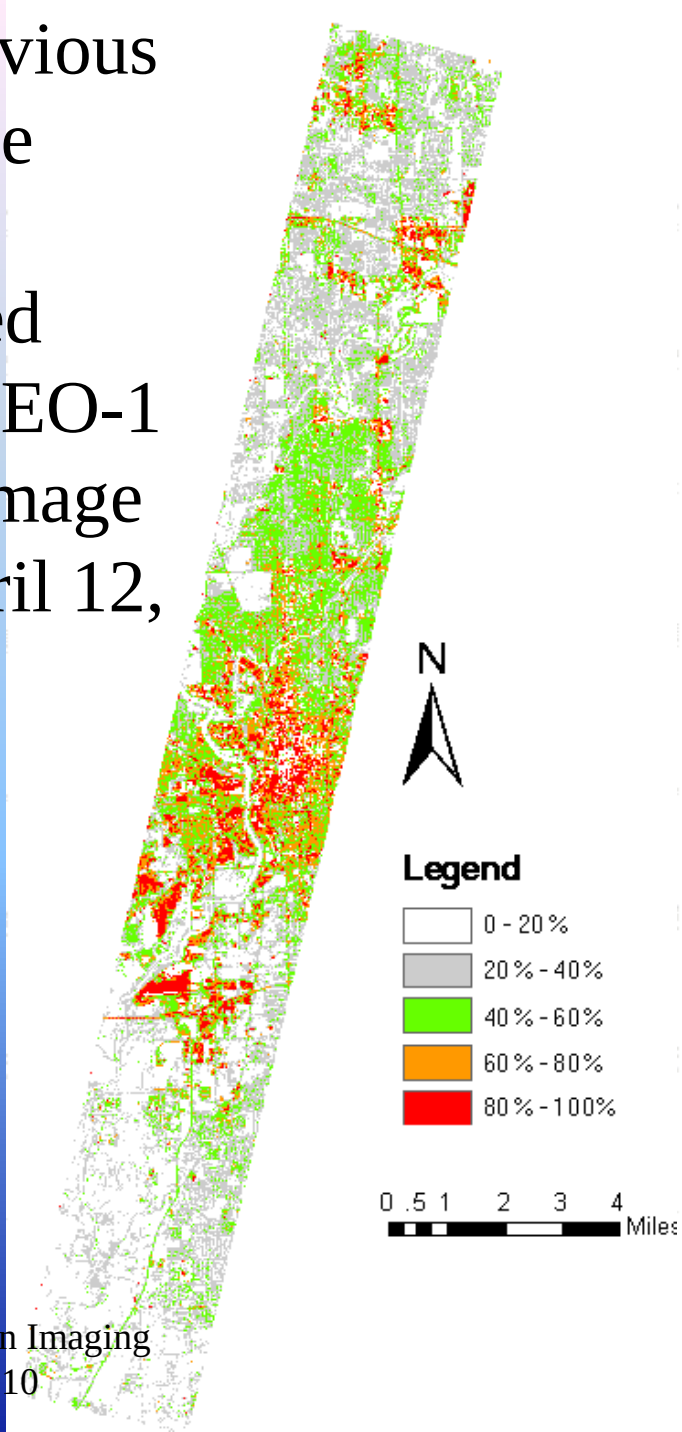
Needs for HyspIRI VSWIR Data in Urban Studies

- Needs for global urban morphological data in urban climate and environmental studies.
- Hyperspectral Imaging: potential to derive detailed information on the nature and properties of different urban surface materials.
- EO-1 Hyperion - very small swath width (7.7 km).
- HyspIRI's spectral, spatial and orbit characteristics will make it very attractive for producing advanced image/data products that can provide more precise and accurate data on various aspects of urban environments for use in analysis and modeling.

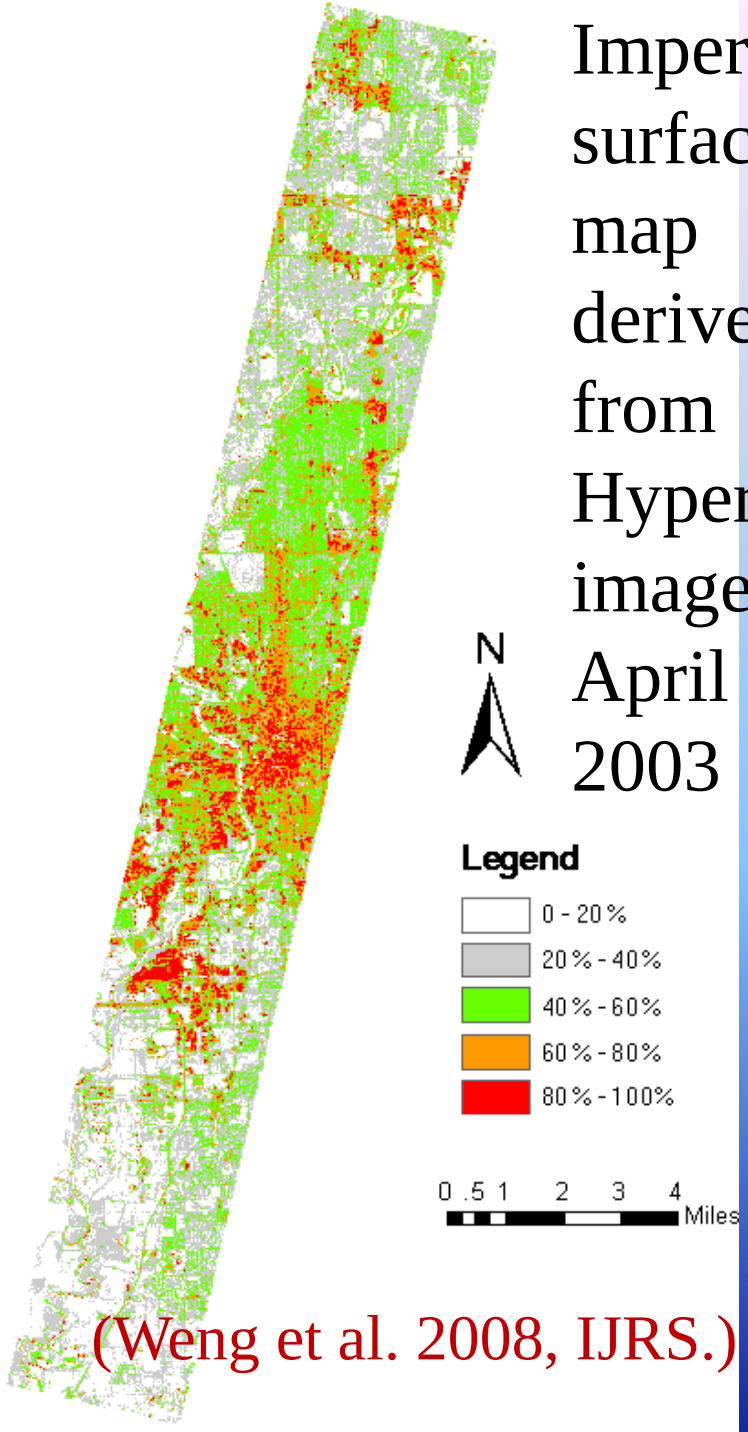
Urban Canopy Parameters Required for MM5 (Dupont, 2001; Lacser and Otte, 2002)

- Building height (mean, std. dev, histograms)
- Vegetation height
- Area-weighted mean building height
- Area-weighted mean vegetation height
- Surface area of walls
- Plan area fraction
- Frontal area index
- Height-to width ratio
- Sky view factor
- Mean orientation of streets
- Roughness length
- Displacement height
- Surface fraction of vegetation, roads, and rooftops
- Impervious areas directly connected to the draining network

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



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



(Weng et al. 2008, IJRS.)

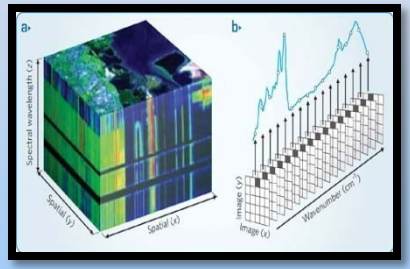
Hyperspectral vs. Multispectral Imaging

- 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).

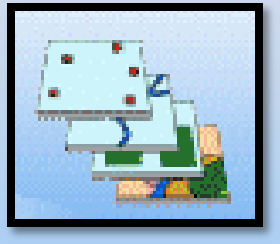
- Implications for HyspIRI: Combined use of VNIR, SWIR, and TIR data for estimation improvement.

HyspIRI Combined with other RS/GIS data to generate Urban Morphological Datasets



HyspIRI VSWIR data Products

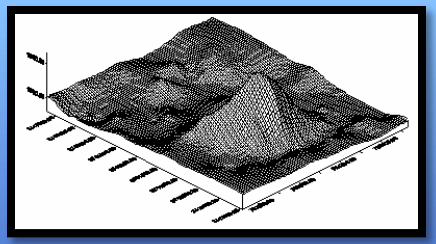
Urban morphological datasets



GIS datasets

Lidar

Digital photogrammetry



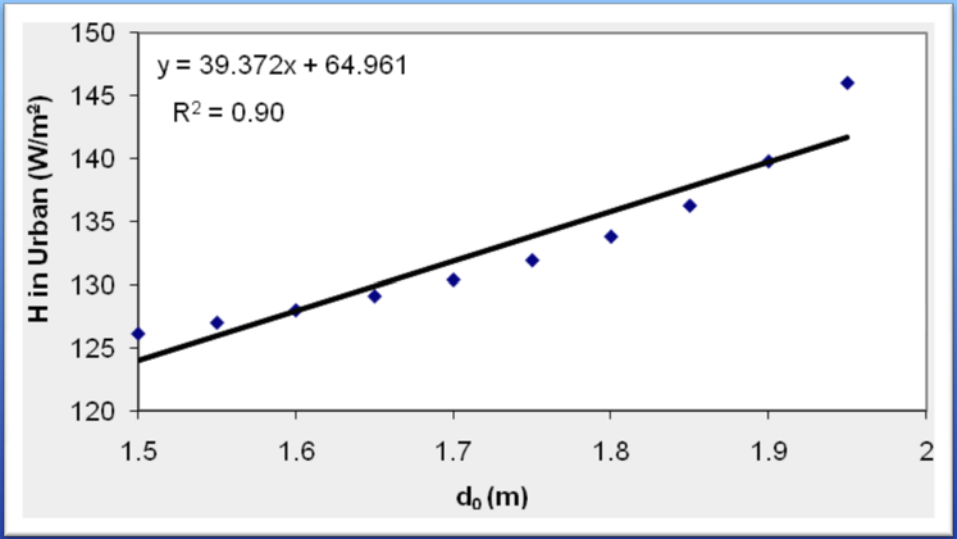
Digital elevation model

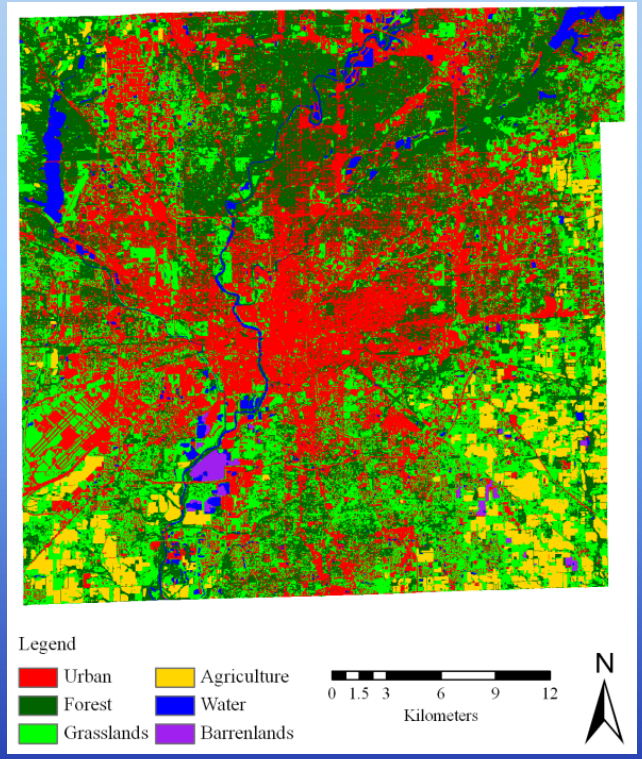
HyspIRI Urban Imaging
Weng et al. 2010

More Detailed, Morphology-Based LULC Data

- Mesoscale modeling use LULC classes as surrogates to define surface parameters (e.g., roughness lengths, displacement height)
- More detailed and morphology-based LULC classes are needed in urban climate modeling and environmental studies.
- USGS NLCD drawbacks: accuracy; update; urban heterogeneity; CIT as a single category)

- A solution is to use morphological characteristics (e.g., building density, mean building height, **vegetative cover, impervious surface fraction**) to subdivide a generalized first level of land use/cover.





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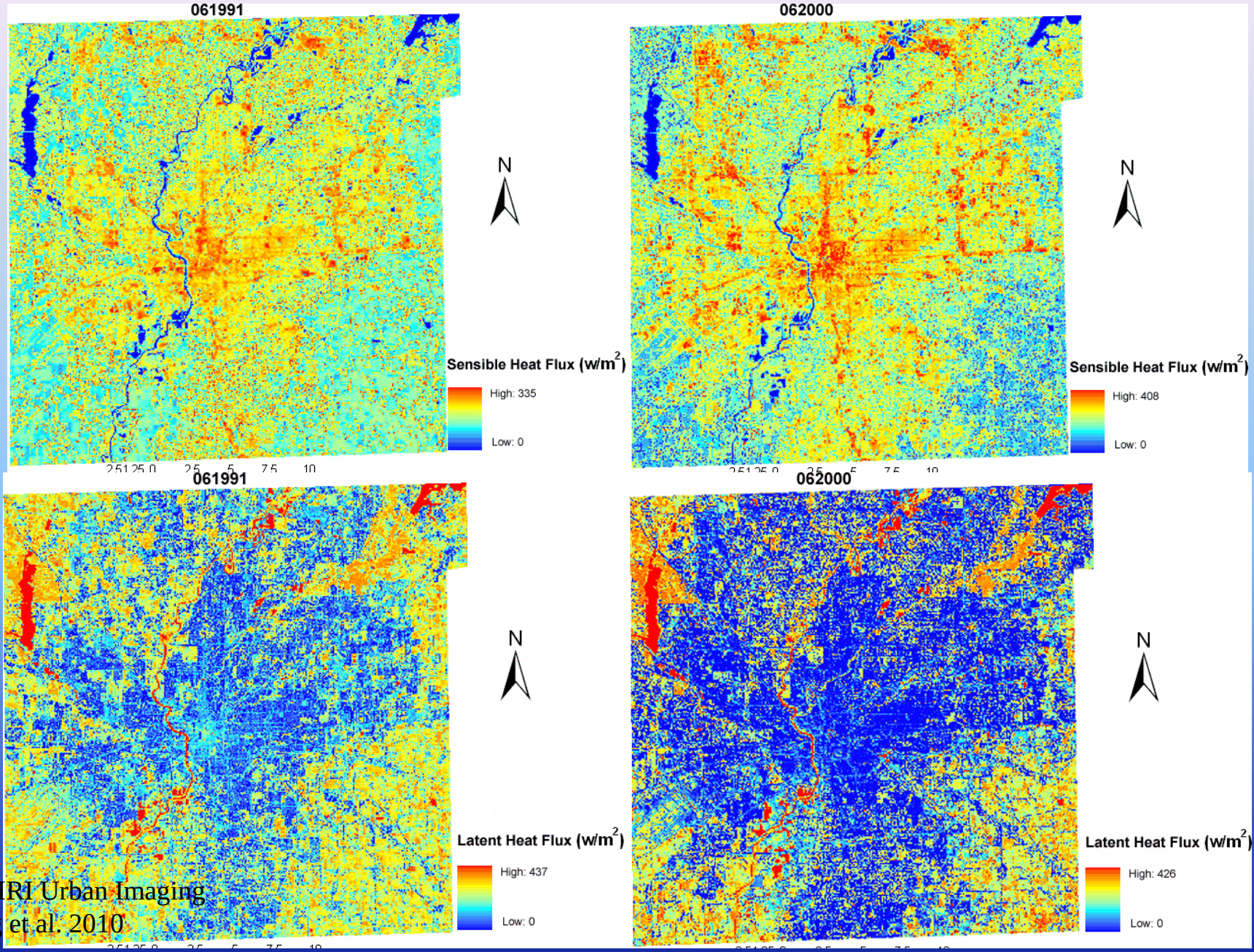
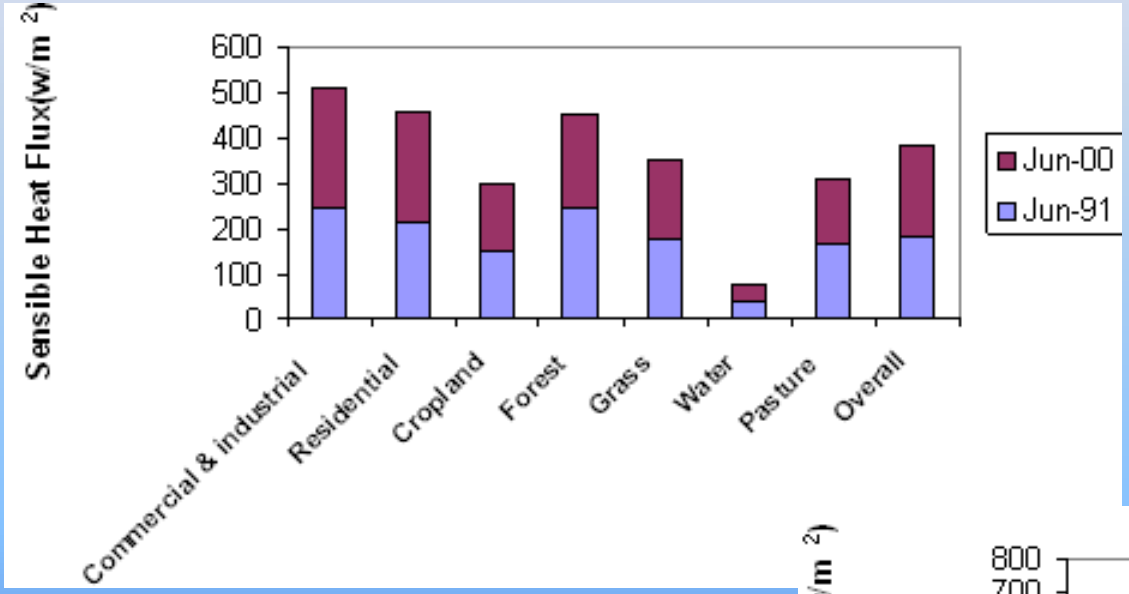
Changes in Surface Heat Fluxes due to Urbanization

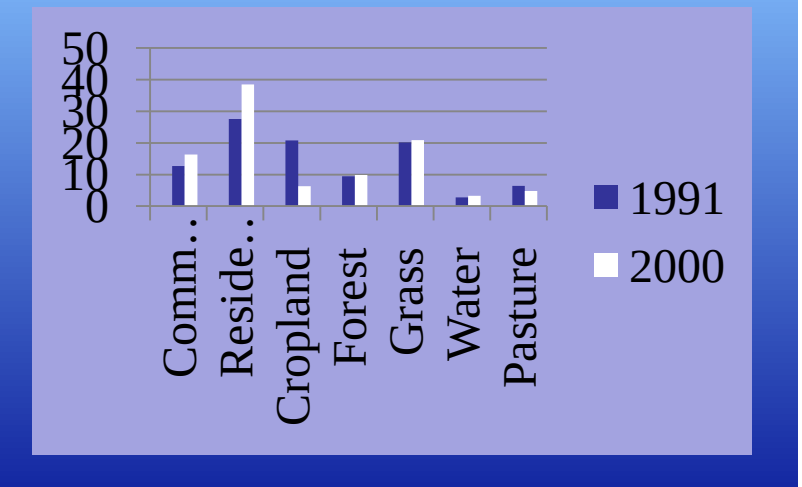


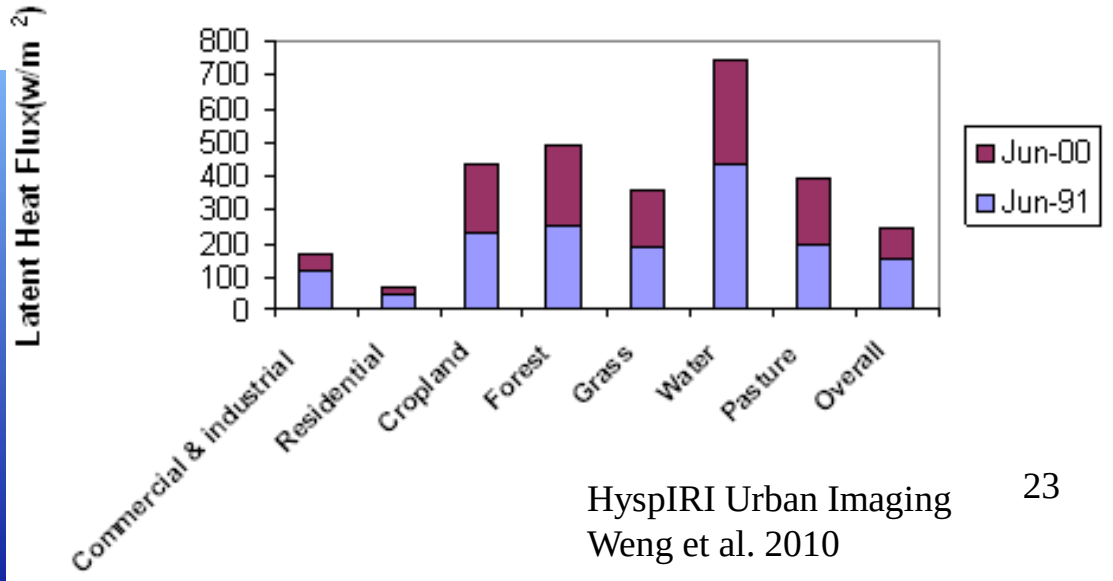
HyspIRI Urban Imaging
Weng et al. 2010

Sensible and Latent Heat Fluxes in Indianapolis (June 6, 1991 *vs*. June 22, 2000) (unit: W/m^2)



Sensible Heat Flux	1991	182.14
	2000	200.29
Latent Heat Flux	1991	151.31
	2000	94.33





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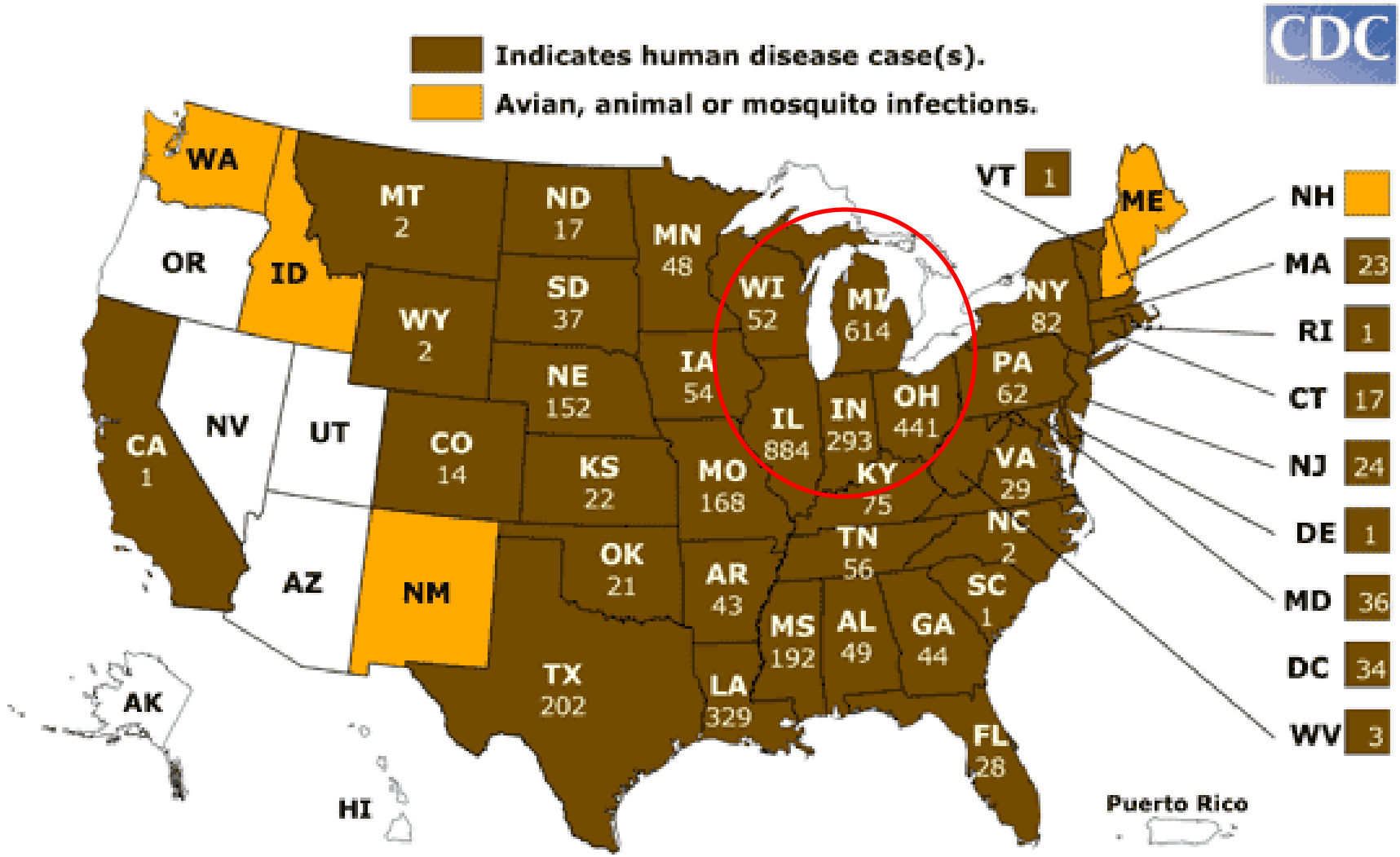
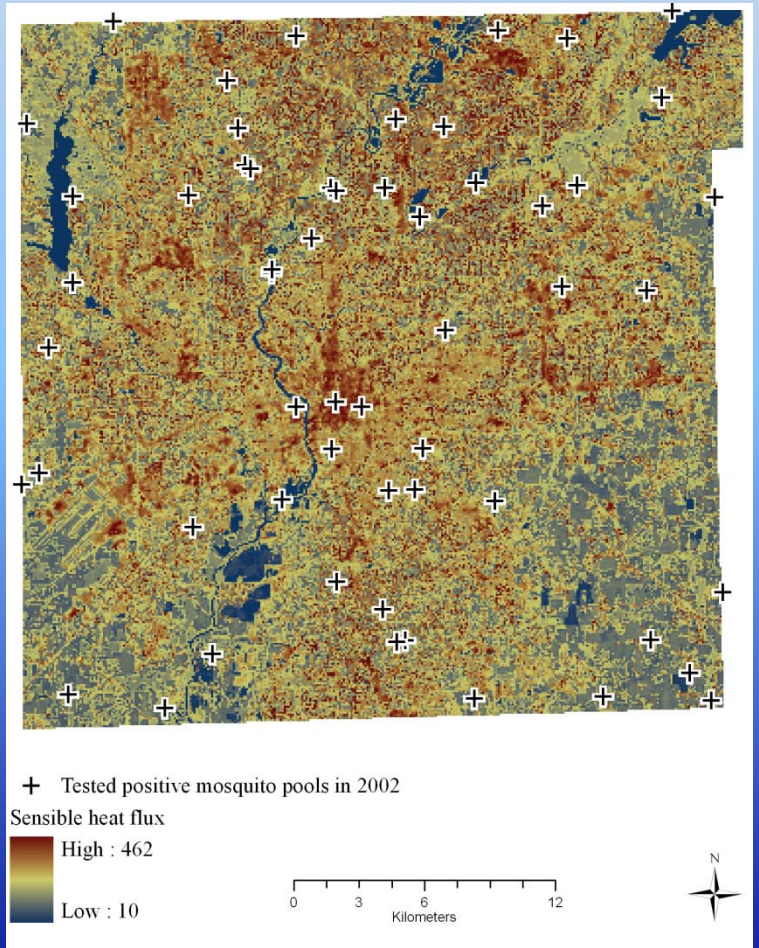
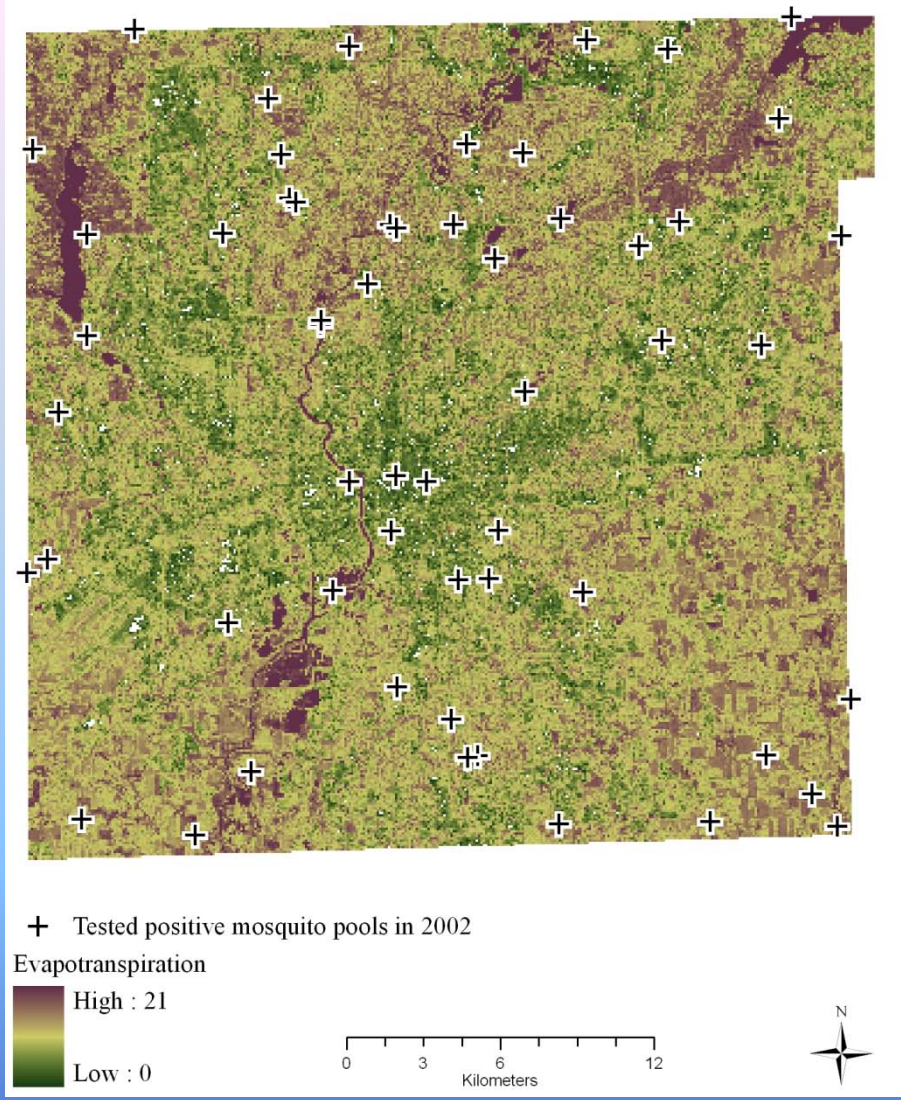
2002 West Nile Virus (WNV) Activity in the United States



http://www.cdc.gov/ncidod/dvbid/westnile/surv&control.htm

In Indianapolis, the occurrence of WNV was found negatively correlated with sensible heat flux, but positively with evapotranspiration (ET).





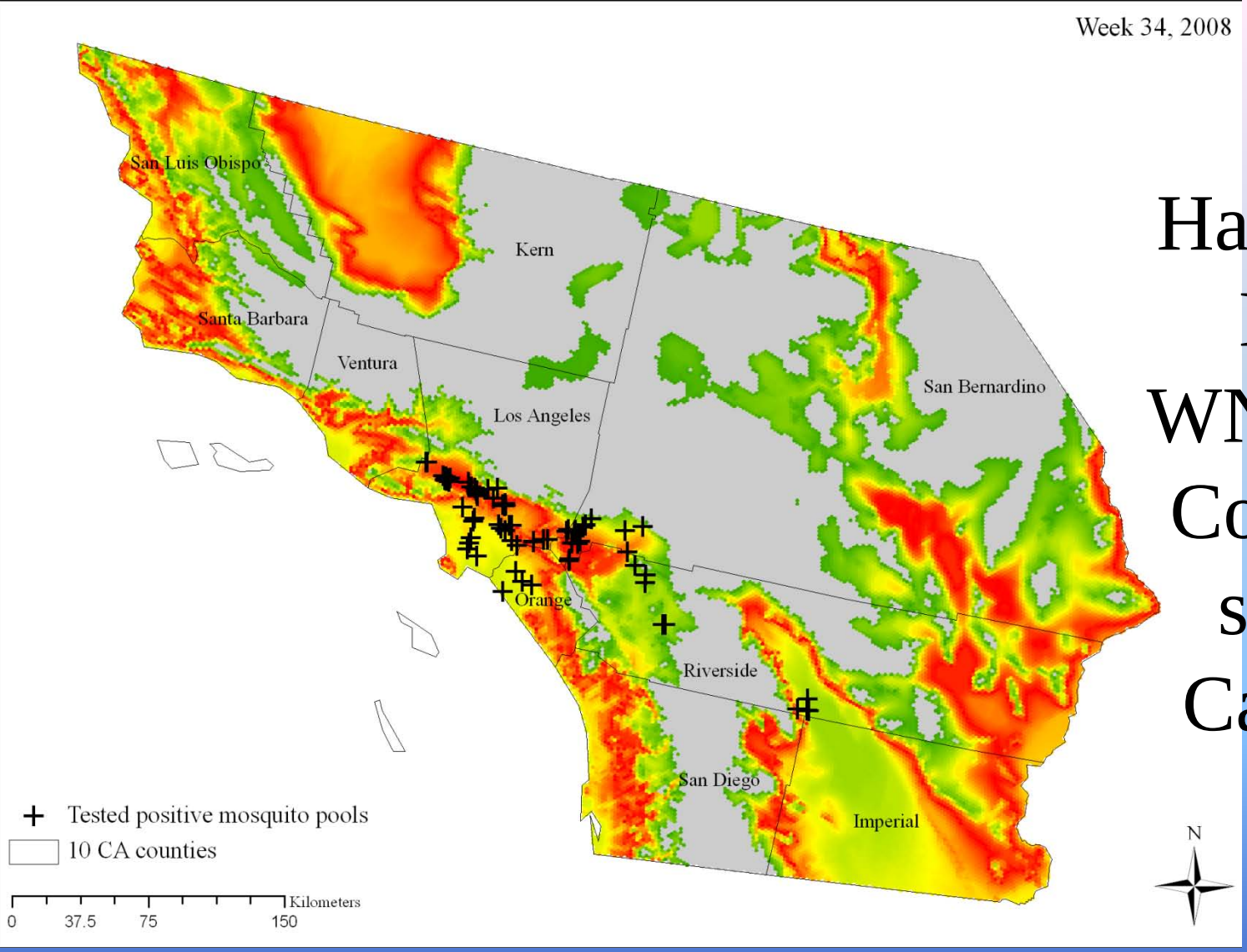
Temporal mismatch: Aster LST data was acquired June 16, 2001, but WNV data in 2002.

Weng et al. 2010

Identification of Health Hazard Risk Areas

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

Health Hazard Risk Map of WNV in Ten Counties of southern California:



High Risk ⇨ low risk: red, yellow, green, and gray.

HyspIRI Urban Imaging
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HyspIRI Data for WNV Studies

- TIR instrument 5-day revisit:
  - Potential one-two observations per epidemic week. Rapid detection and tracking of events.
- TIR 60-m spatial resolution:
  - Better health hazard risk maps of WNV. Targeted interventions to reduce the vulnerability of humans.
- VSWIR Data: Higher temporal resolution, spectral (7 bands) and spatial (60-m) resolution:
  - Precise spatiotemporal variations of envi. variables.
  - Better prediction of disease outbreaks.

Conclusions

- HyspIRI TIR data are essential for improving knowledge on urban heat island and related climate characteristics, air quality, ozone, and CO2 “domes”.
- The combined VSWIR and TIR data: Rapid detection and tracking of diseases, targeted interventions, better prediction of disease outbreaks.
- VSWIR data in conjunction with other NASA satellite and ancillary data: potential to provide detailed, global urban morphological datasets, key to climate modeling and characterization/quantification of urban surface heat fluxes and urban environments.