Measurement of Urban Land Surface Temperatures as Related to Land Cover Change Dynamics: The HysplRI Advantage

Moving Towards an Integrated Interdisciplinary Urban Science

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Huntsville, Alabama

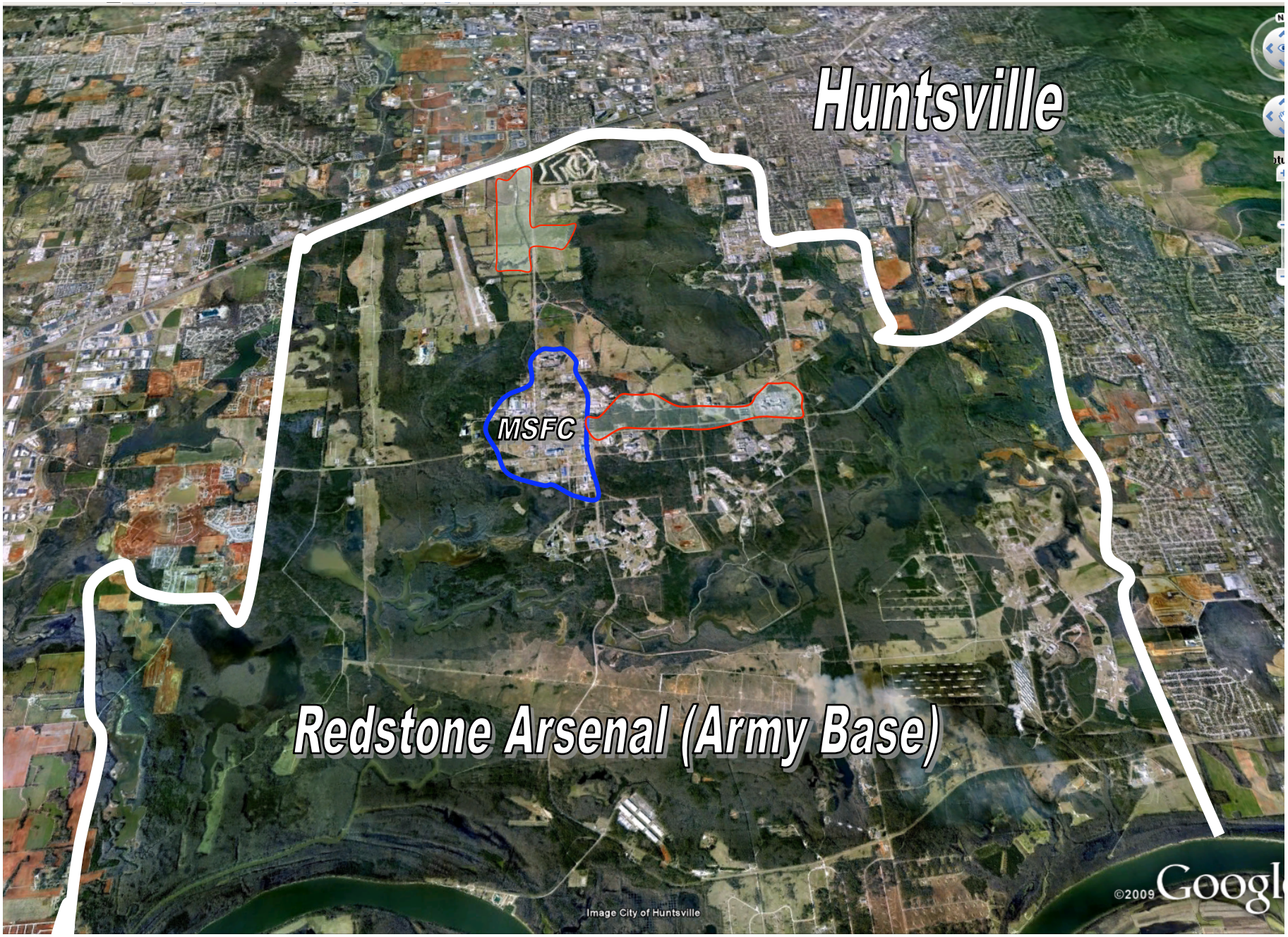
The Talk

Perceptions of HyspIRI Data Applications to Urban Land Use/Land Cover Change, Analysis of the Urban Heat Island Effect, and Climate Impacts

- HyspIRI VSWIR-TIR data for Land Cover/Land Use Change (LULCC) relationships with Land Surface Temperature (LST) for analysis of Urban Heat Island (UHI) at the local scale

- HyspIRI LULCC and LST relationships for UHI analysis at local to regional, or potentially even global, scales

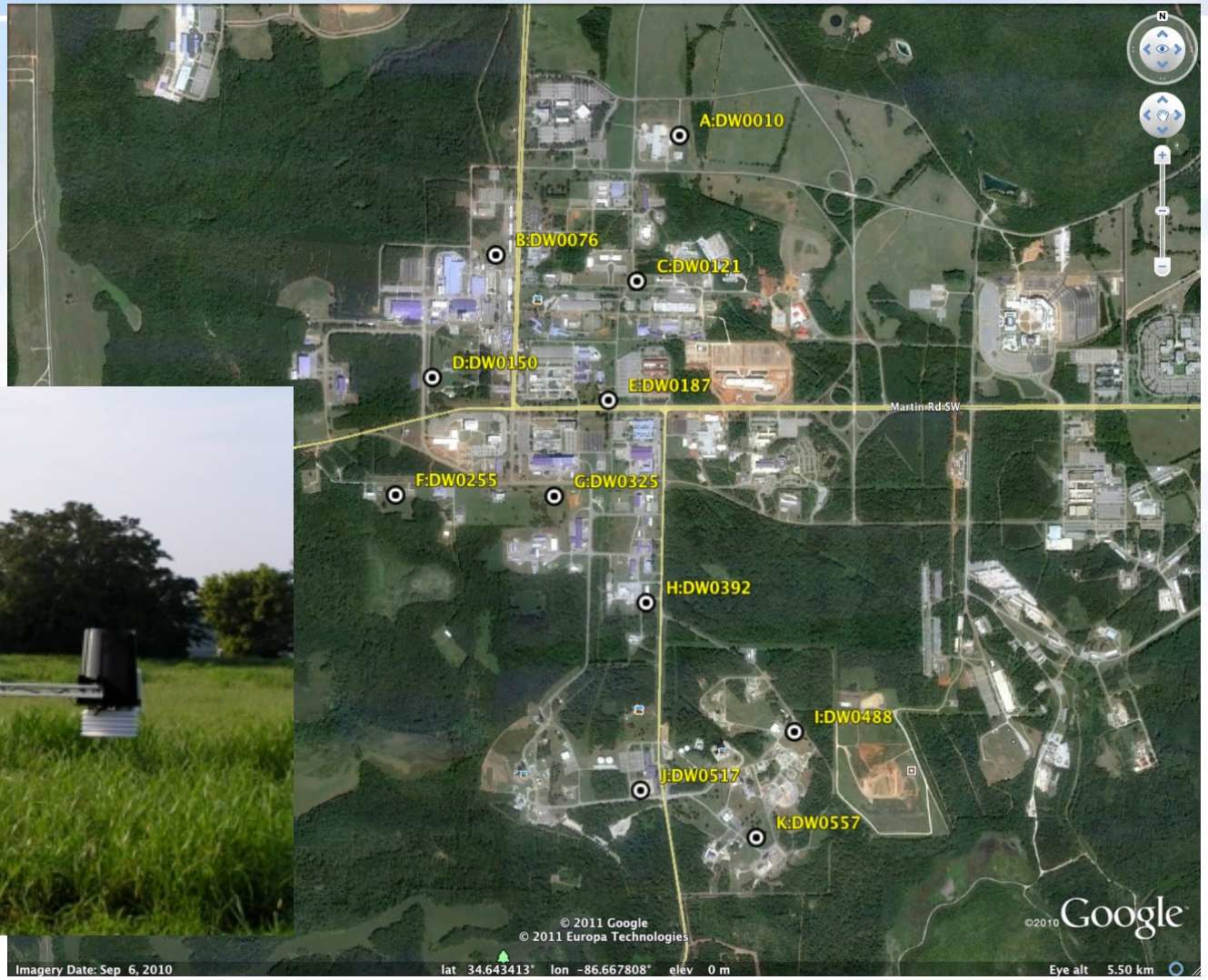
- Integration of HyspIRI data with multi-scaled geospatial data for modeling and assessment of urbanization impacts on the peri-urban environment and climate


Huntsville
MSFC
Redstone Arsenal (Army Base)
Image City of Huntsville
©2009 Google

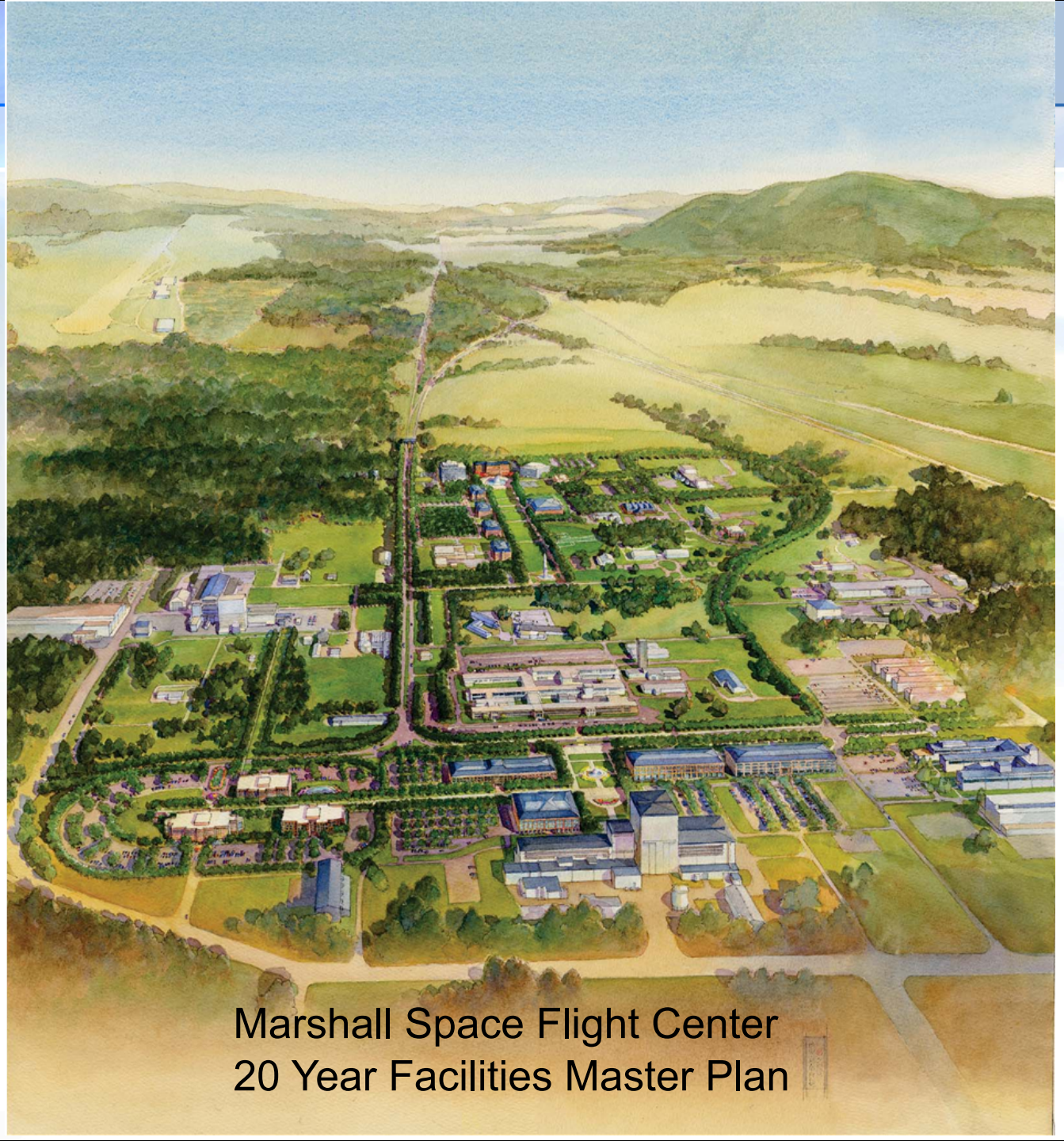
Weather Station Installation

- 11 sites across MSFC
- 10m wind speed and direction (not shown)
- 2m temperature, humidity, rainfall (below)

Real-time transmission (1-5 min intervals)



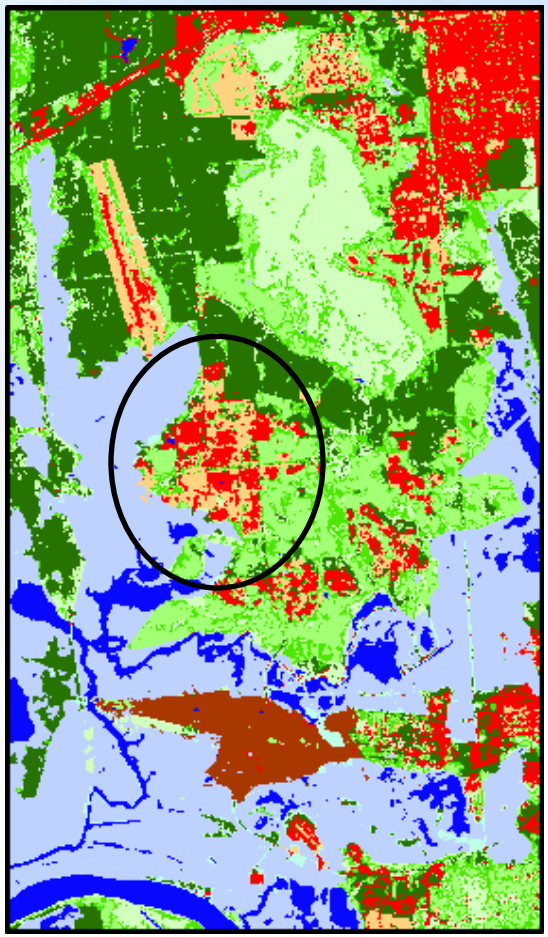
Land Cover and Climate Change Impacts



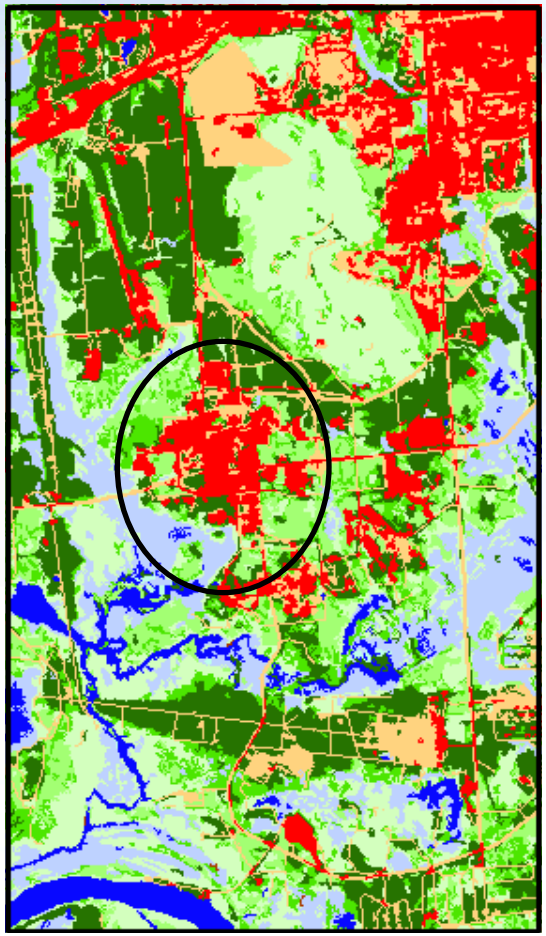
Marshall Space Flight Center
20 Year Facilities Master Plan

Land Use Change around MSFC

Dramatic increase in urban-residential land use category from 1992-2001

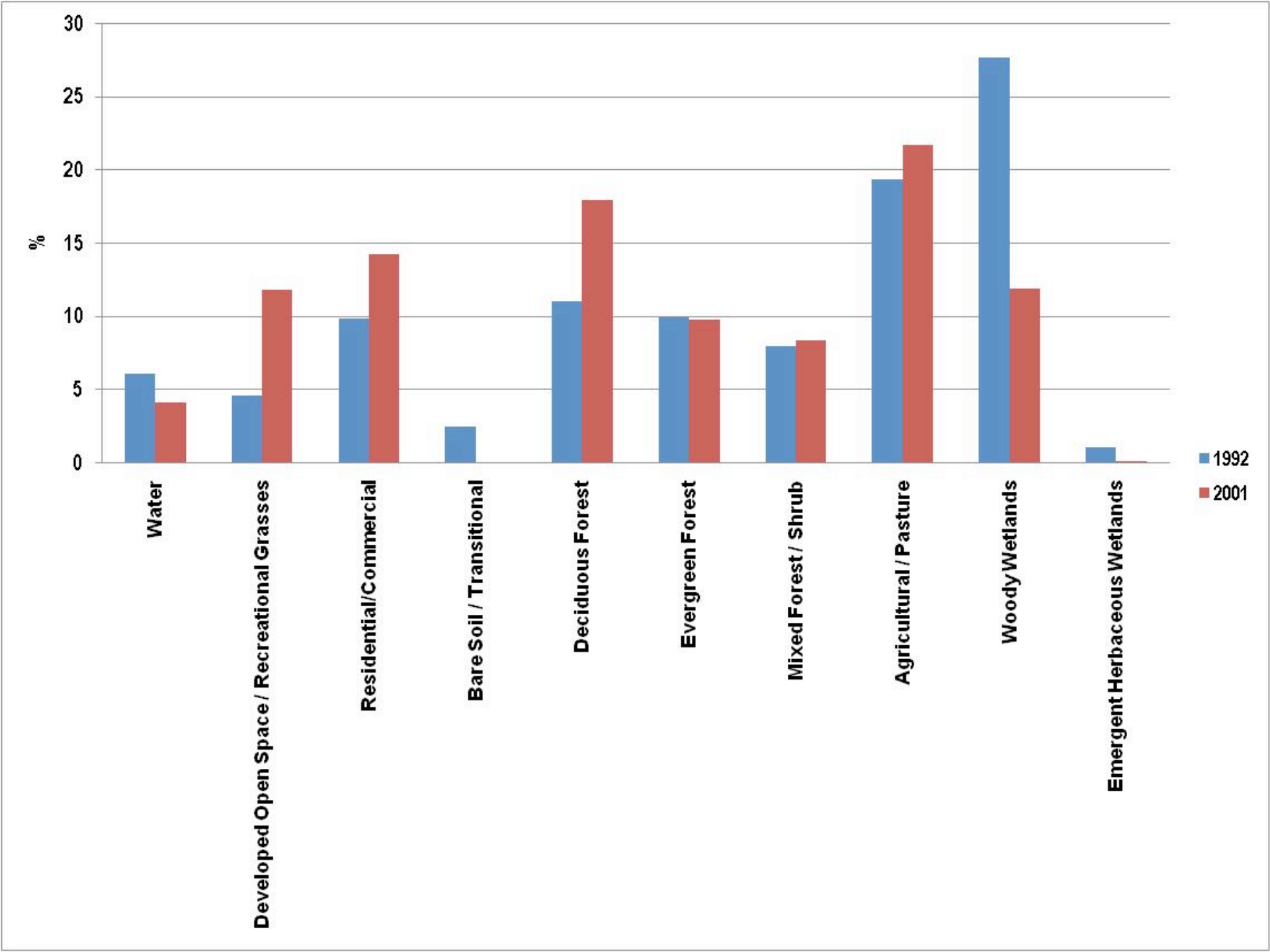


1992

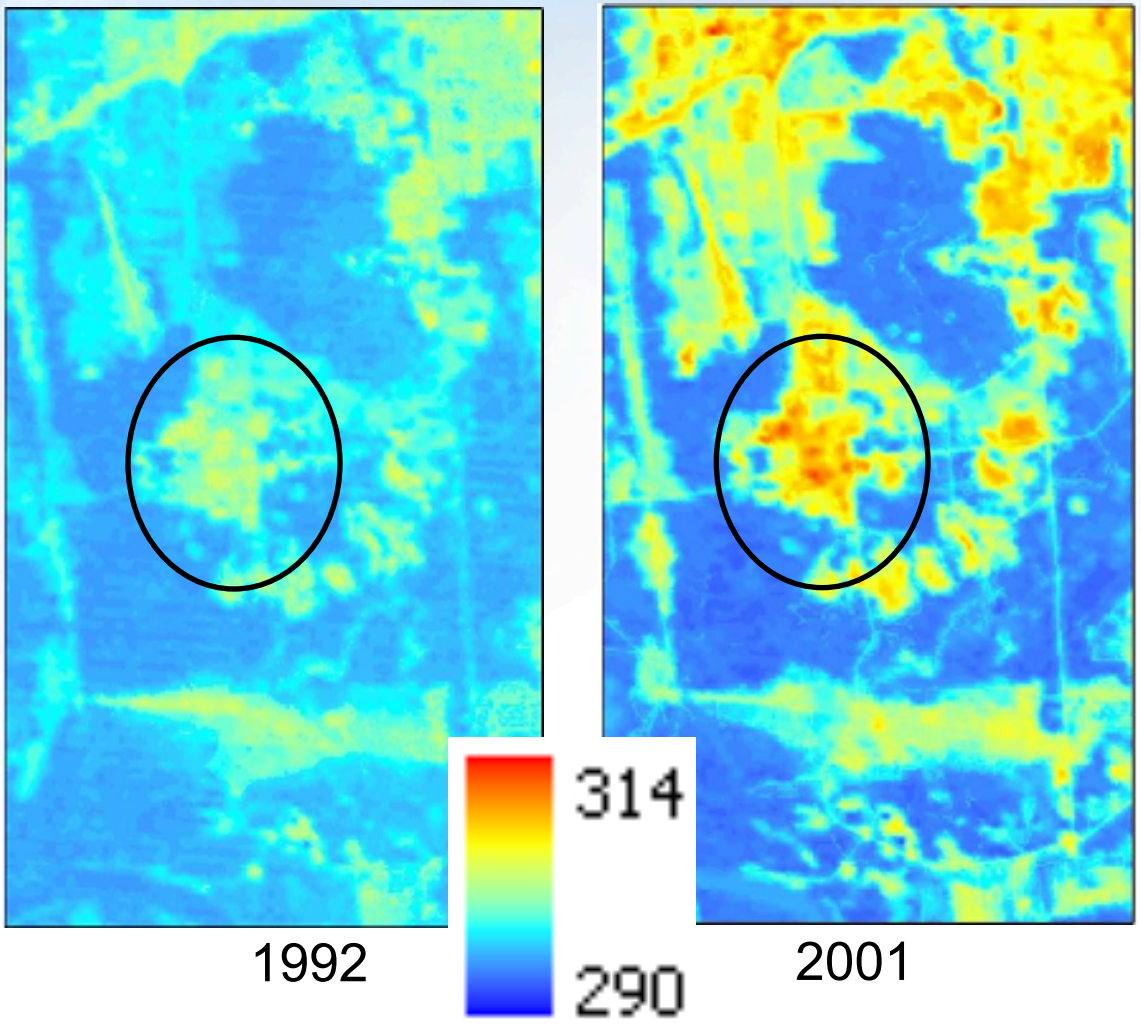


2001

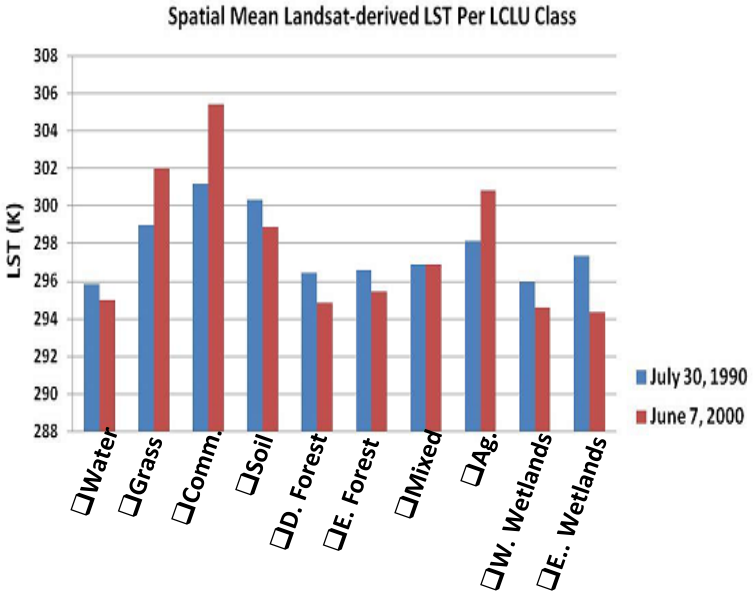
- Water
- Developed Open Space/Recreational Grasses
- Residential/Commercial
- Bare Soil / Transitional
- Deciduous Forest
- Evergreen Forest
- Mixed Forest / Shrub
- Agricultural / Pasture
- Woody Wetlands
- Emergent Herbaceous Wetlands


30
25
20
15
10
5
0
%
Water
Developed Open Space / Recreational Grasses
Residential/Commercial
Bare Soil / Transitional
Deciduous Forest
Evergreen Forest
Mixed Forest / Shrub
Agricultural / Pasture
Woody Wetlands
Emergent Herbaceous Wetlands
1992
2001

Land Use Change Drives Thermal Change

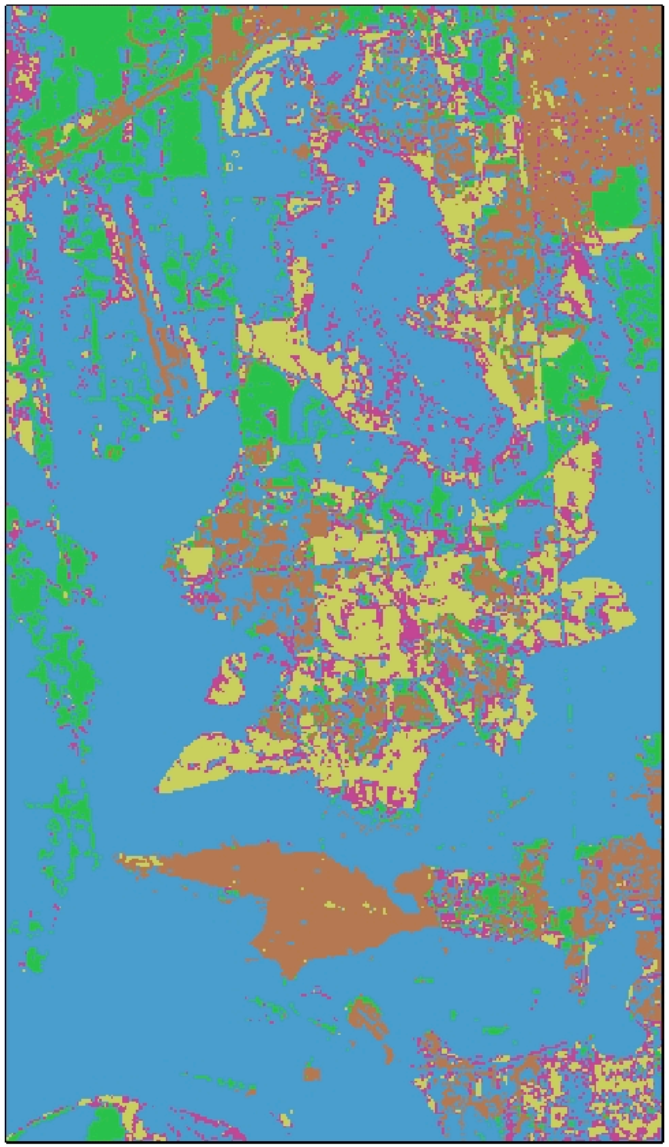


Conversion of forest, shrub, and agricultural land to MSFC infrastructure substantially changes surface thermal signatures



Need to determine impact on local temperatures

Emissivity 1992

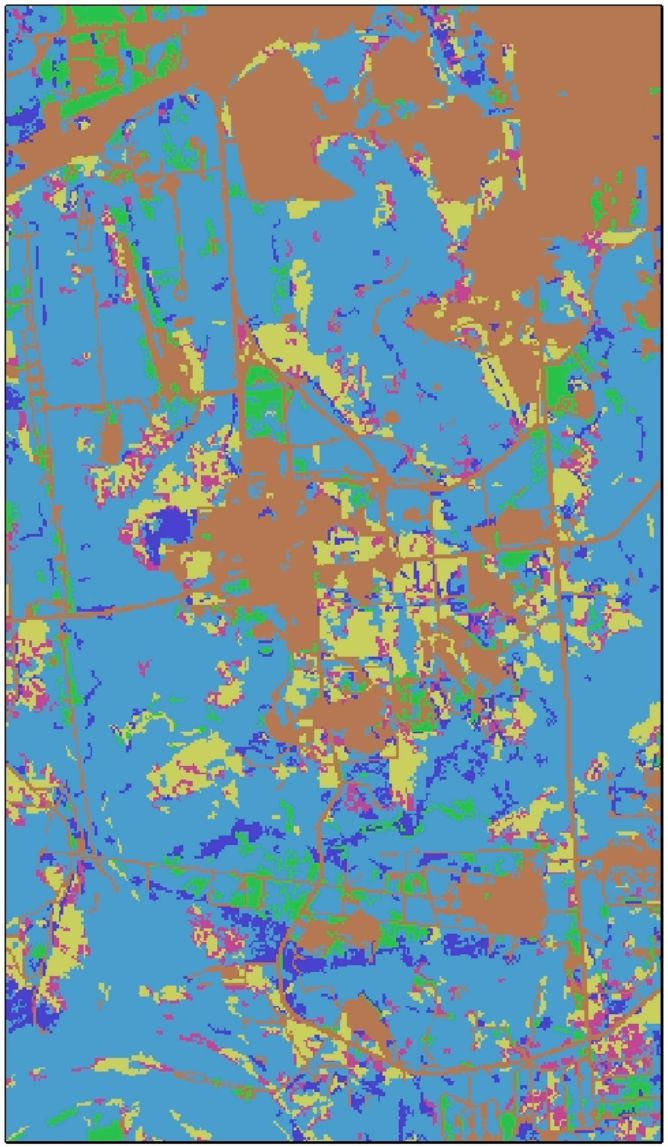


❑**Emissivity**

- 0.969 (Used for Bare Soil; and Developed Pixels)
- 0.974 (Used for Shrub Pixels)
- 0.980 (Used for Crops Pixels)
- 0.989 (Used for Deciduous Forests (assuming they're mostly Broadleaf); Wetlands, and Water Pixels)
- 0.9895 (Used for Mixed Forests Pixels)
- 0.990 (Used for Evergreen Pixels (assuming they're mostly Needle))

❑Based on a look-up table in Snyder et al. 1998 and given that our analysis is for a period when the vegetation is green.

Emissivity 2001



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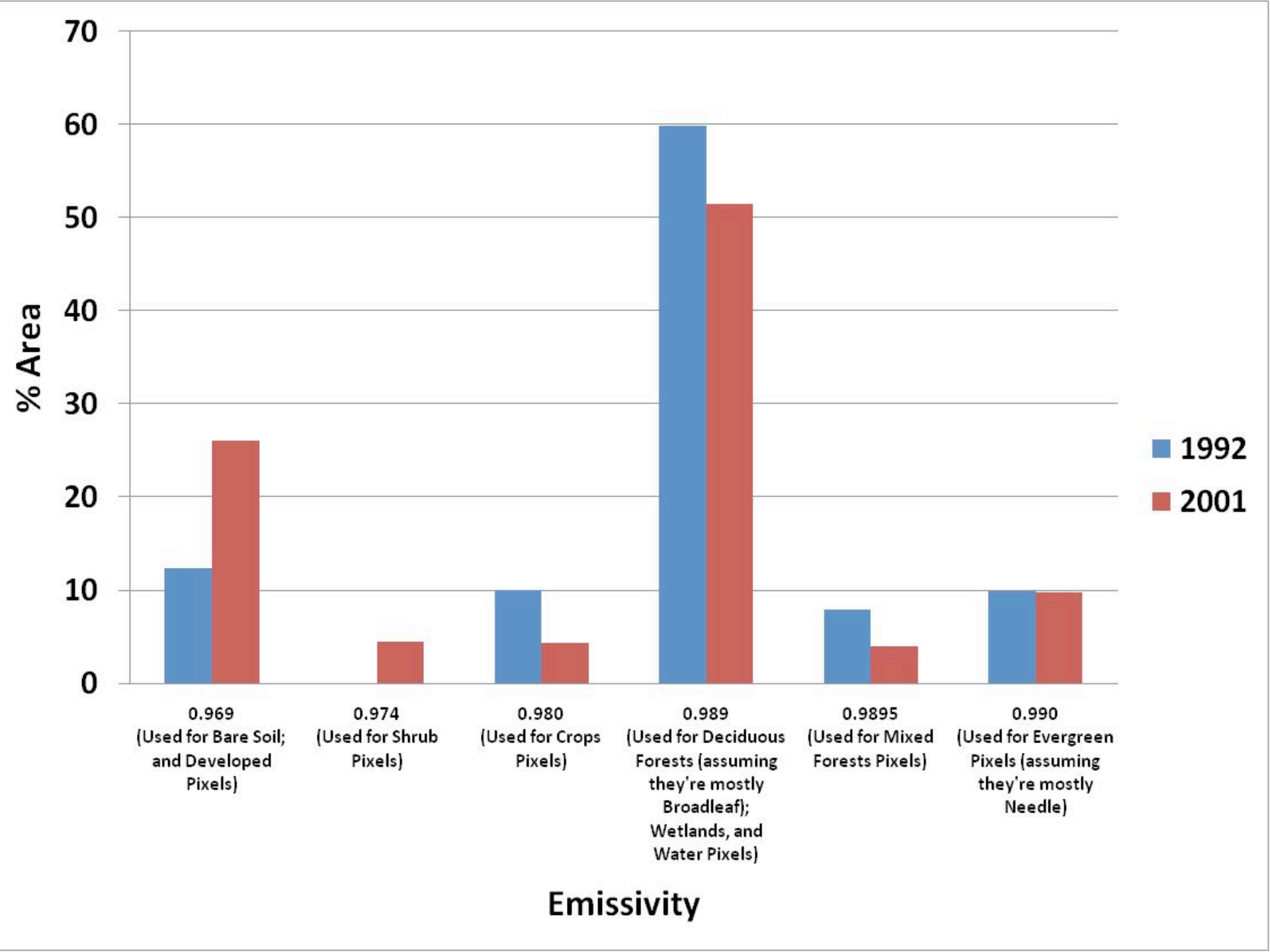
70
60
50
40
30
20
10
0
% Area
1992
2001
0.969 (Used for Bare Soil; and Developed Pixels)
0.974 (Used for Shrub Pixels)
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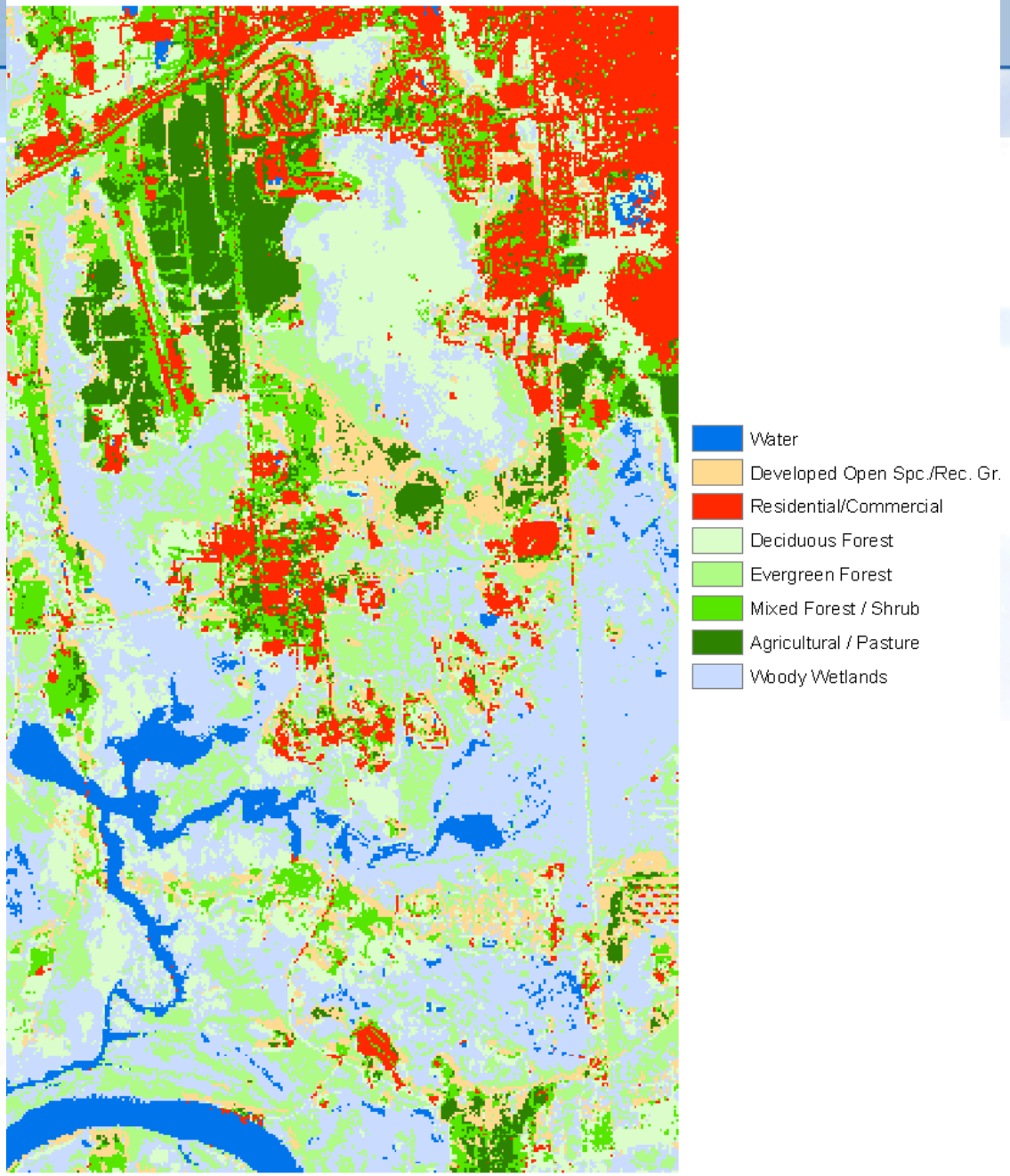
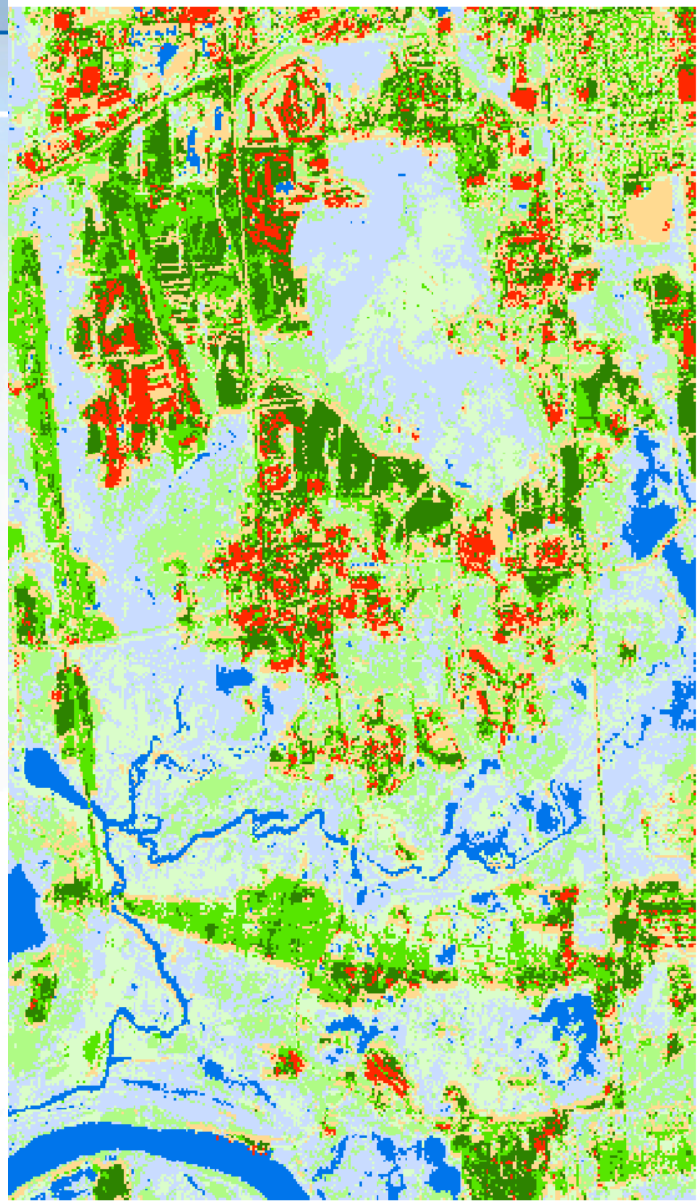
Emissivity

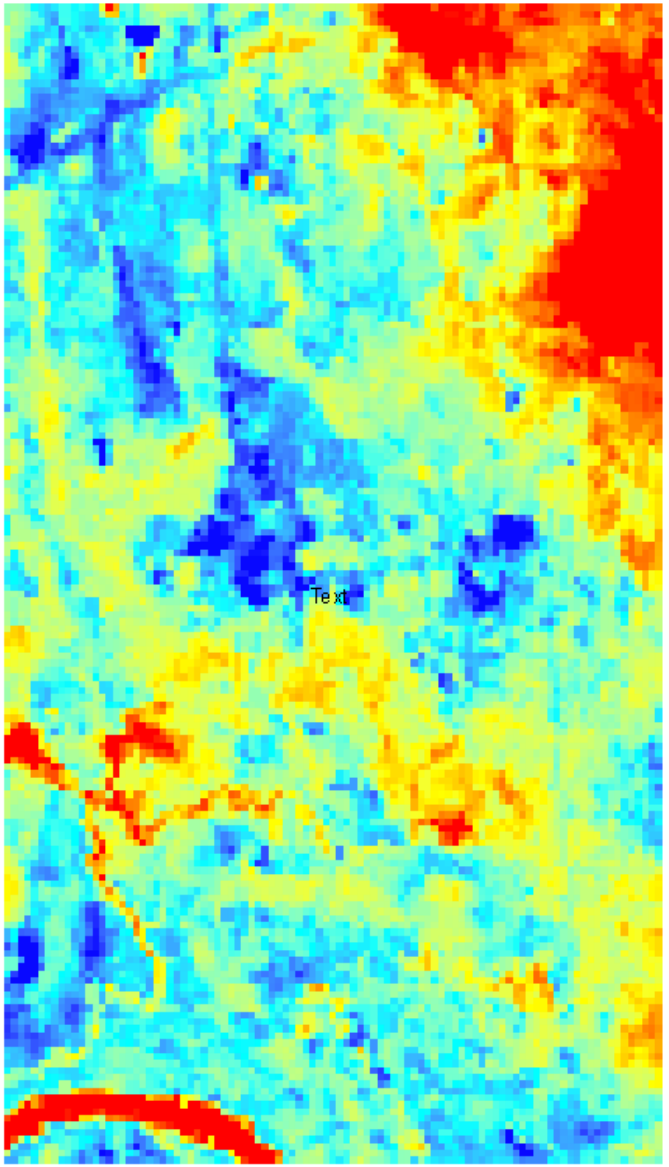
ASTER LULC (APR 6, 2001)



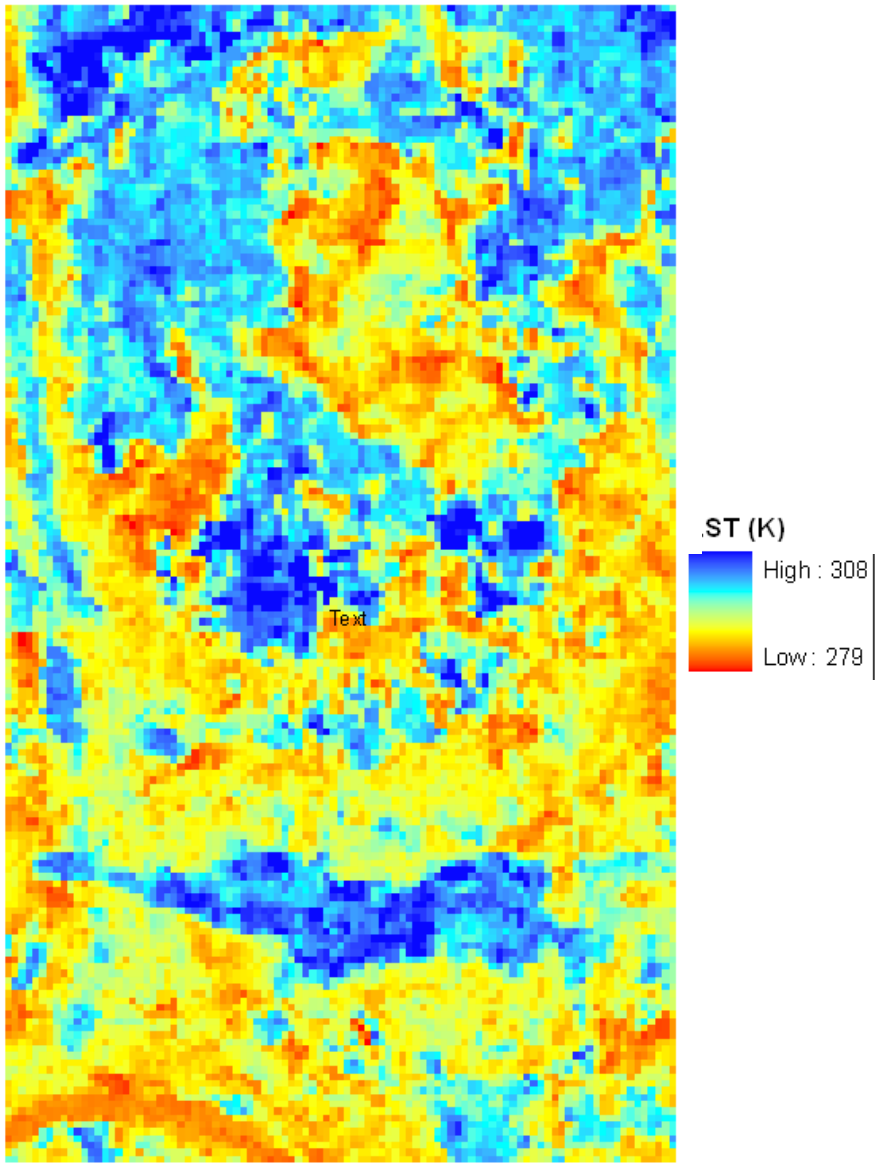
ASTER LULC (MAR 1, 2011)



ASTER LST (K) (APR 6, 2001)

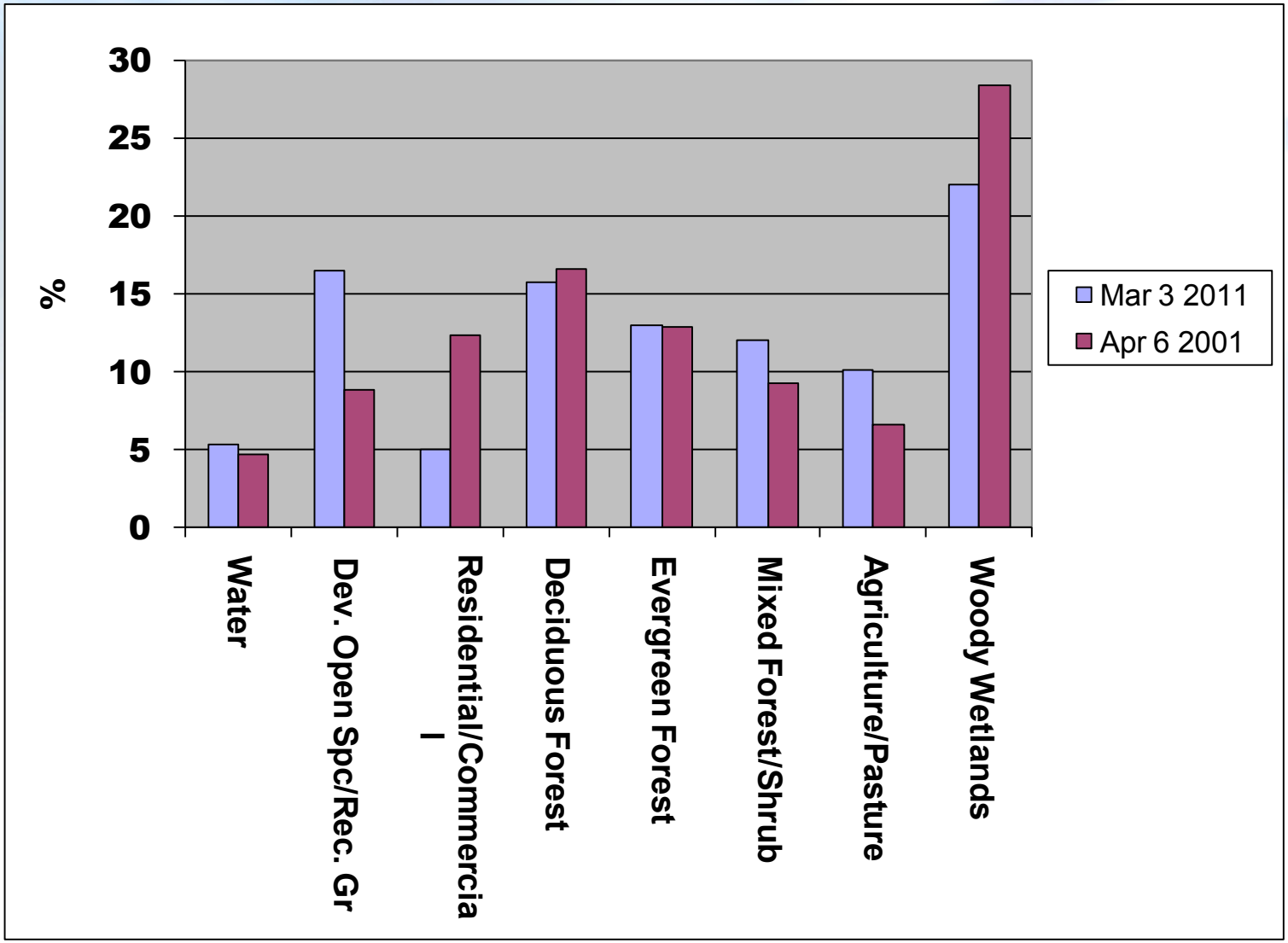


ASTER LST (K) (MAR 1, 201 l)

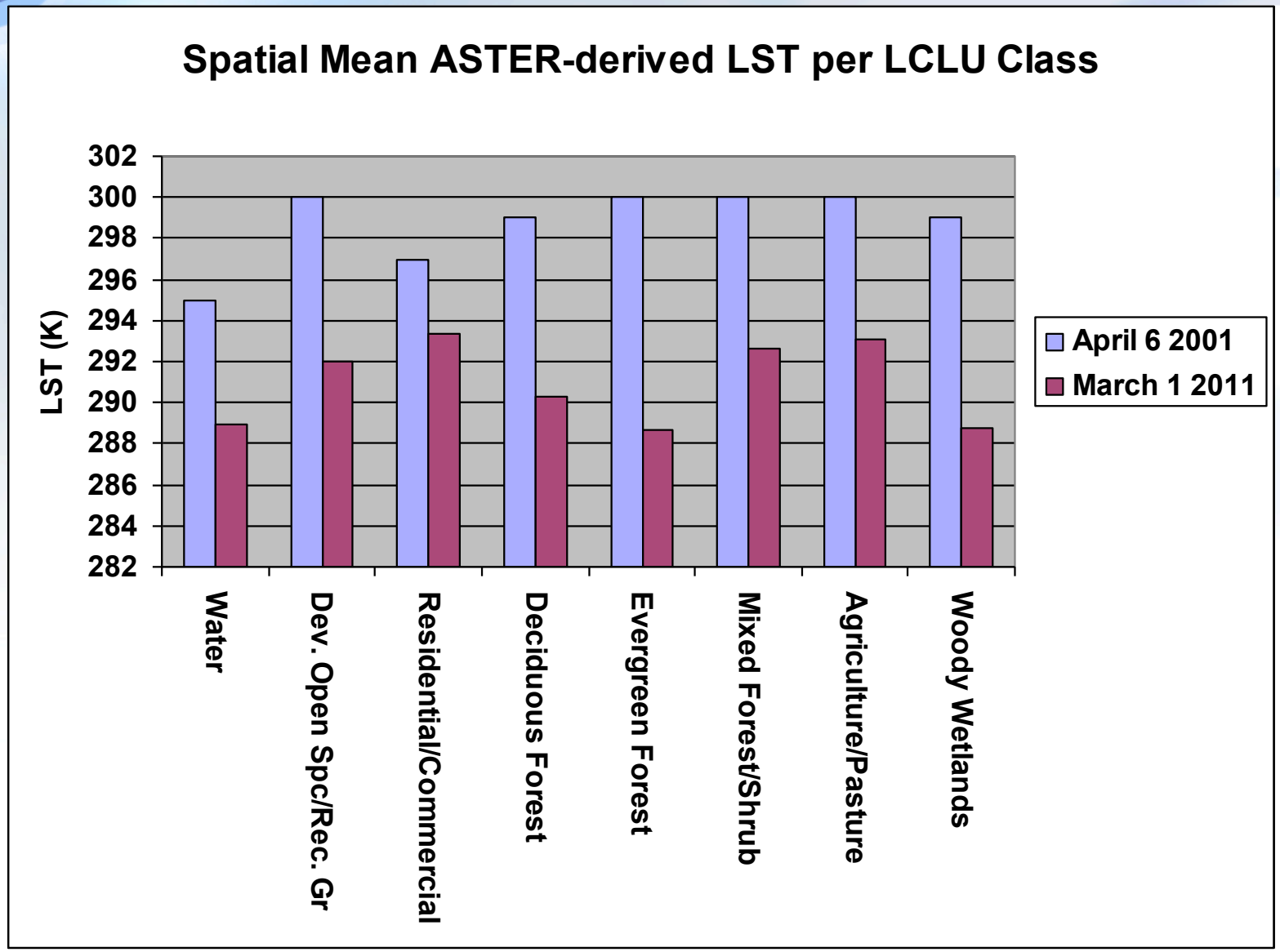


Land Cover and Climate Change Impacts

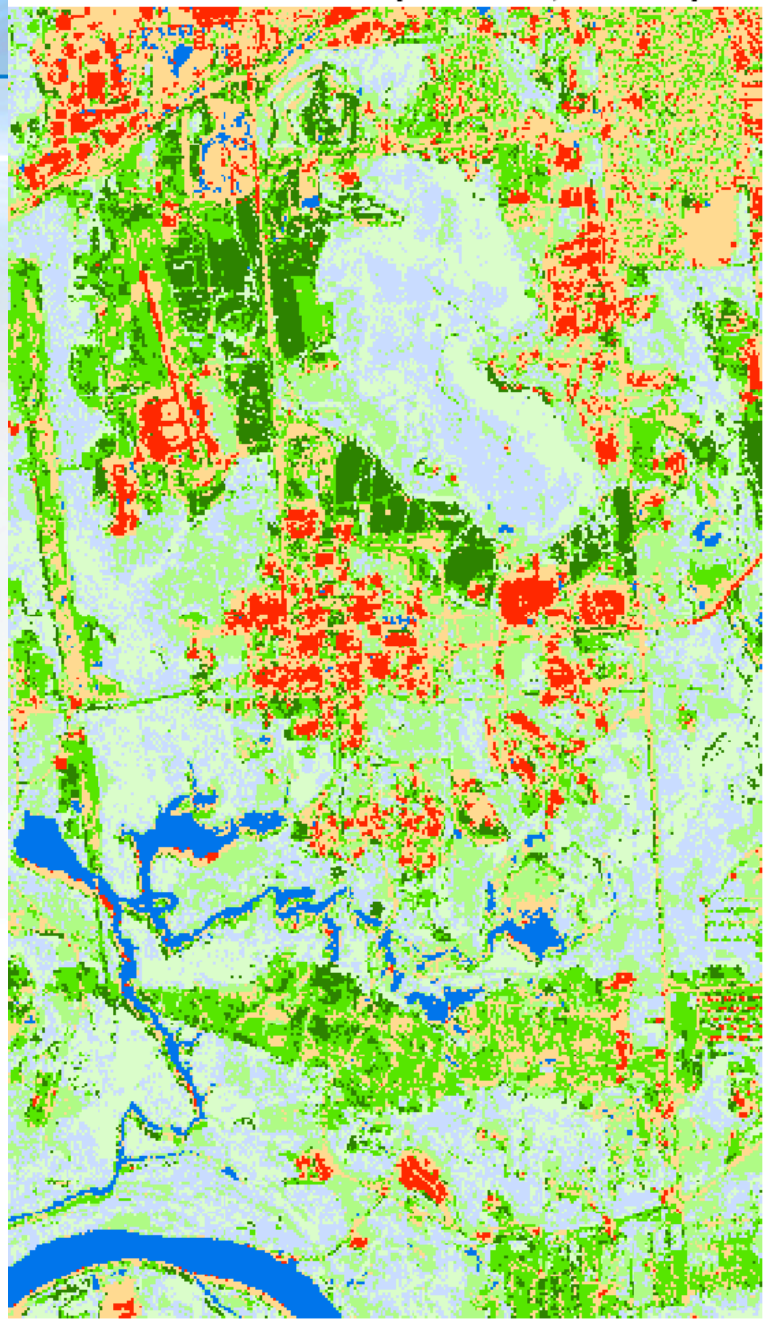
Spatial Mean ASTER-derived LULC per Class



Land Cover and Climate Change Impacts

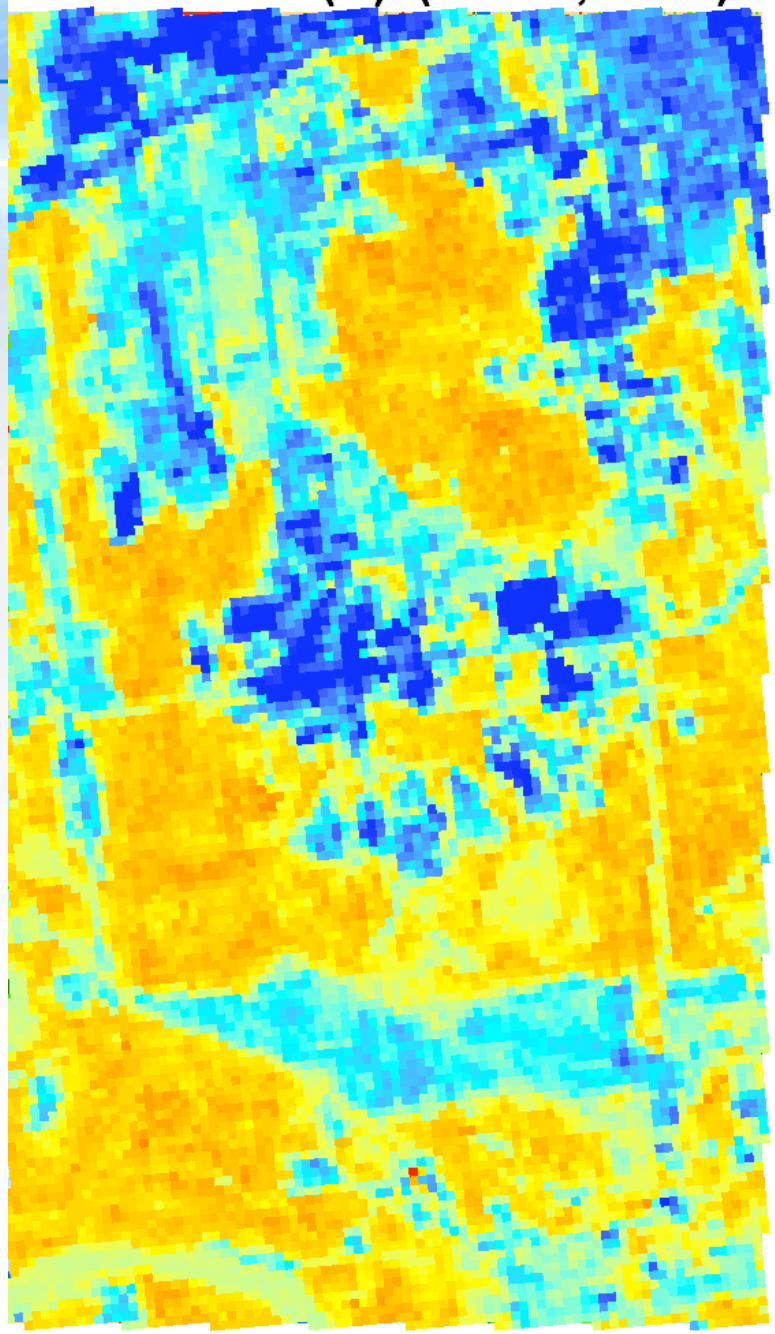


ASTER LULC (MAY 4, 2011)



- Water
- Developed Open Spc./Rec. Gr.
- Residential/Commercial
- Deciduous Forest
- Evergreen Forest
- Mixed Forest / Shrub
- Agricultural / Pasture
- Woody Wetlands

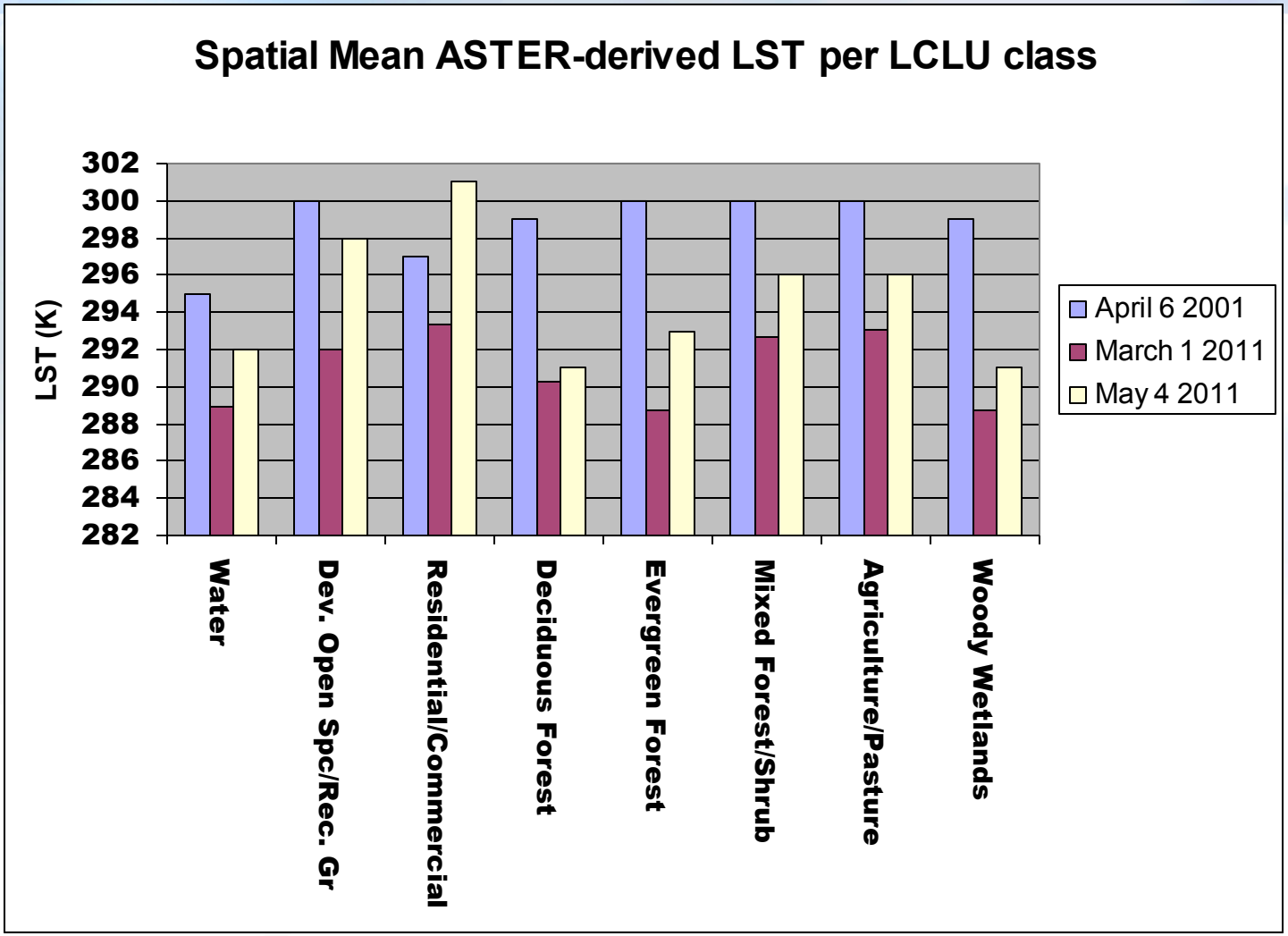
ASTER LST (K) (MAY 4, 2011)



LST(K)

High : 3173

Low : 2860


Spatial Mean ASTER-derived LST per LCLU class
LST (K)
302
300
298
296
294
292
290
288
286
284
282
Water
Dev. Open Spc/Rec. Gr
Residential/Commercial
Deciduous Forest
Evergreen Forest
Mixed Forest/Shrub
Agriculture/Pasture
Woody Wetlands
April 6 2001
March 1 2011
May 4 2011

The Need For HyspIRI Data for More Quantitative Analysis of Urban Land Change and Affects on LSTs and the Urban Heat Island:

- NASA Earth science satellites currently in orbit are aging and are beginning to have sensor difficulties (e.g., ASTER SWIR Bands)

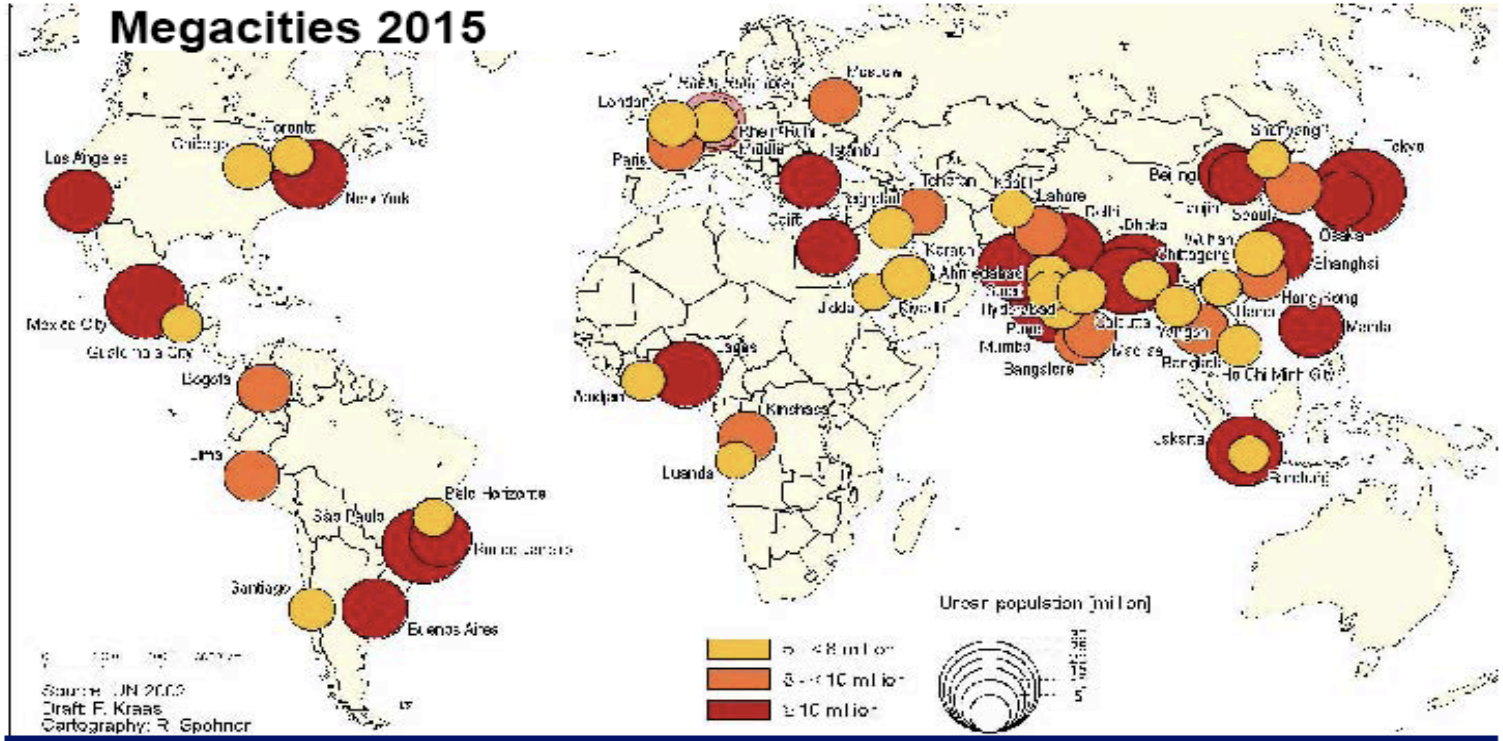
- More hyperspectral bands needed for analysis of urban vs. non-urban land cover/landscape attributers (e.g., detailed identification of urban surfaces)

- Planned satellites (e.g., LDCM) will not have multispectral thermal IR bands with 60m spatial resolution to derive thermal responses from urban vs. non-urban surfaces (e.g., separation of bare soil vs. other impervious surfaces)

- 5 day revisit time and day/night collection of thermal IR data will greatly increase the opportunity for diurnal analysis of urban LSTs at frequent time intervals

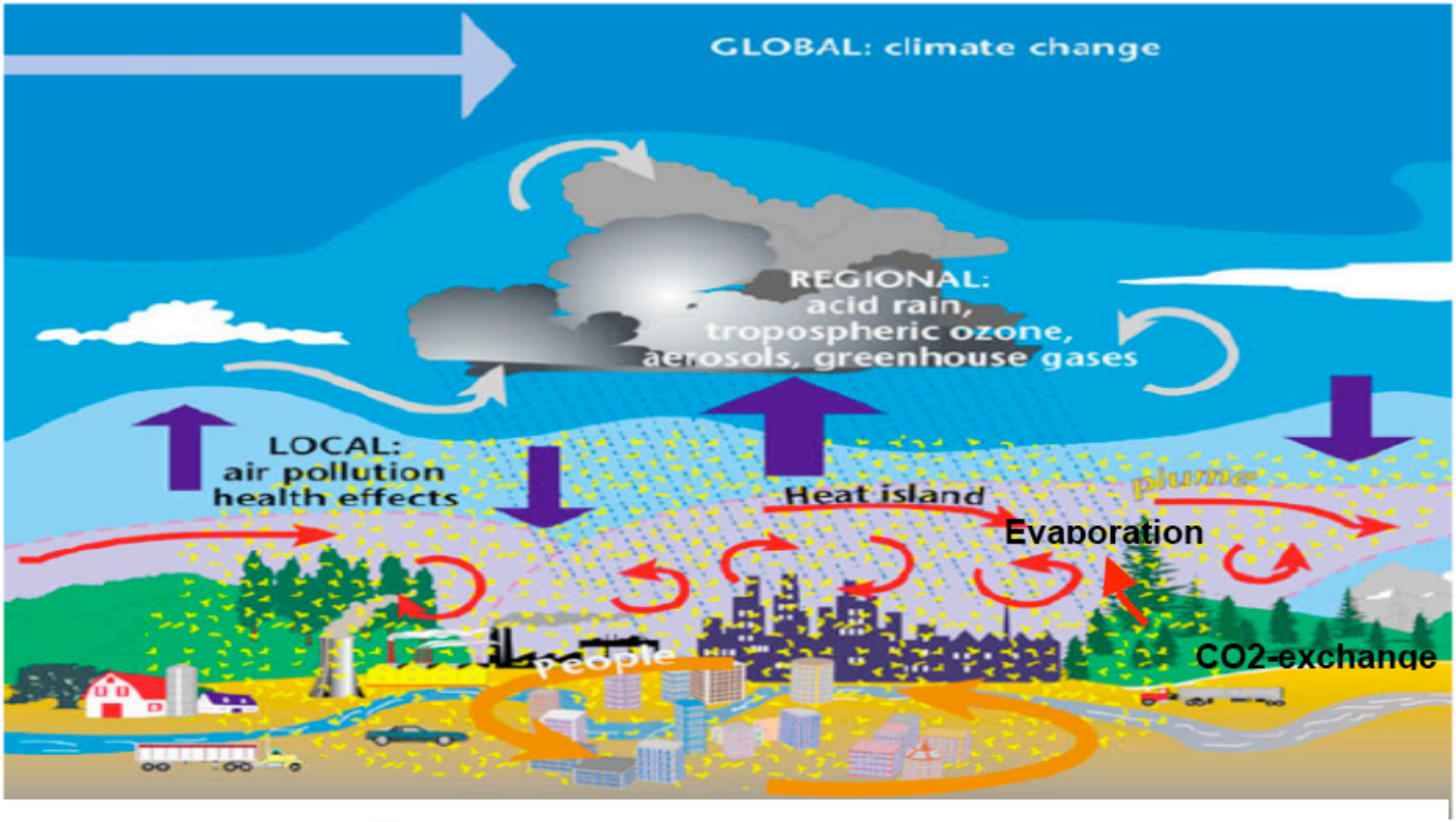
- SWIR channels will provide for excellent analysis of albedo from urban surface types

Growth of Global Megacities



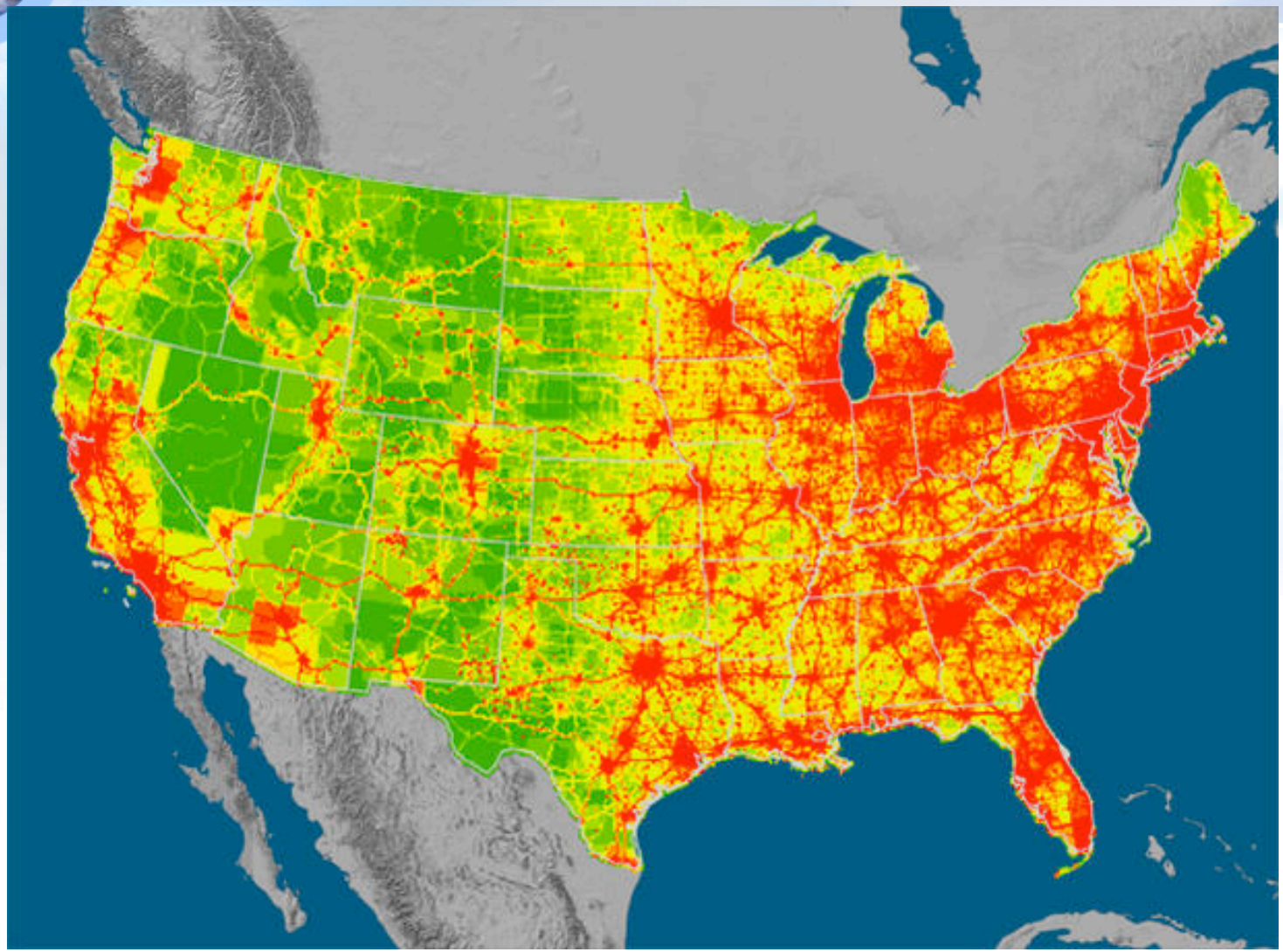
- 1950: 4, 1980: 28, 2002: 39, 2015: 59 megacities worldwide; 2/3 in developing countries, resp. South and East Asia
- 2002: 394 Mio. people, of these: 246 Mio. in developing countries, oder 215 Mio. in Asia; in the year 2015: 604 Mio. worldwide
- Population data tripled between 1970 and 2000: e.g. Mexico City, São Paulo, Seoul, Mumbai, Jakarta, Teheran

The Urban Dynamic



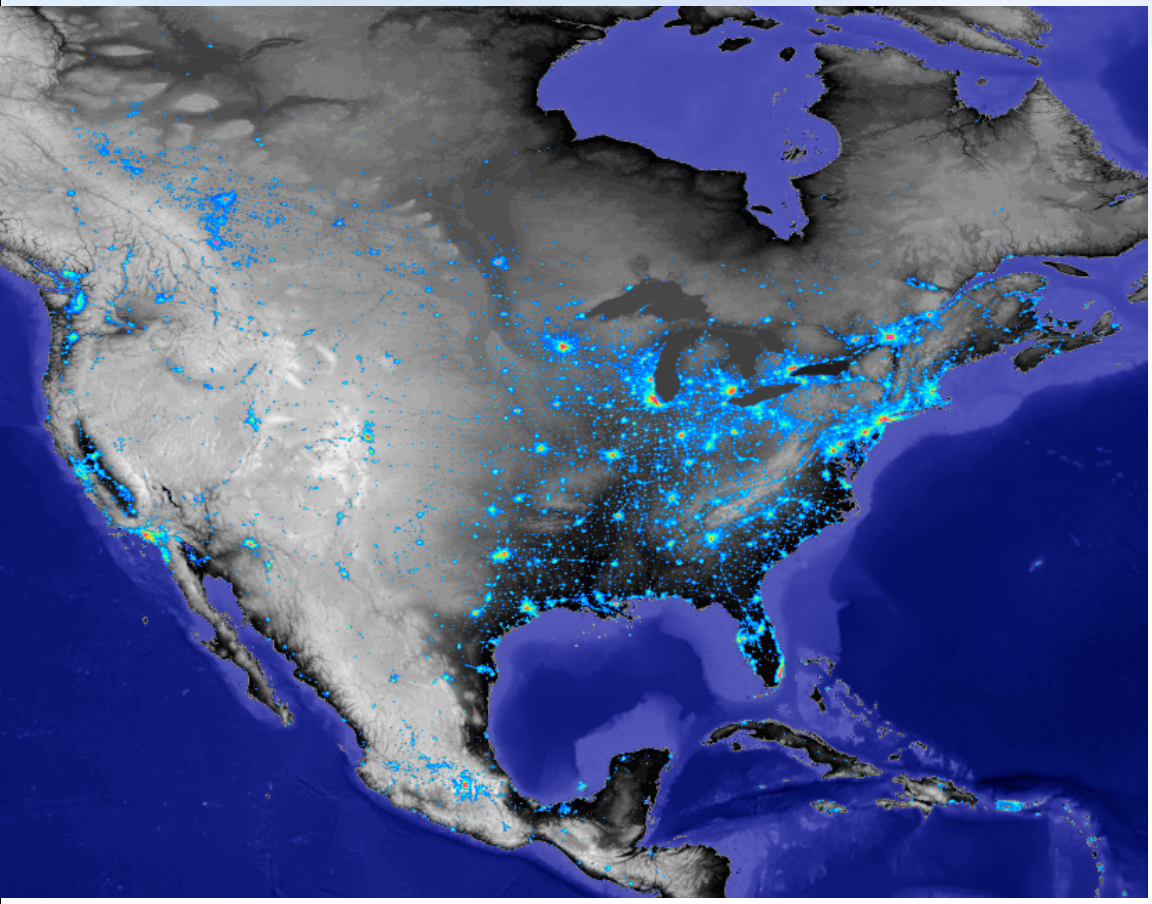
Seto and Shepherd (2009) originally in Hidalgo et al--38. Hidalgo J, Masson V, Baklanov A, Pigeon G, Gimenoa L: Advances in Urban Climate Modeling:Trends and Directions in Climate Research. *Annual New York Academy of Sciences* 2008, 1146.

Urban Heat Islands and Emissions?



- Emission Sources (Source: Purdue University)

Consequences of Urbanization on NPP-Carbon in the United States



- What is the overall impact in North America?
  - Has the NPP-carbon sink been reduced?
  - What are the consequences?
- How does urbanization interact with climate locally?
  - Is there a recognizable effect in the NDVI signal at 1km spatial resolution?
  - What are the seasonal dynamics?
  - Is urbanization's impact on NPP balance positive or negative?

Consequences of Urbanization on NPP-Carbon in the U.S.

Urbanization and NPP

- NPP decreased <u>41.5 M tons C / year</u>.
- Roughly equivalent to the increase
  - ❑ created by 300 years of agricultural
  - ❑ development.

❑How can this happen when urban areas occupy only 3% of the land surface and agriculture occupies 29%?

<u>Location, Location, Location.</u>

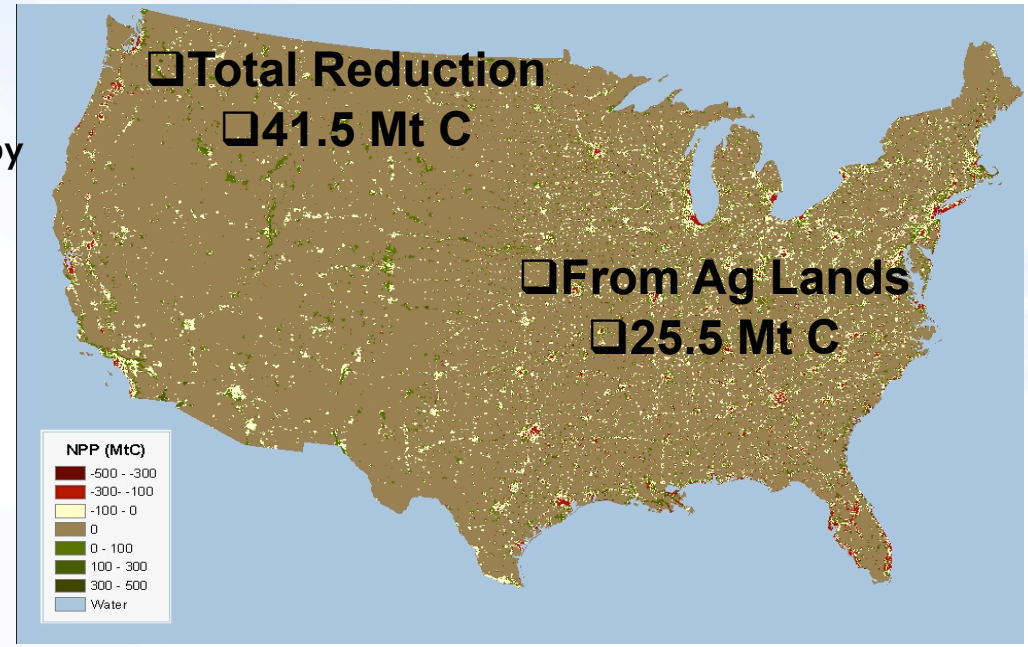
Urbanization is taking place on the most fertile lands

❑Reduction of NPP may have biological significance:

NPP Lost or Gained (annual)

Due to Urbanization

❑Going from a pre-urban to a post urban world

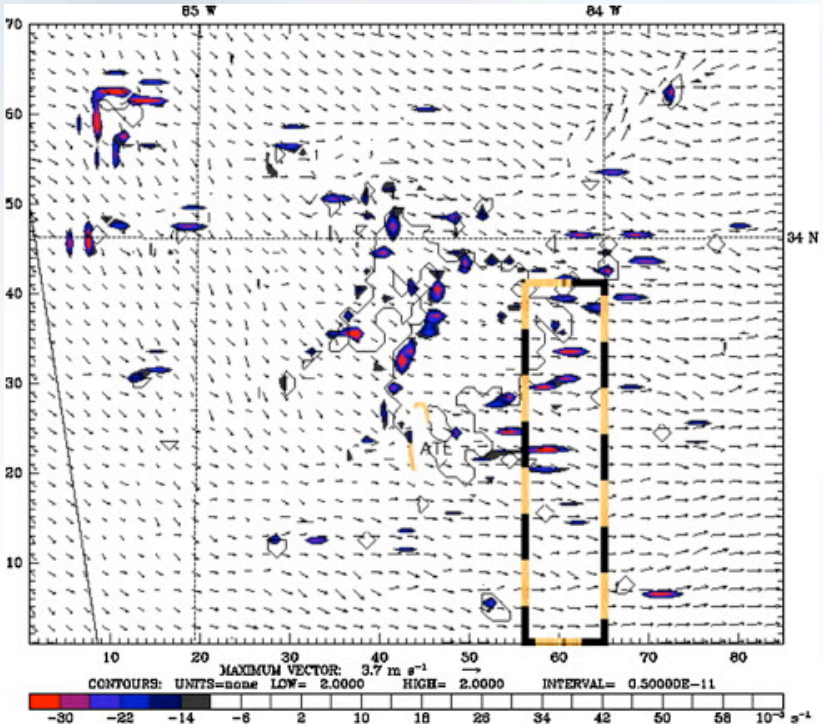


-Annual loss of food web energy 400 Trillion kilocalories

- ❑ (roughly equal to food energy requirement for 448 million people).
- Reduction of actual food products equivalent to needs of 16.5 million persons annually
- ❑ (about 6% of US population).

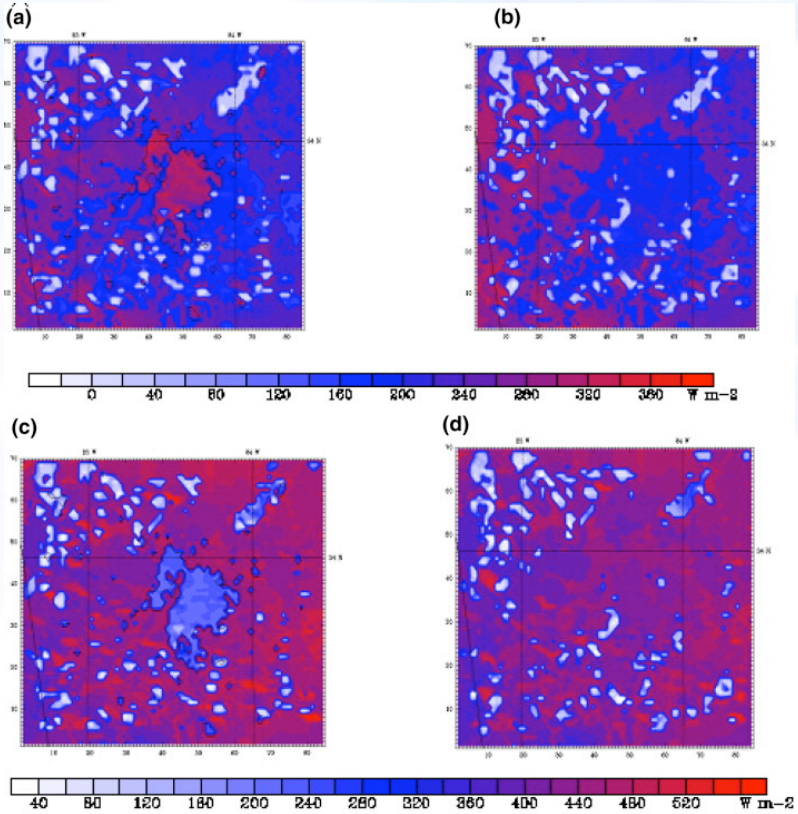
Mechanisms: Convergence and Fluxes?

Difference in Divergence (Atlanta - No Atlanta)



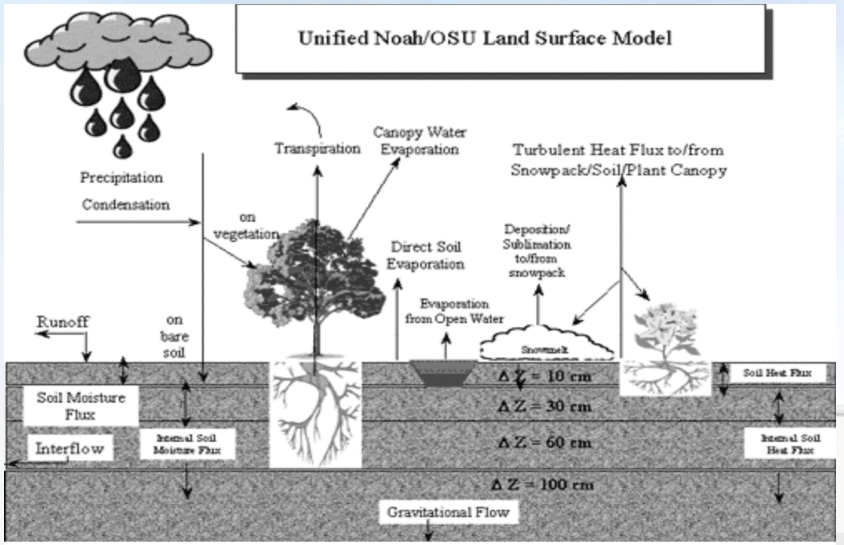
Atlanta

No Atlanta



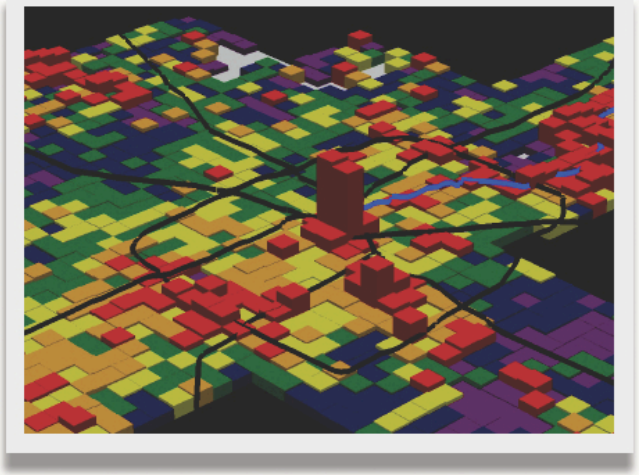
- Shem and Shepherd (2009) found that Atlanta can initiate or enhance pre-existing convection through enhanced convergence (left) and sensible heat flux (right and top)

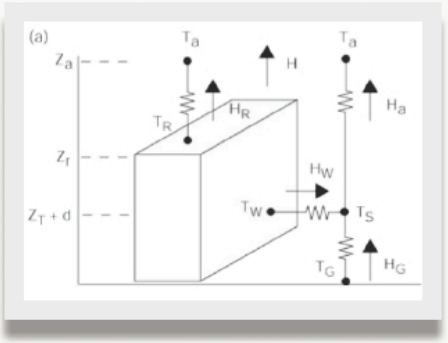
Urban Surfaces and Morphological Parameters

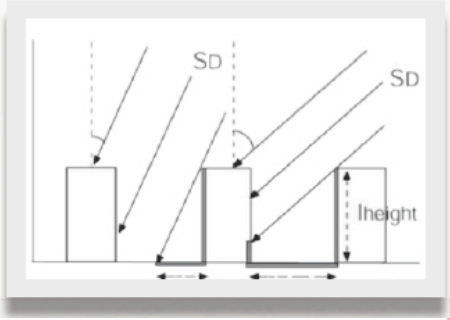


Urban surfaces and morphological parameters are still poorly represented in most studies of urban effects

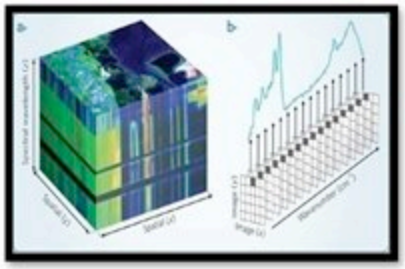
Shepherd, Burian, and colleagues (2009) have used lidar derived urban canopy parameters and an Urban Canopy Model embedded in WRF NOAH.







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



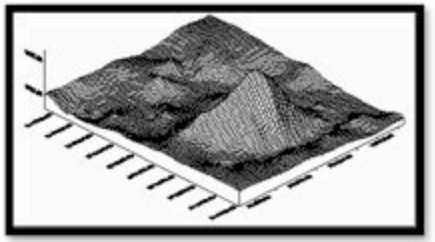
HyspIRI VSWIR data Products

Urban morphological datasets

GIS datasets

Lidar

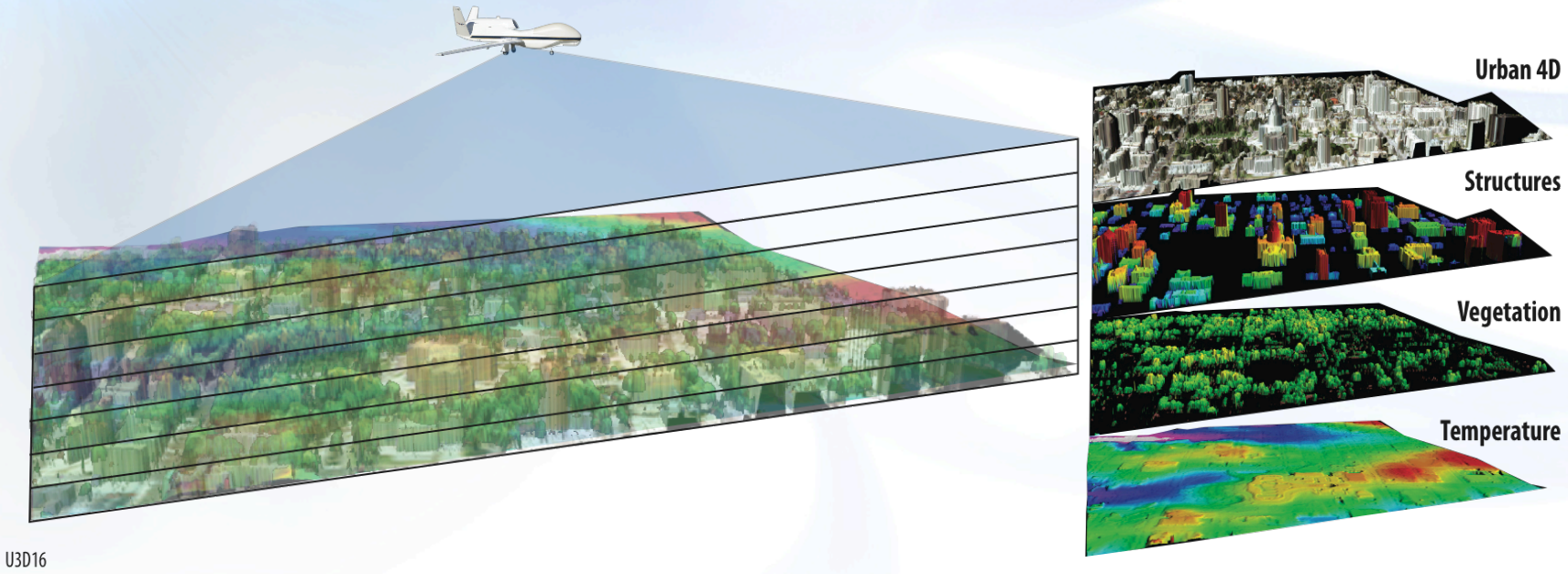
Digital photogrammetry



Digital elevation model

Weng et al., 2010

Moving Towards and Integrated Interdisciplinary Urban Science – The Need for HysplRI Data



- Time series of airborne lidar, multispectral, and thermal sensors to provide the 4-dimensional (space and time) observations required to parameterize, test, and further develop models that explain and predict the influence of urbanization on earth system processes at the local, regional, and global scales.
  - **MASTER (MODIS/ASTER Simulator (50 channels 0.4 - 13 μm @ 12 m –diurnal)**
  - **LVIS full waveform and elevation products at (7.5m spot size)**

The Need for HyspIRI Data

Summary

- HyspIRI data will greatly advance our scientific understanding of the coupling between urban surface materials, land covers/ land uses, and LSTs as they drive the formation of the UHI

- HyspIRI data will for the first time, help us to measure UHI dynamics at frequent time intervals and on a diurnal basis across seasons from a synoptic perspective

- HyspIRI data will help us to measure and model the impacts of urbanization on land-atmosphere interactions that affect local to regional meteorology and ultimately, the urban climate

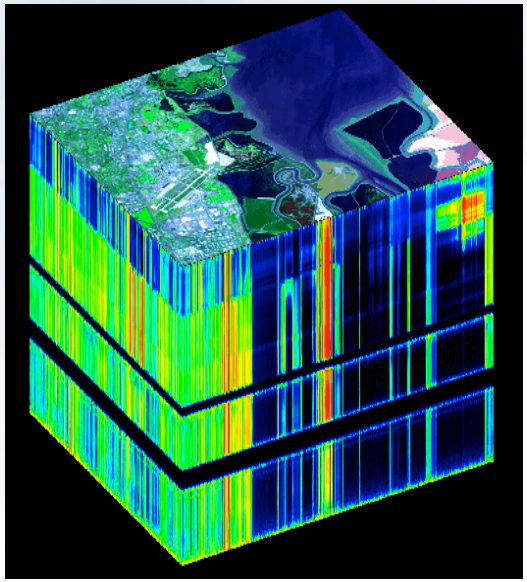
The Need for HyspIRI Data

- HyspIRI data will offer a unique opportunity to better measure the albedo and thermal responses from different building/ surface materials ubiquitous to the urban environment (e.g., rooftops)

- HyspIRI data will be of critical importance in providing LCLU and land surface energy measurements (LSTs) that are key to the emerging “Science of the City” (i.e., the interdisciplinary study of the physical, atmospheric, biological, environmental and socioeconomic interactions that comprise “the city” as an entity)

BACK UP

HyspIRI Combined Composite Data Set Advanced Product for Urban Ecosystems Analysis

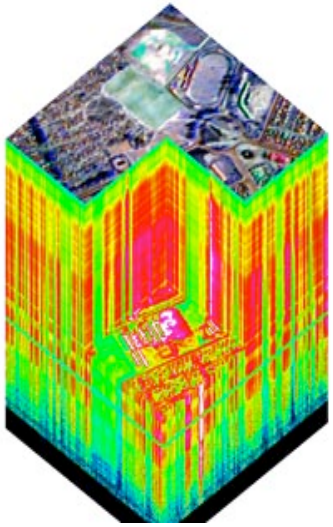


HyspIRI Hyperspectral VSWIR Level II Product
(NDVI, fPAR, surface reflectance characteristics)

+

HyspIRI TIR multispectral Level II product (8 TIR Bands)
(surface temperature, radiance, [day/night], emissivity)

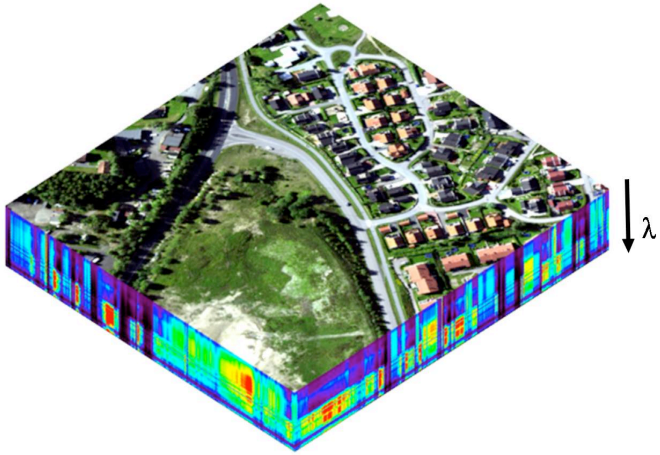
=



HyspIRI VSWIR/TIR composite data set
(quantitative integrative measurement of urban surface reflectances, temperatures, and emissivity across the urban ecosystem)

HyspIRI Combined Composite Land Use Change Advanced Product for Urban Ecosystems Analysis

Through Time



HyspIRI Hyperspectral VSWIR Level II Product

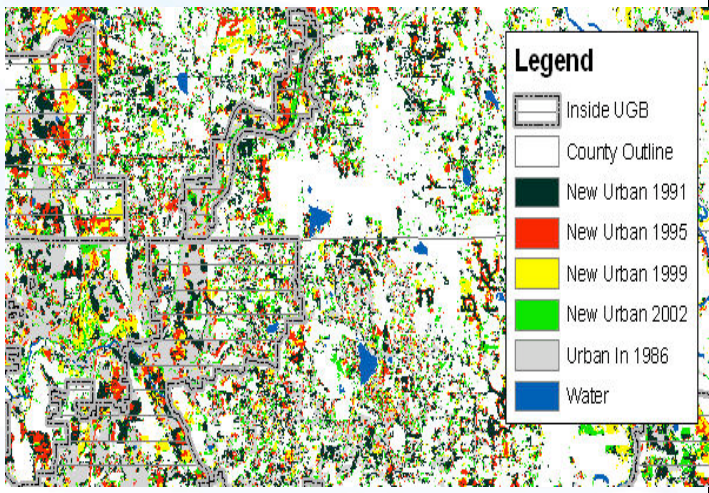
(NDVI, fPAR, surface reflectance characteristics)

+

HyspIRI TIR multispectral Level II product (8 TIR Bands)

(surface temperature, radiance, [day/night], emissivity)

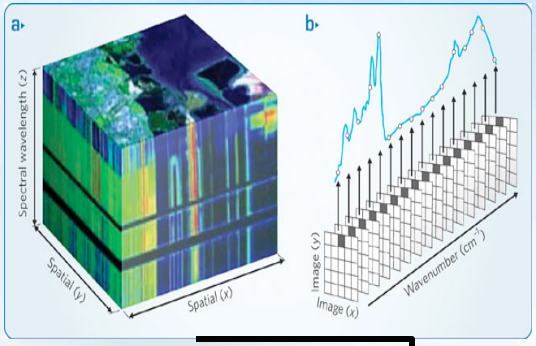
=



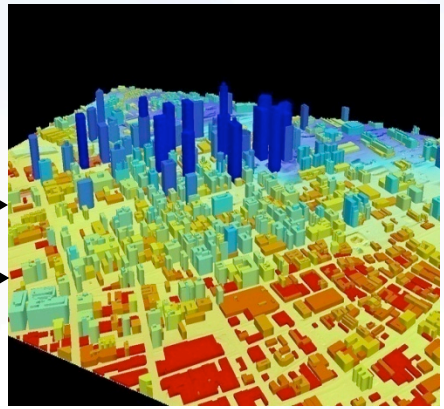
HyspIRI VSWIR/TIR composite land cover change data set

(quantitative integrative measurement of urban surface reflectances, temperatures, and emissivity across the urban ecosystem as they change through time)

HyspIRI Combined "Integrated" Advanced Product for Urban Ecosystems Analysis



HyspIRI Hyperspectral VSWIR Level II Product
(NDVI, fPAR, surface reflectance characteristics)



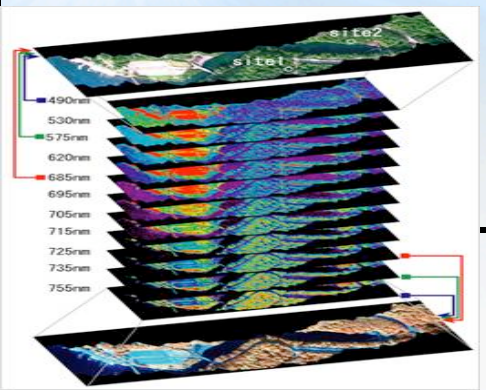
Lidar Data

=

HyspIRI VSWIR/TIR and Lidar composite data set
(X, y, z surface reflectance/thermal interactions of urban ecosystem processes)

HyspIRI TIR multispectral Level II product (8 TIR Bands)
(surface temperature, radiance, [day/night], emissivity)

HyspIRI Combined "Integrated" Topographic Advanced Product for Urban Ecosystems Analysis



Hyperspectral VSWIR Level II Product
(NDVI, fPAR, surface reflectance characteristics)

Digital Topographic Data
(DEM)

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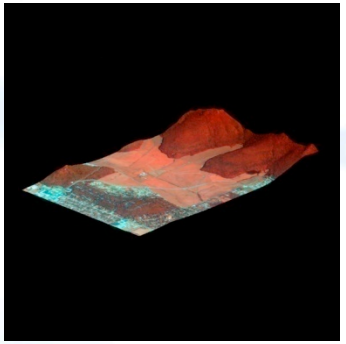

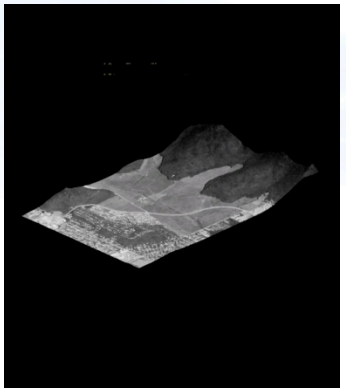

HyspIRI VSWIR/TIR and DEM composite data set
(hyperspctral/day/night TIR digital elevation model data sets))

HyspIRI TIR multispectral Level II product (8 TIR Bands)
(surface temperature, radiance, [day/night], emissivity)