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

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NASA

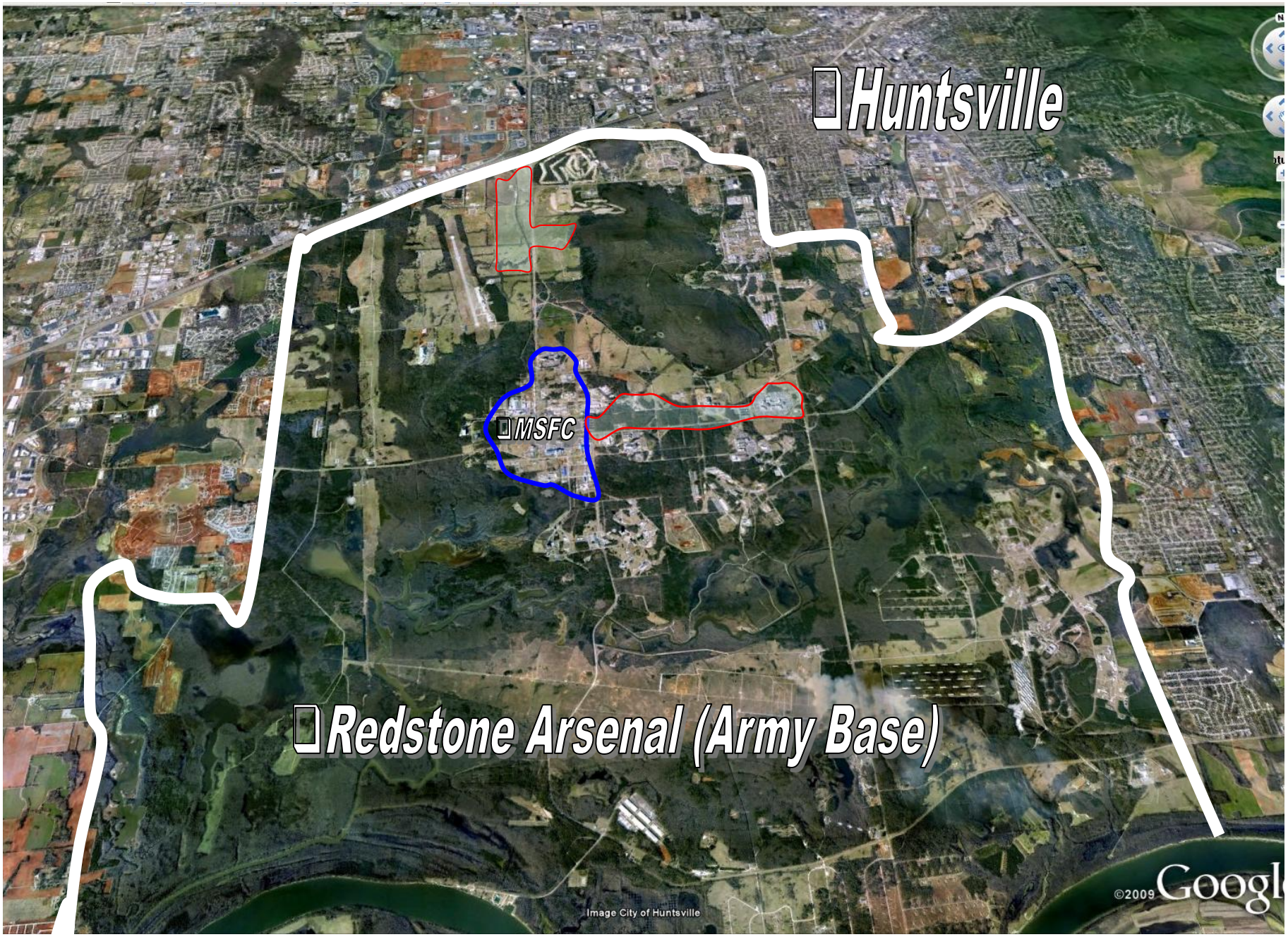
Earth Science Office

Marshall Space Flight Center

Huntsville, Alabama

Land Cover Change and Climate Impacts: MSFC and Huntsville, AL

- Huntsville, Alabama (pop, 180,000, metro region 410,000)
- MSFC occupies about 2 sq miles, 2500 C.S., 4500 contractors
- Centered within Redstone Arsenal Army Base, a 100 sq mile facility bordering Huntsville and the Tennessee river, employing over 25,000 government and contractor workers
- Support exploration, leading development of a new family of launch vehicles and lunar / other landing missions
- Propulsion, space transportation, and Space and Earth science activities
- Test stands, world class instrument calibration facilities


Huntsville
MSFC
Redstone Arsenal (Army Base)
Image City of Huntsville
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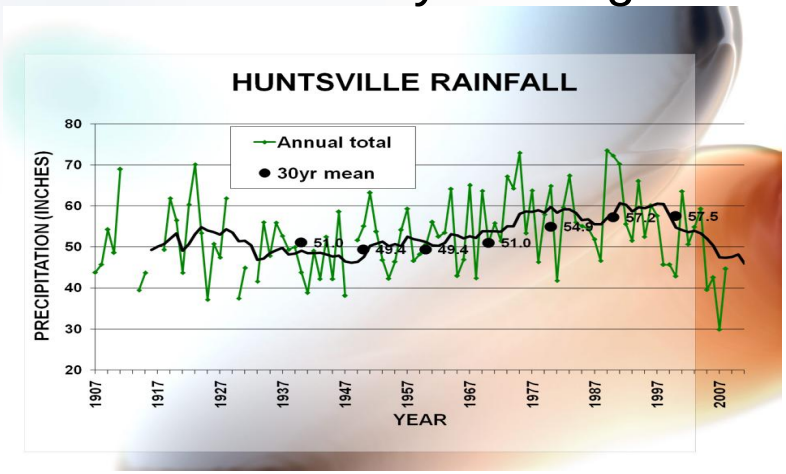
Land Cover and Climate Change Impacts

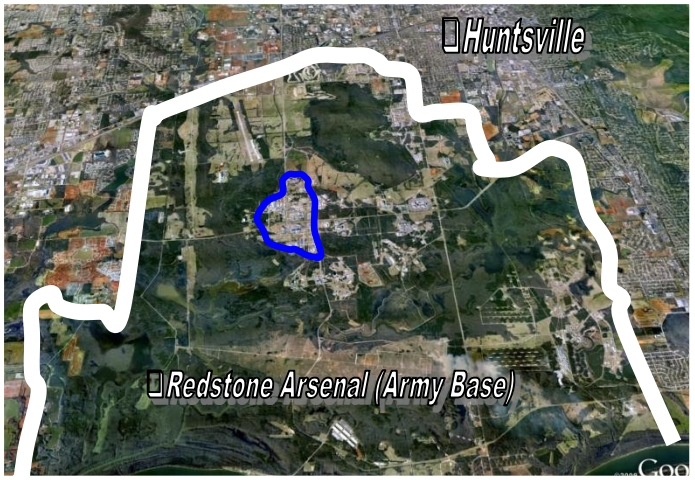
Expected climate change indicators

- extremes in temp. and precipitation
- prolonged periods of drought

Impacts on MSFC

- Unique facilities at risk from localized flooding, wildfires, severe weather
- Extreme heat and air quality issues also enhanced by urban growth



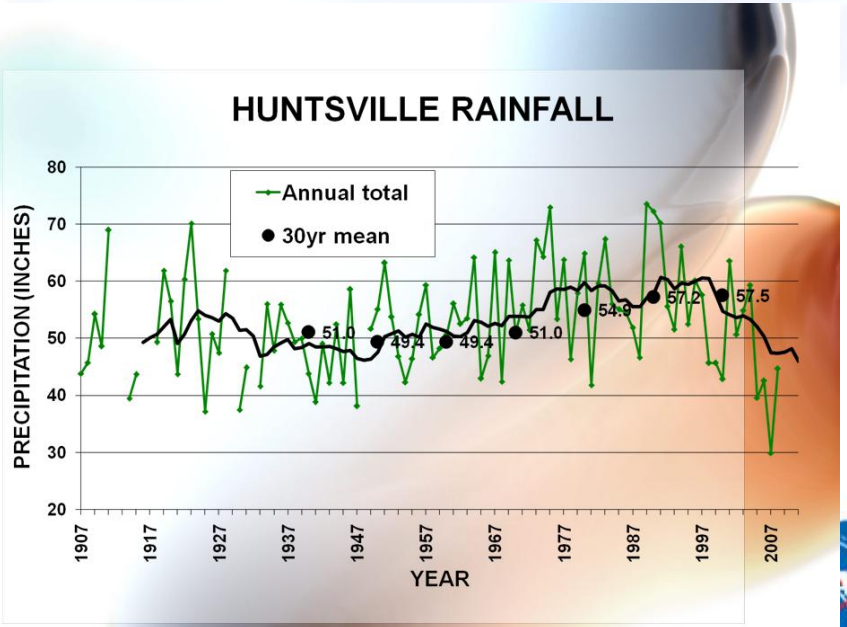


Evaluate micro-climate of MSFC

- Install 12 weather stations and integrate data into Center operations
- Monitor / evaluate variability of temperature and precipitation
- Assess land use change / urban heat island issues with satellite data
- Integrate results into long-term facilities plan for Center

Climate Hazards and Vulnerabilities

- Hot and humid summers, mild winters, >55” rain (mainly convective), long periods of drought
- Prone to tornadoes, numerous localized flooding events (damage to infrastructure and clean rooms), air quality issues related to ozone and PM2.5
- Expected climate change impacts – warmer temperatures, more extremes in temperature and moisture – more extensive floods, droughts, and air quality issues
- Flooding of facilities, wildfires, severe weather risks (lightning / tornados), air quality health risks to employees
- New infrastructure designed with climate impacts in mind – e.g. Bldg 4220



Land Cover and Climate Change Impacts

Land Cover and Climate Change Impacts

❑Assess land use changes – Urban heat island effect

- use NASA satellite data to assess land use change across the Center and surrounding areas
- extend 1994 urban heat island (UHI) study of Huntsville to include MSFC and RSA relating land use change to increase in UHI

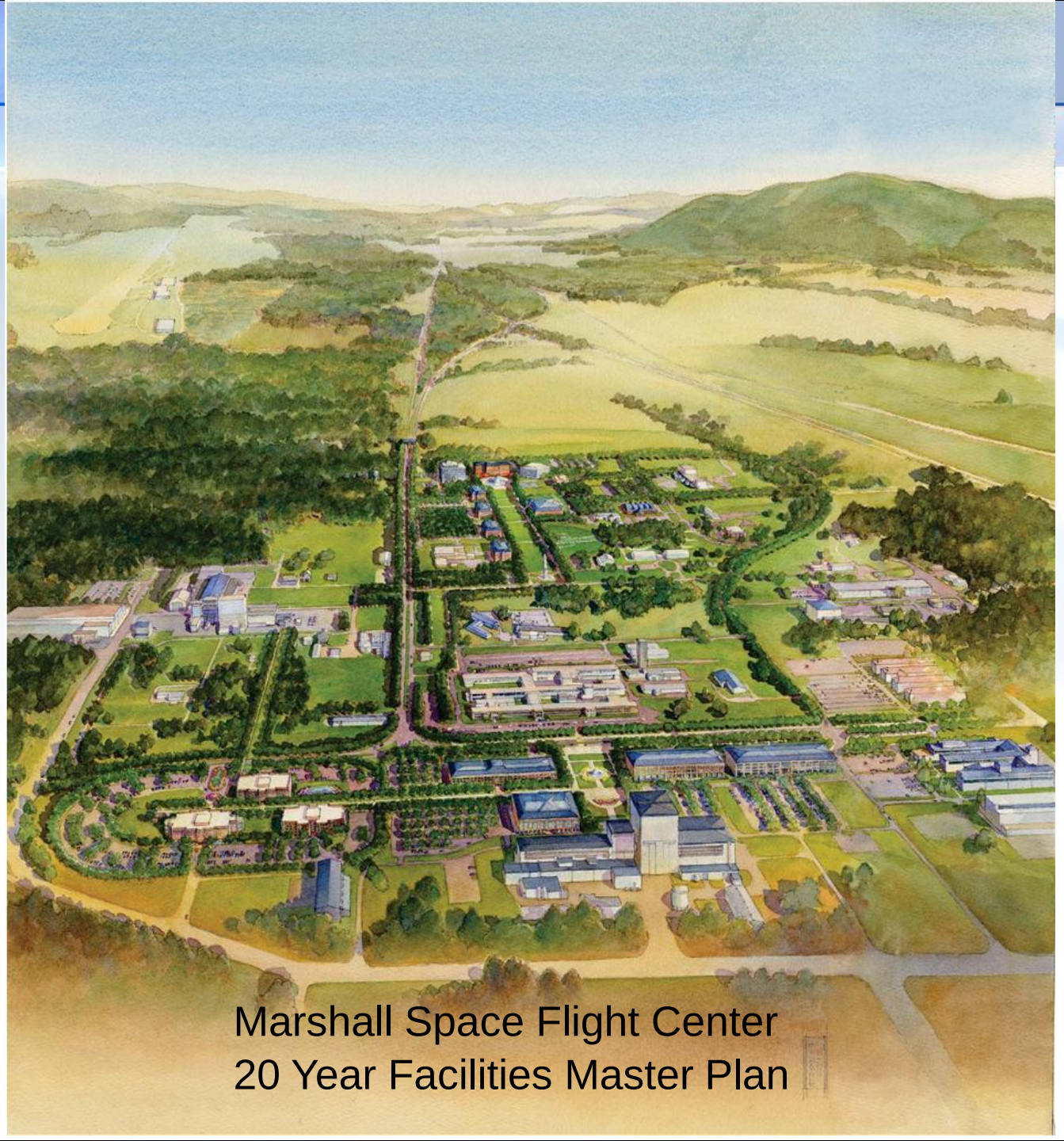
❑Data

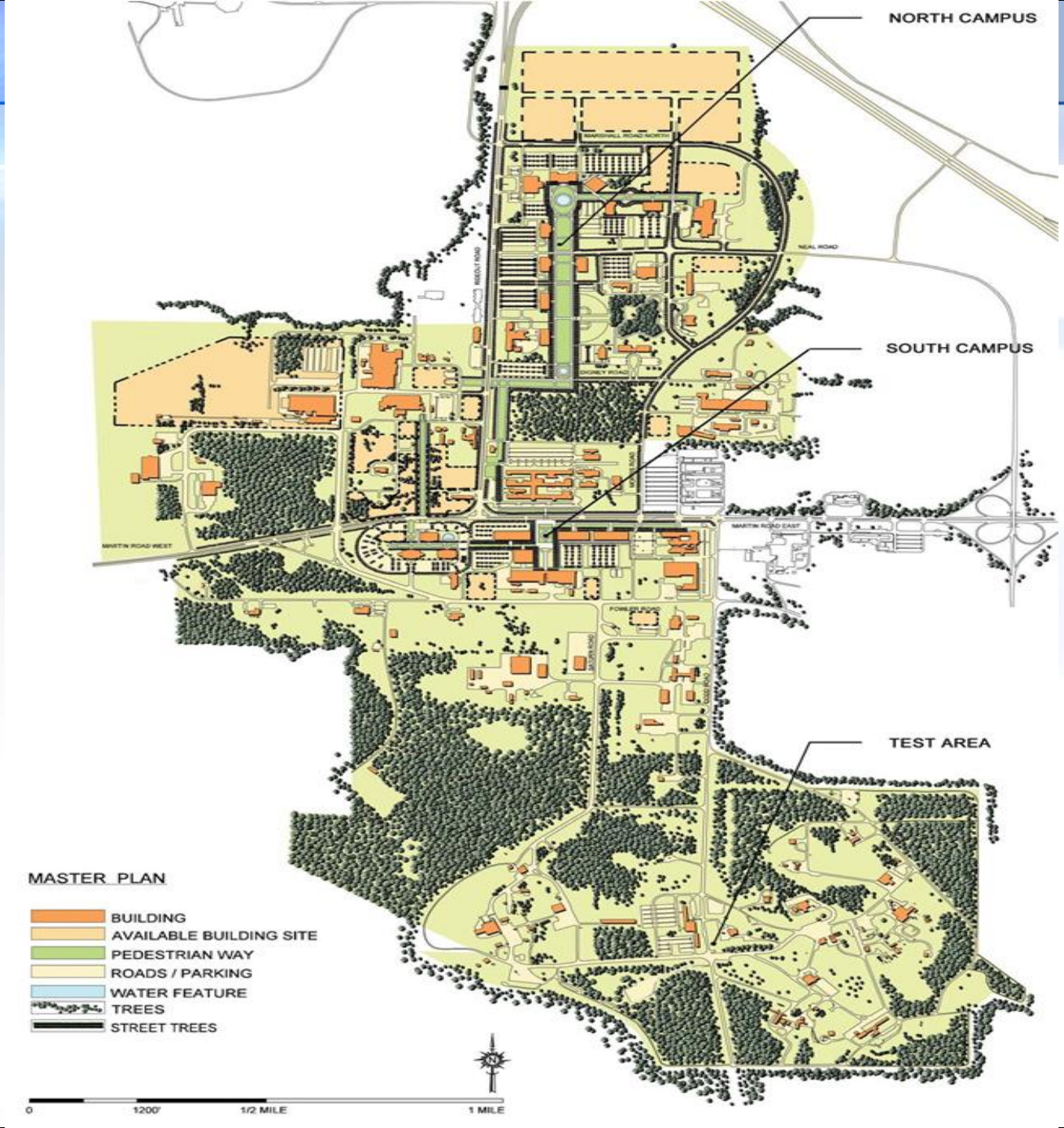
- Landsat data – airborne thermal infrared sensors (1994)
- MODIS, ASTER, Landsat, others for 2010

❑Work to mitigate effects of land use
❑change and heat island on Center
❑activities

- facilities planning
- landscape design
- building modifications

❑*Night-time infrared map of urban temperatures*

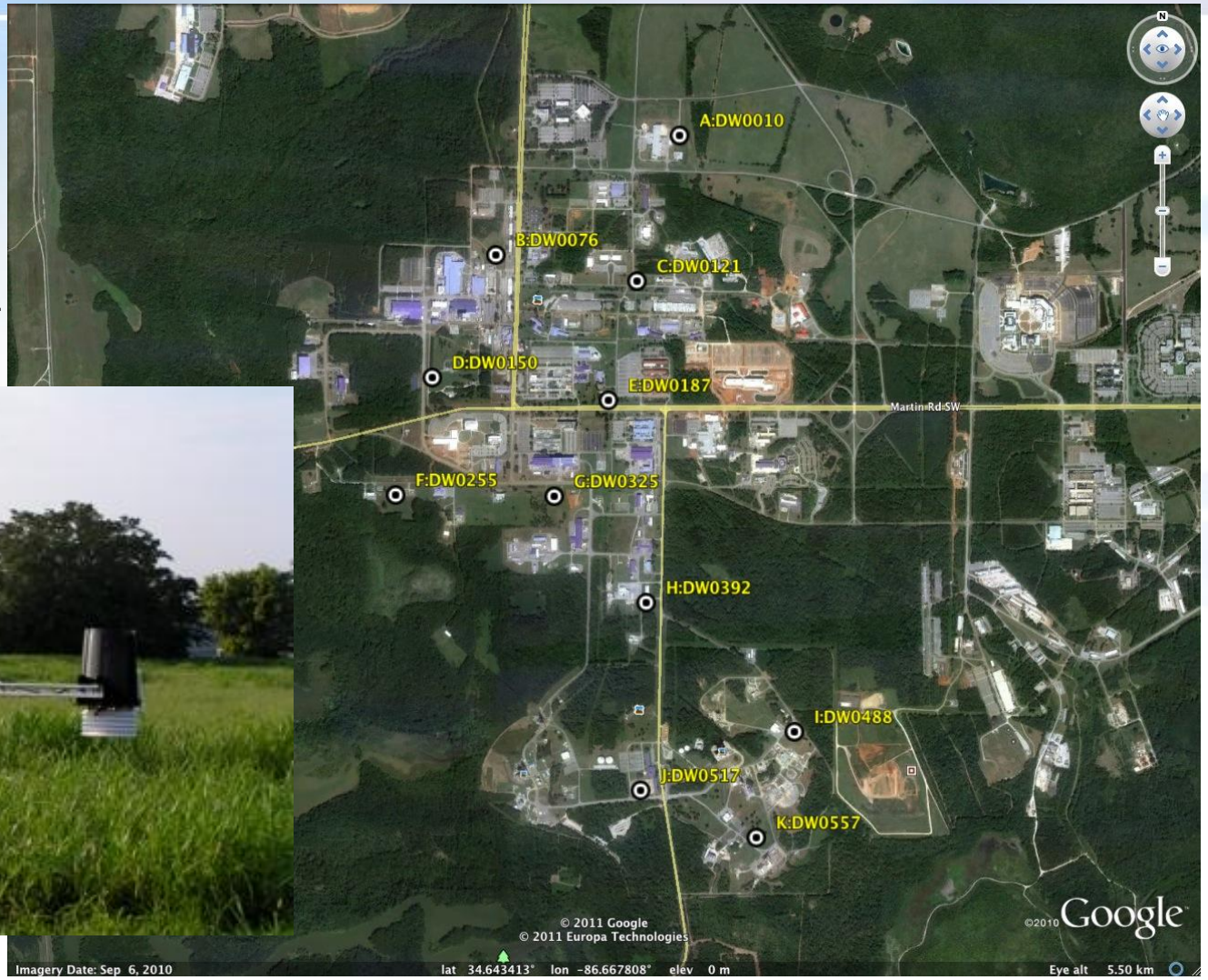

Marshall Space Flight Center
20 Year Facilities Master Plan


NORTH CAMPUS
SOUTH CAMPUS
TEST AREA
MASTER PLAN
BUILDING
AVAILABLE BUILDING SITE
PEDESTRIAN WAY
ROADS / PARKING
WATER FEATURE
TREES
STREET TREES
0
1200'
1/2 MILE
1 MILE

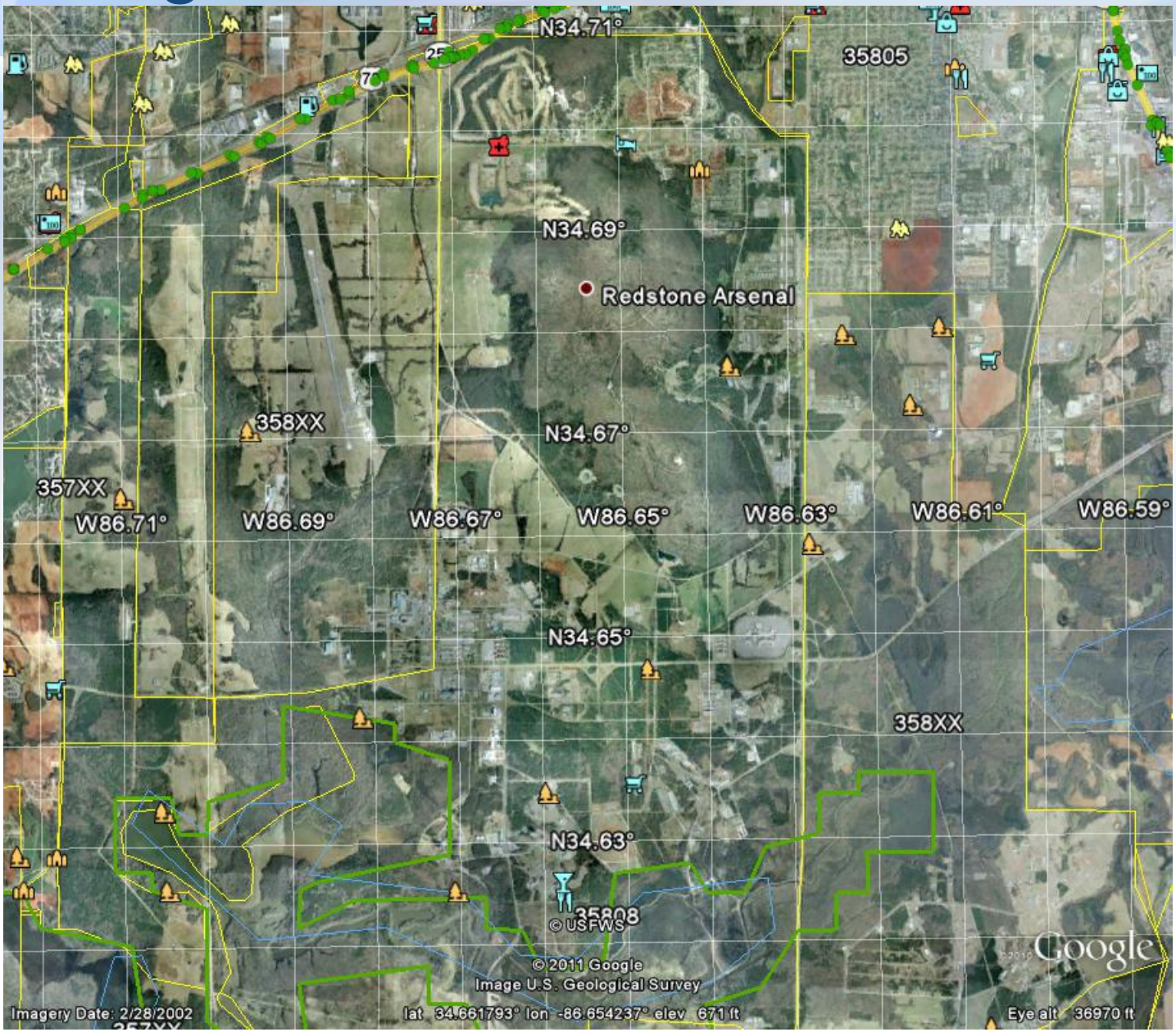
Land Cover and Climate Change Impacts

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

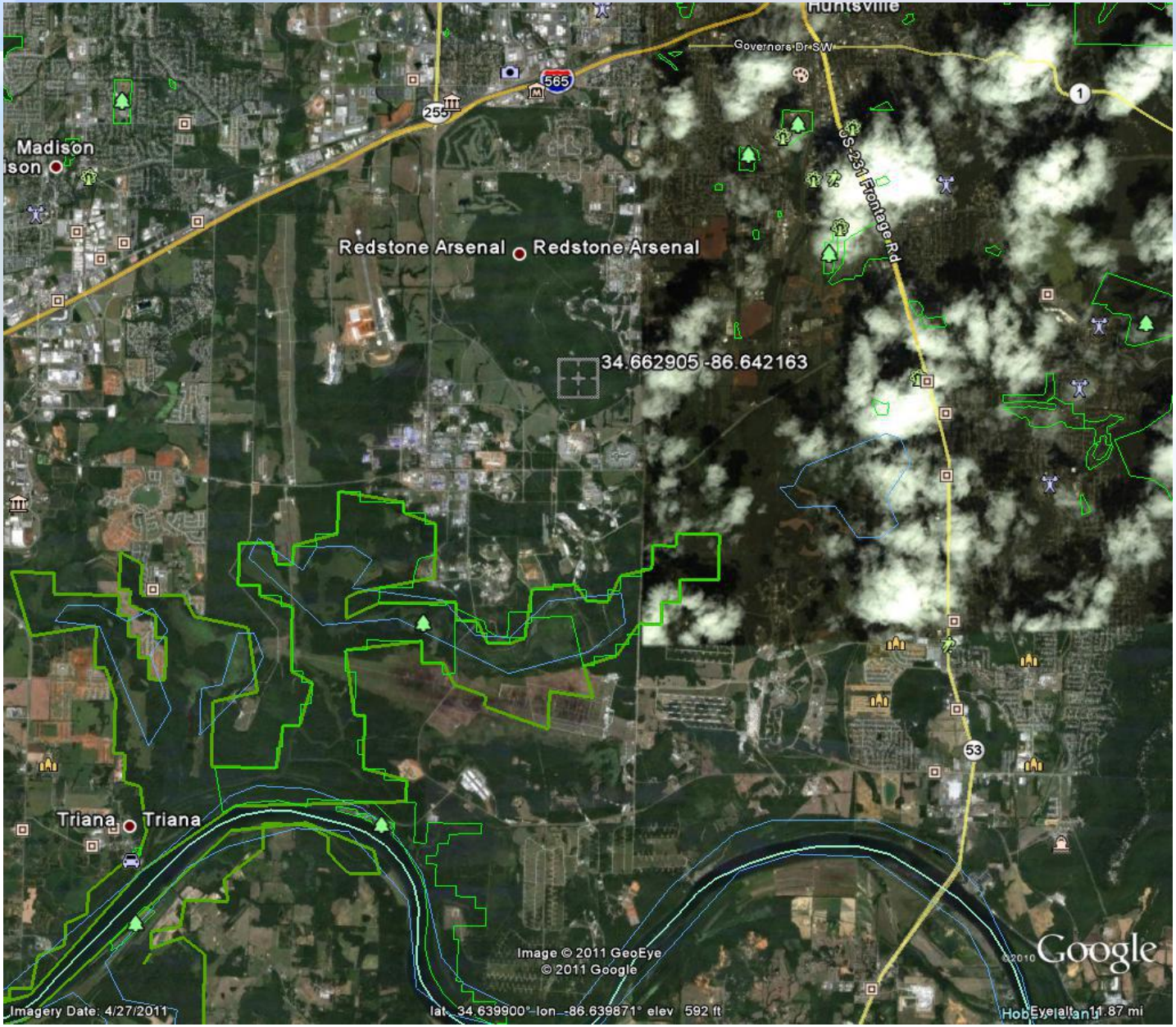
❑Real-time transmission (1-5 min intervals)



Google Earth Land Cover 2002

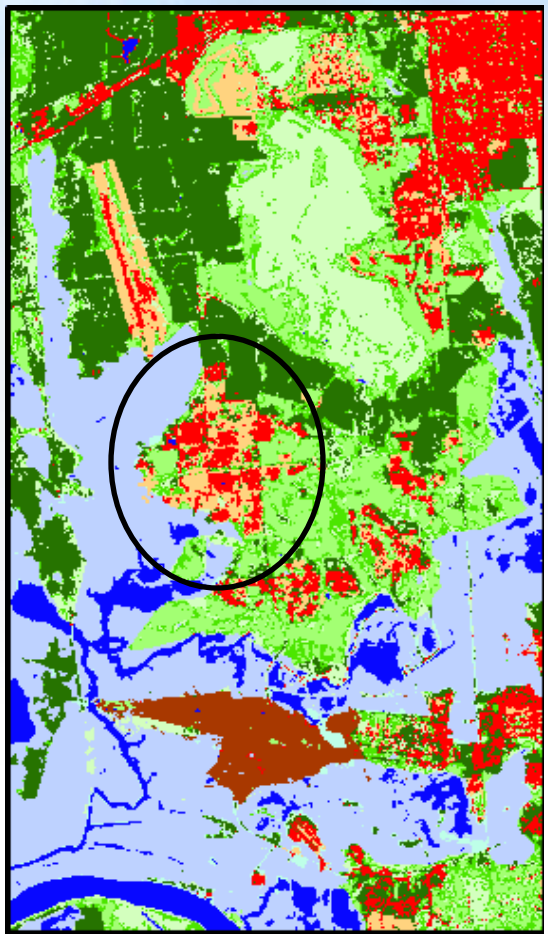


Google Earth Land Cover - 2011

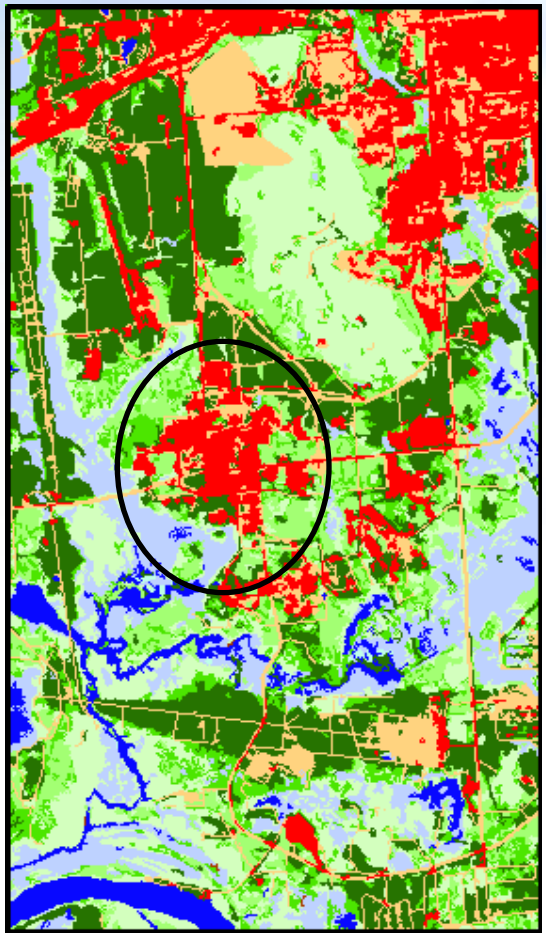


Land Use Change around MSFC

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



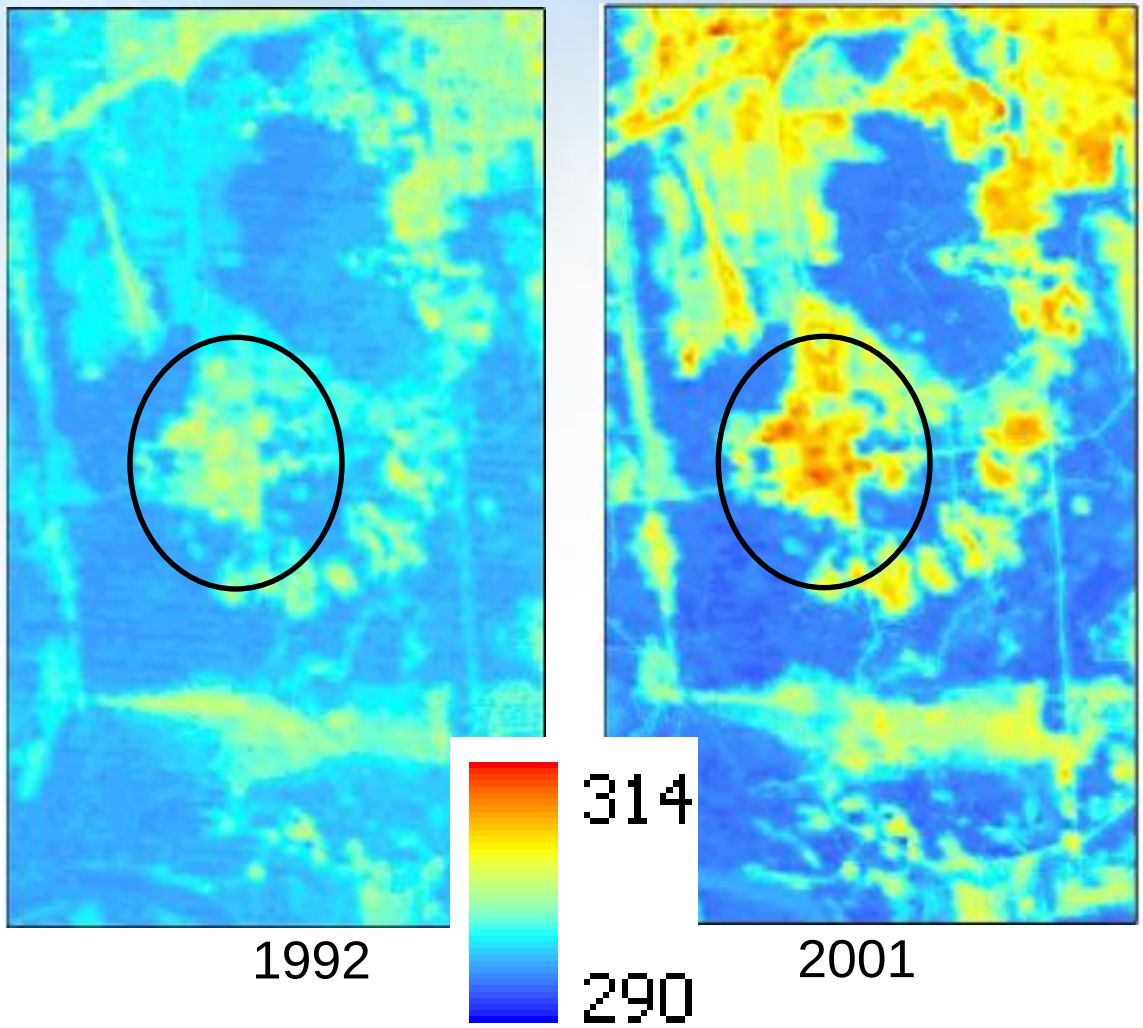
1992



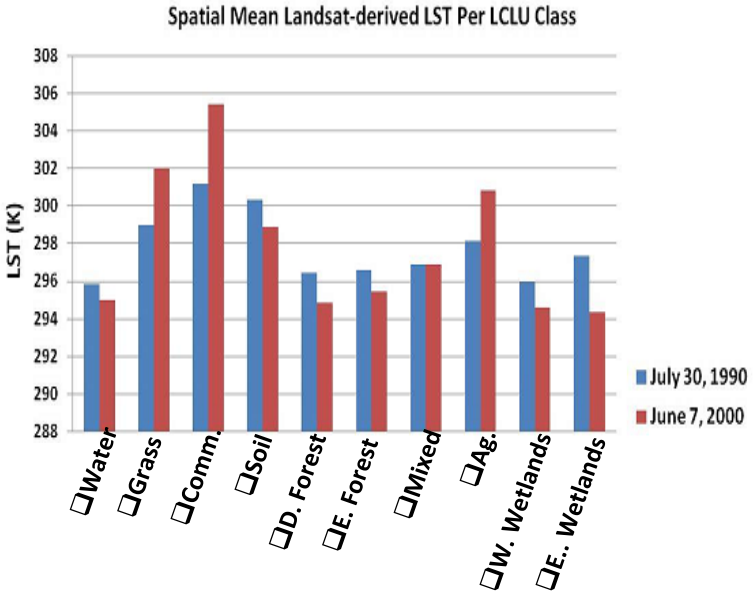
2001

- 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

Land Use Change Drives Thermal Change

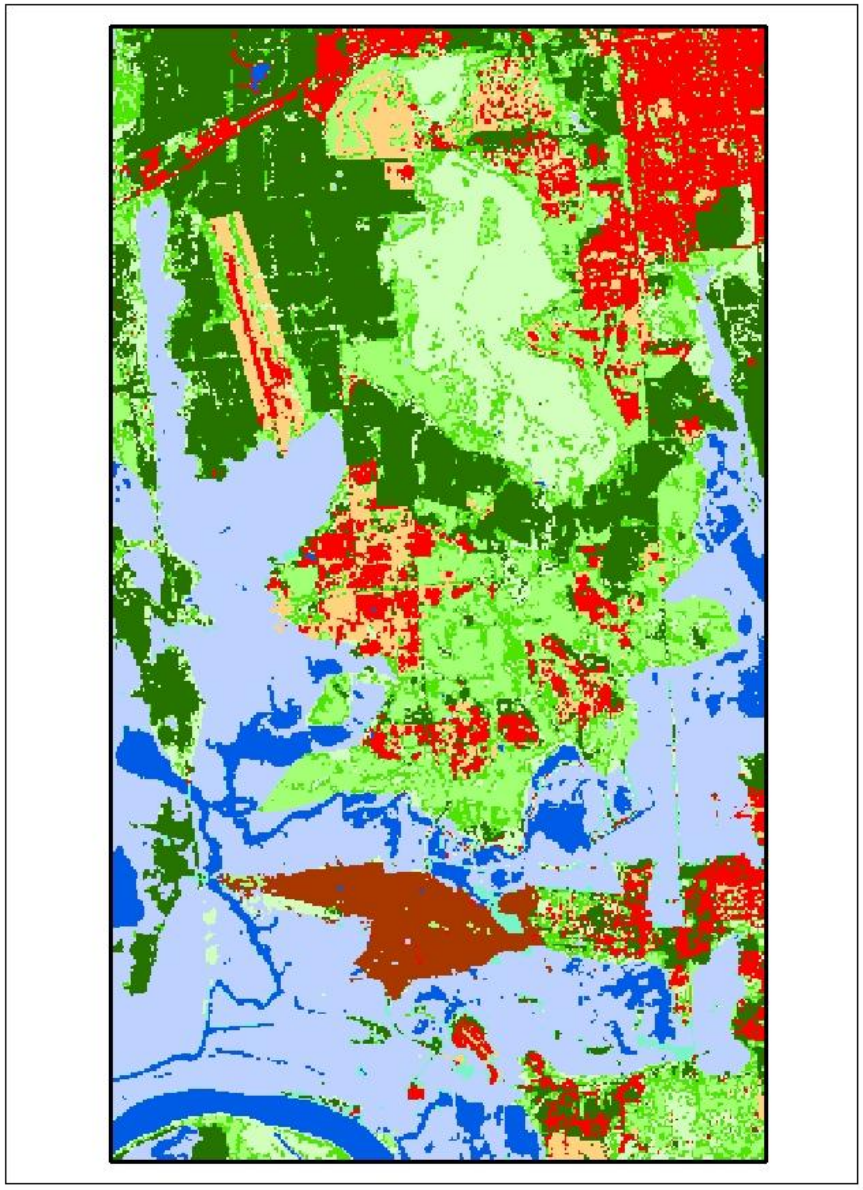


Conversion of forest, shrub, and agricultural land to MSFC infrastructure substantially changes surface thermal signatures



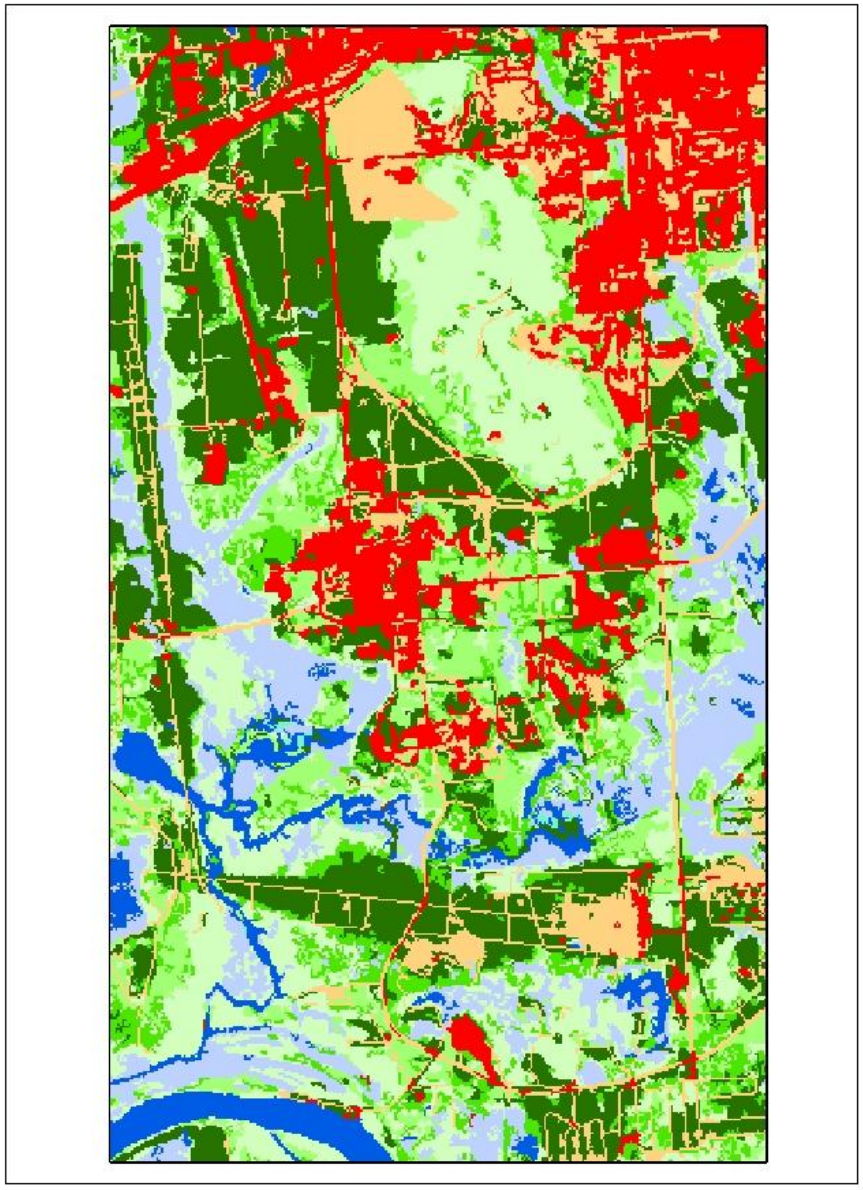
❑***Need to determine impact on local temperatures***

Landsat-derived NLCD-1992



- Slide Prepared By:
- Dr. Mohammad Al-Hamdan
- USRA at NASA/MSFC
- April 14, 2011

Landsat-derived NLCD-2001



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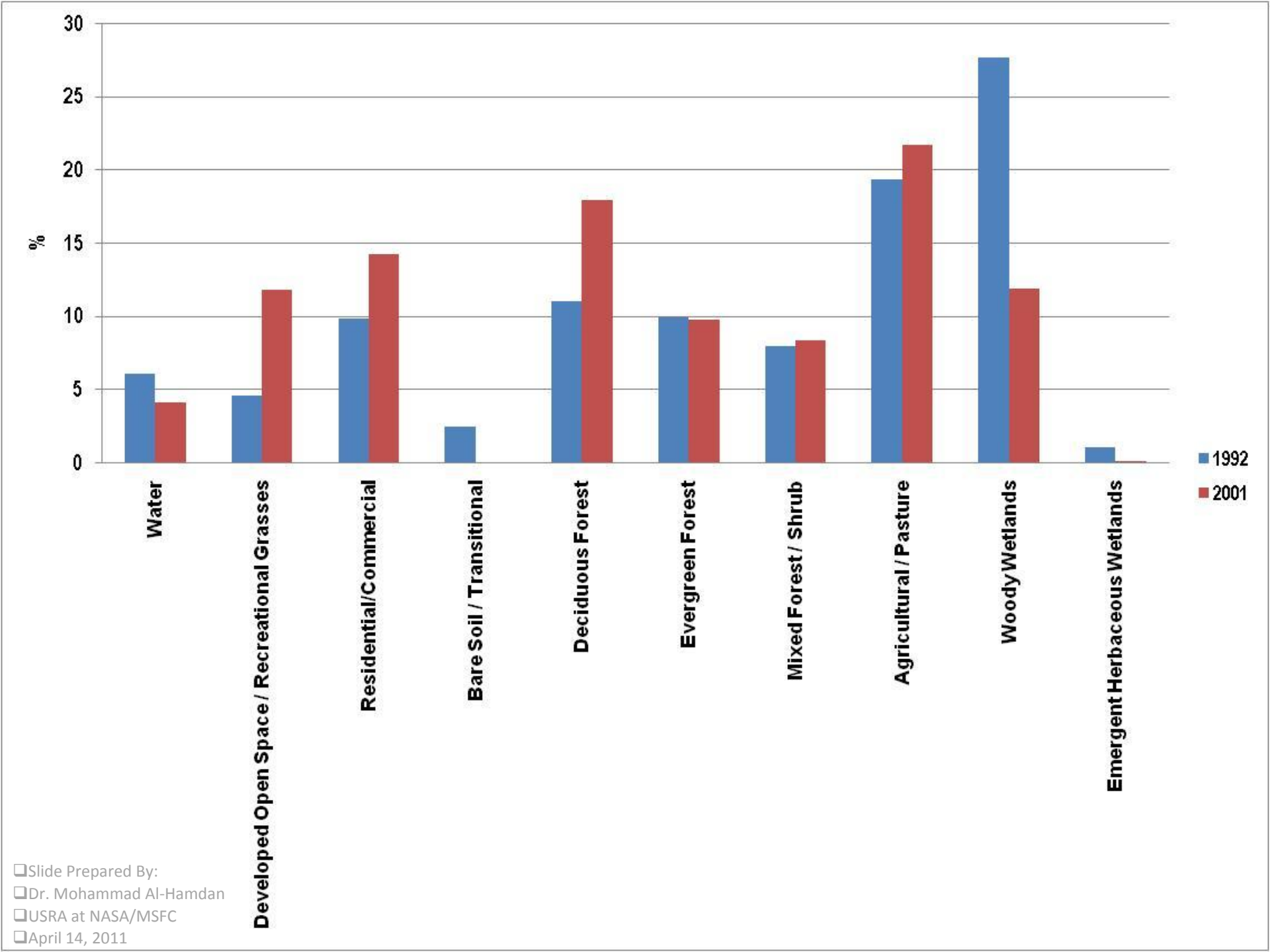

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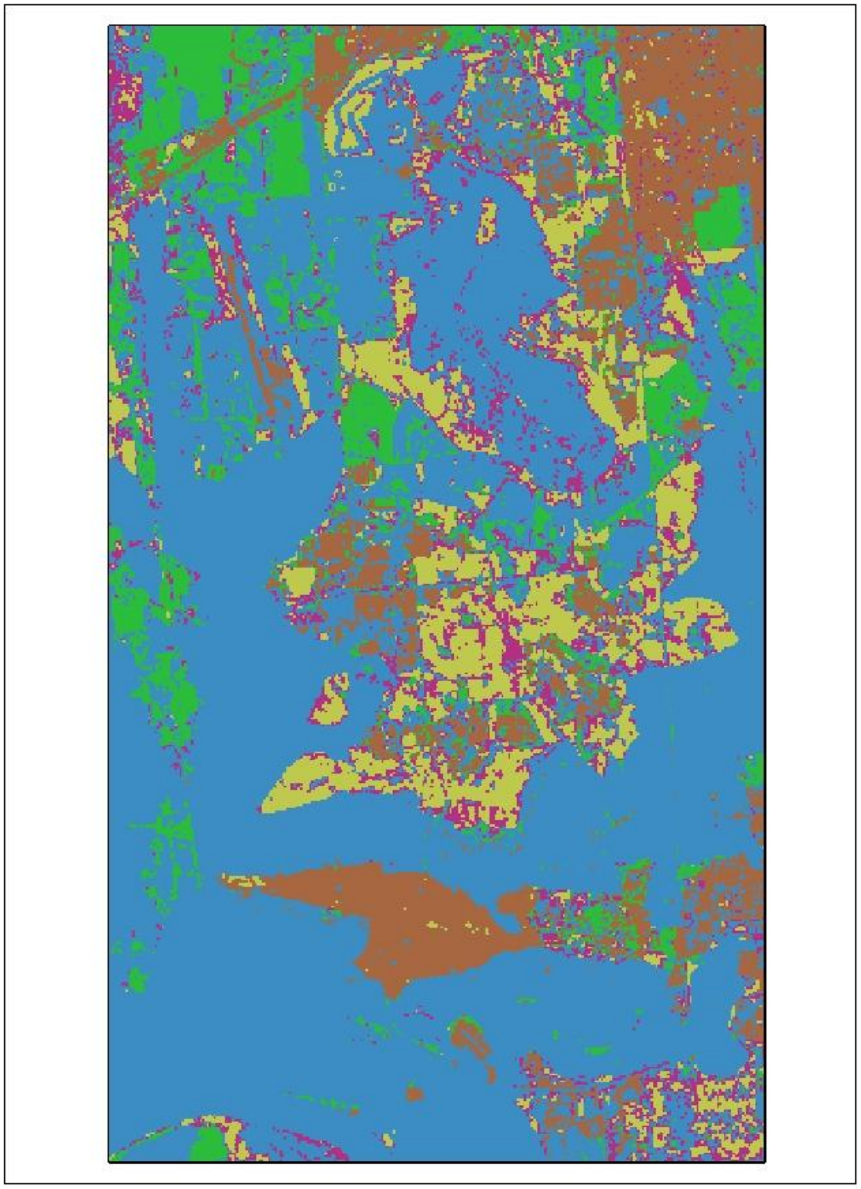
Emissivity 1992



❑**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.

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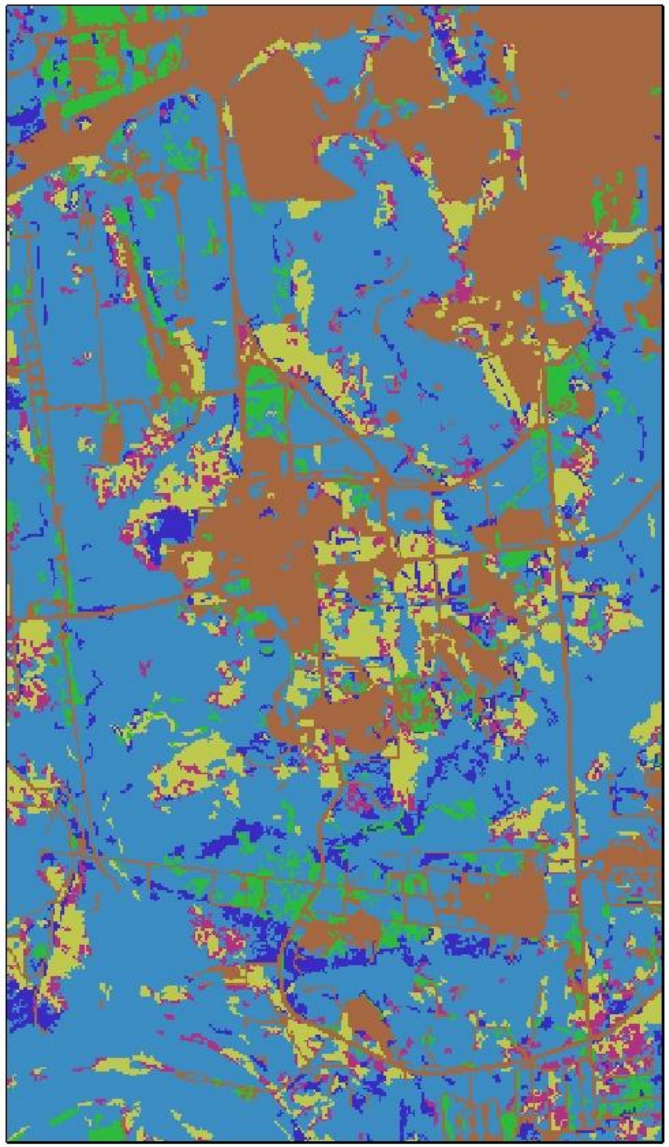

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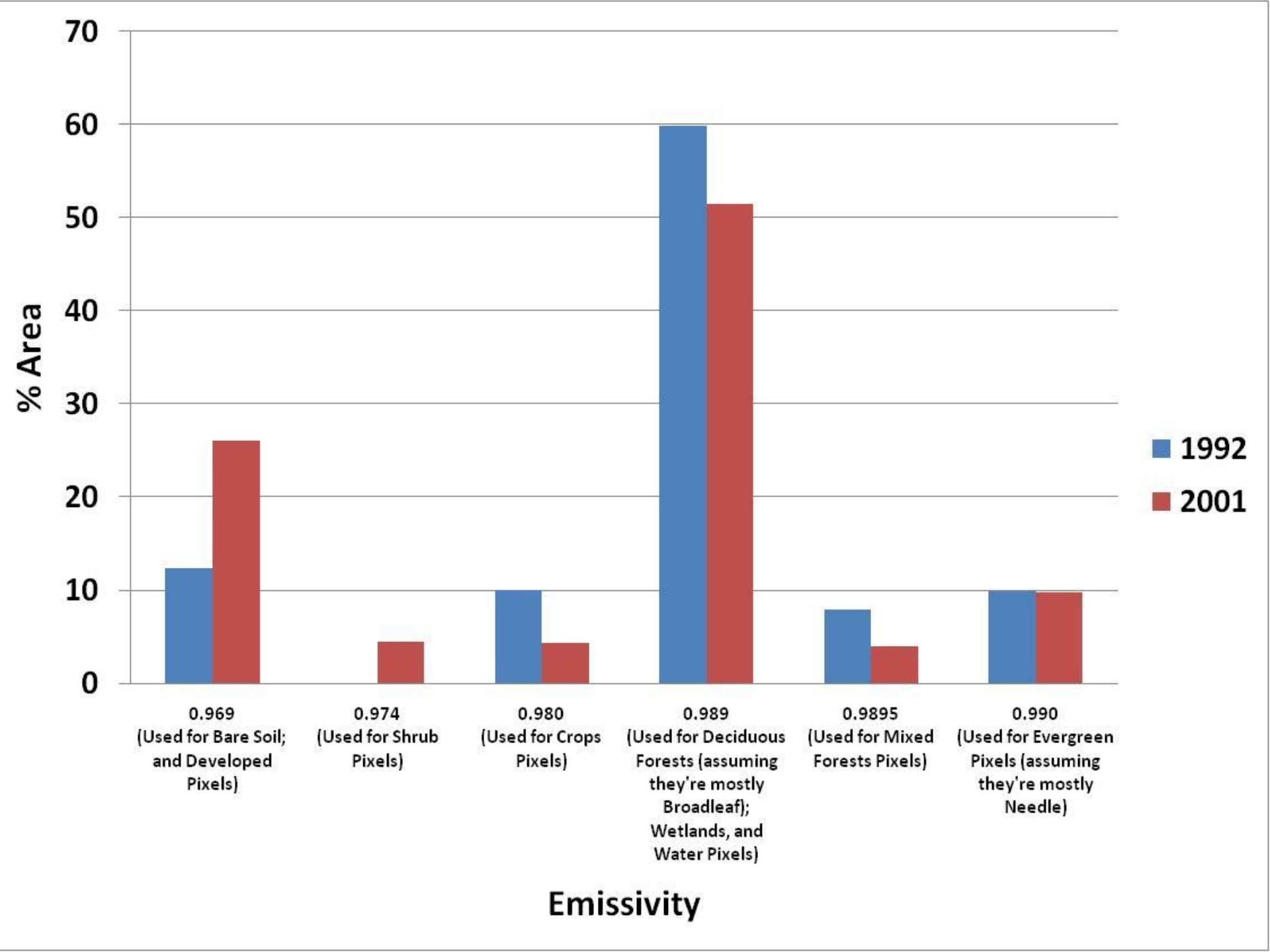
70
60
50
40
30
20
10
0
% Area
1992
2001
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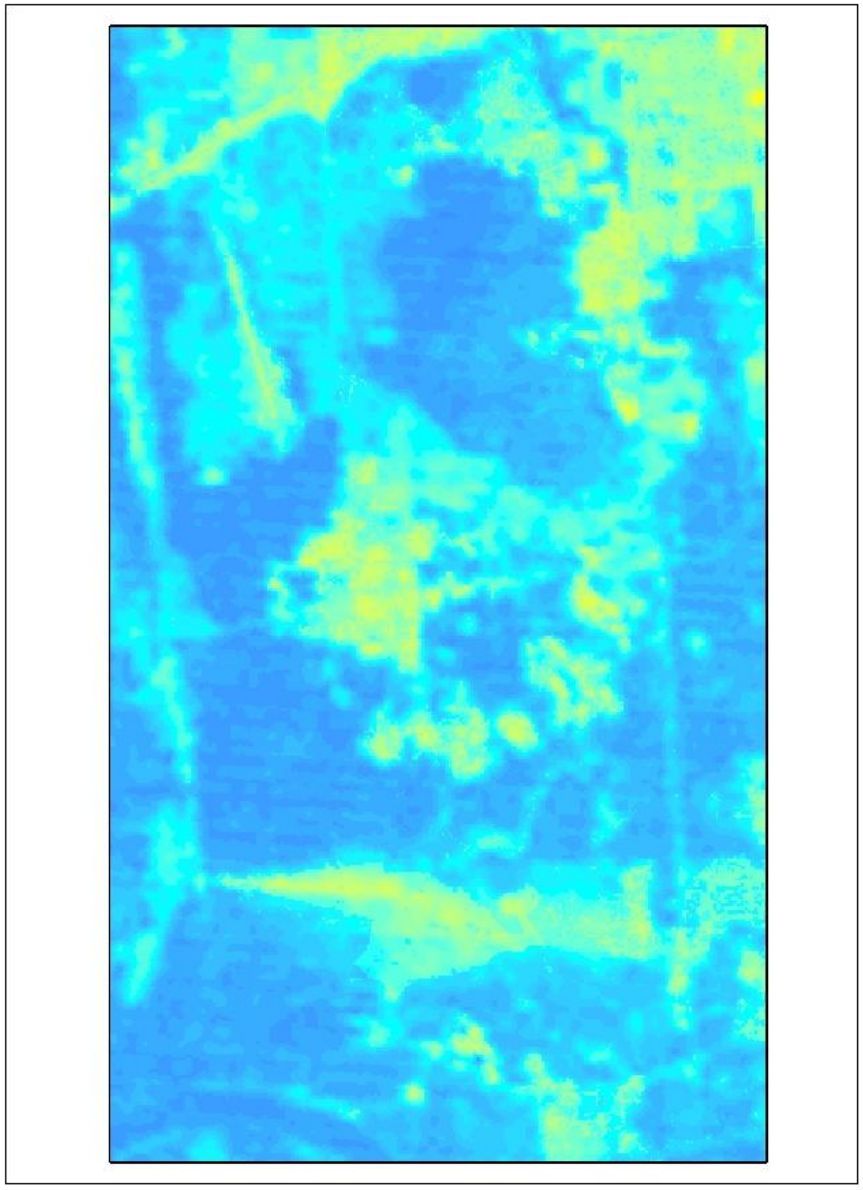
Emissivity

Landsat-derived LST July 30, 1990



❑LST (K)

314

290

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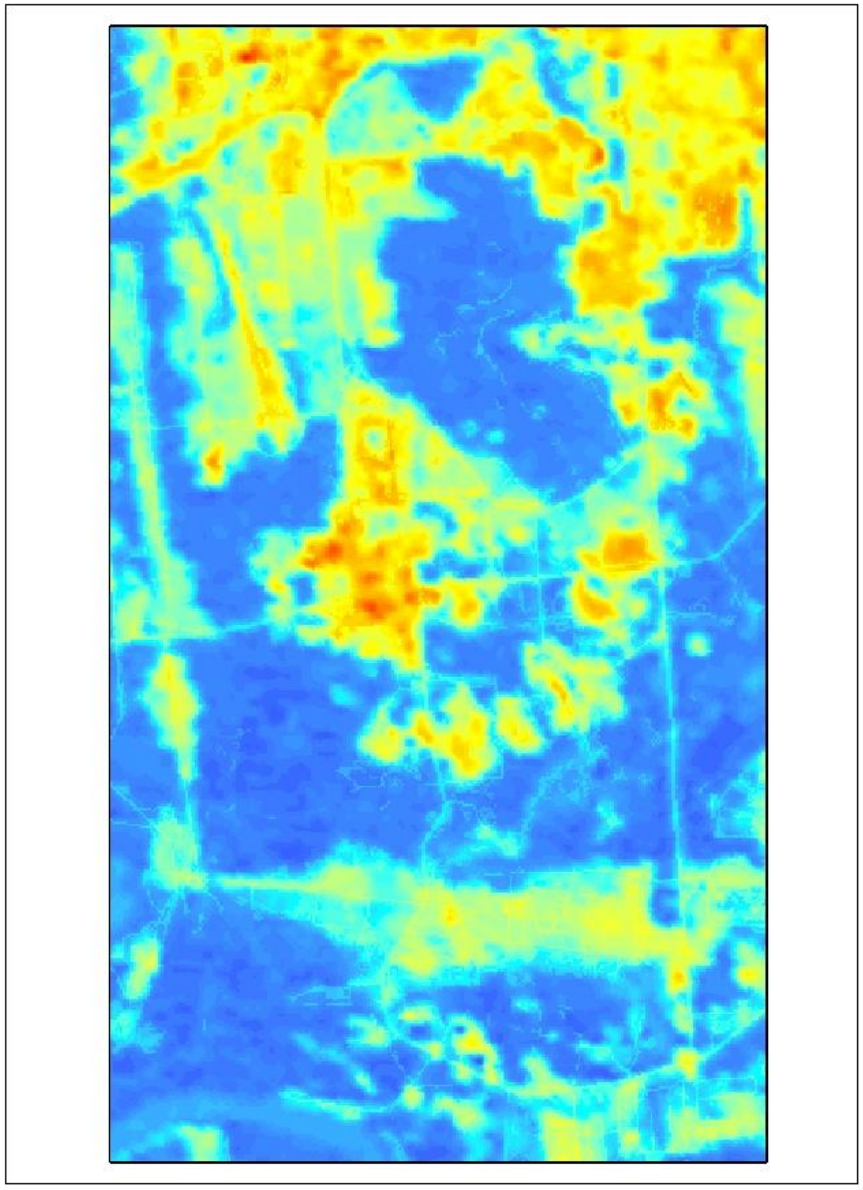
❑Dr. Mohammad Al-Hamdan
❑USRA at NASA/MSFC
❑June 8, 2011

Landsat-derived LST June 7, 2000



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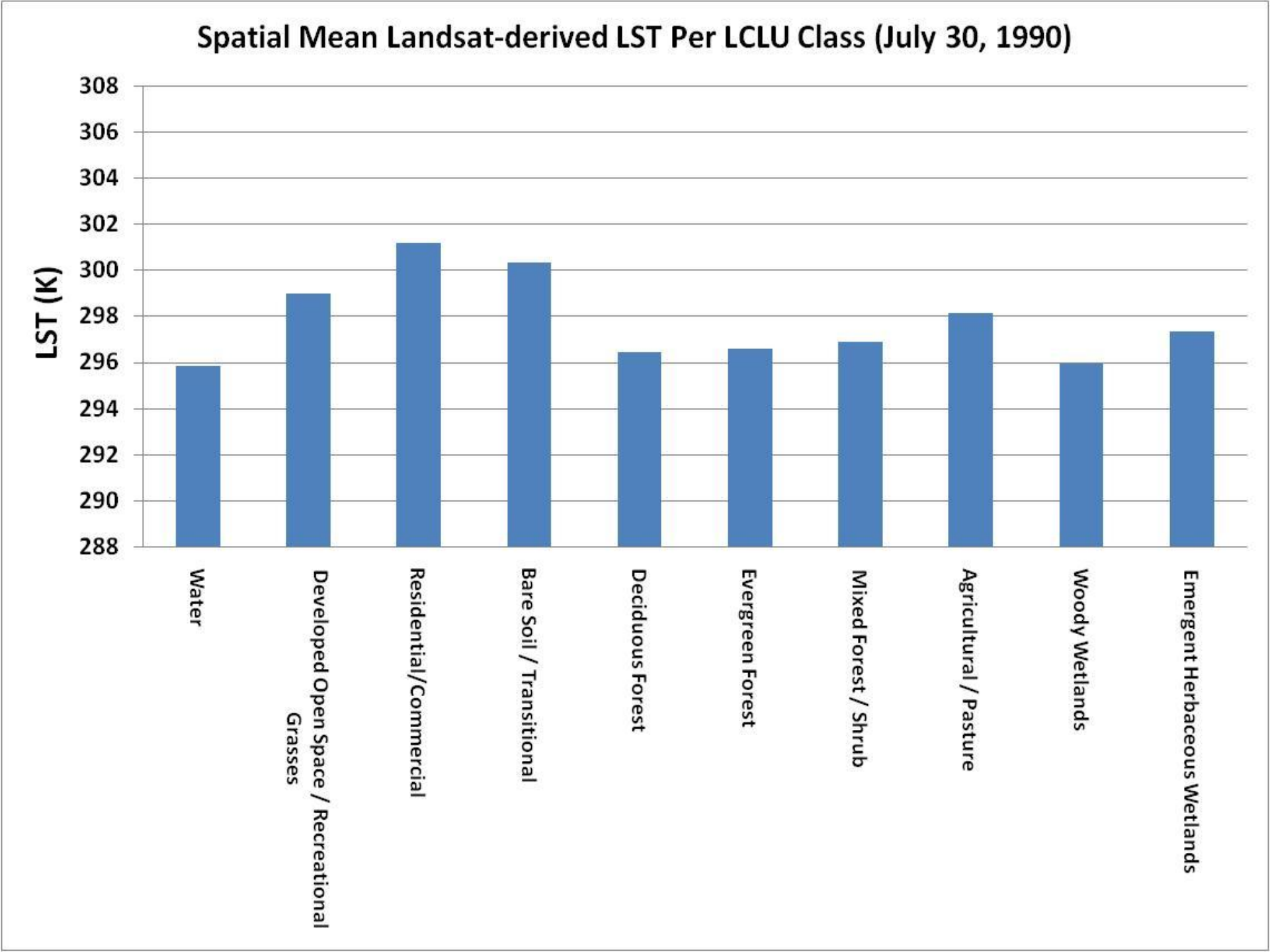
Spatial Mean Landsat-derived LST Per LCLU Class (July 30, 1990)
LST (K)
308
306
304
302
300
298
296
294
292
290
288
Water
Developed Open Space / Recreational Grasses
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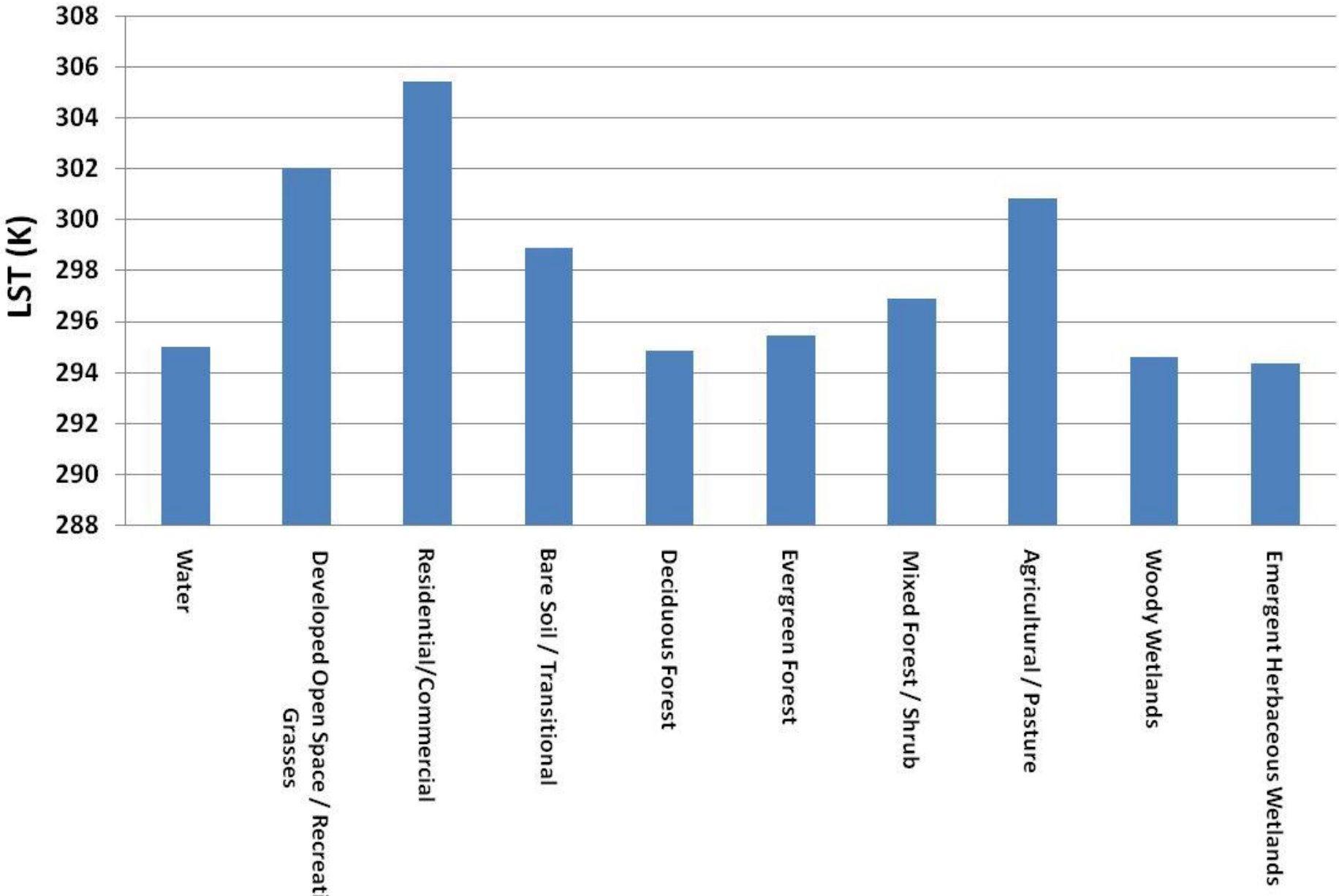
Woody Wetlands
Emergent Herbaceous Wetlands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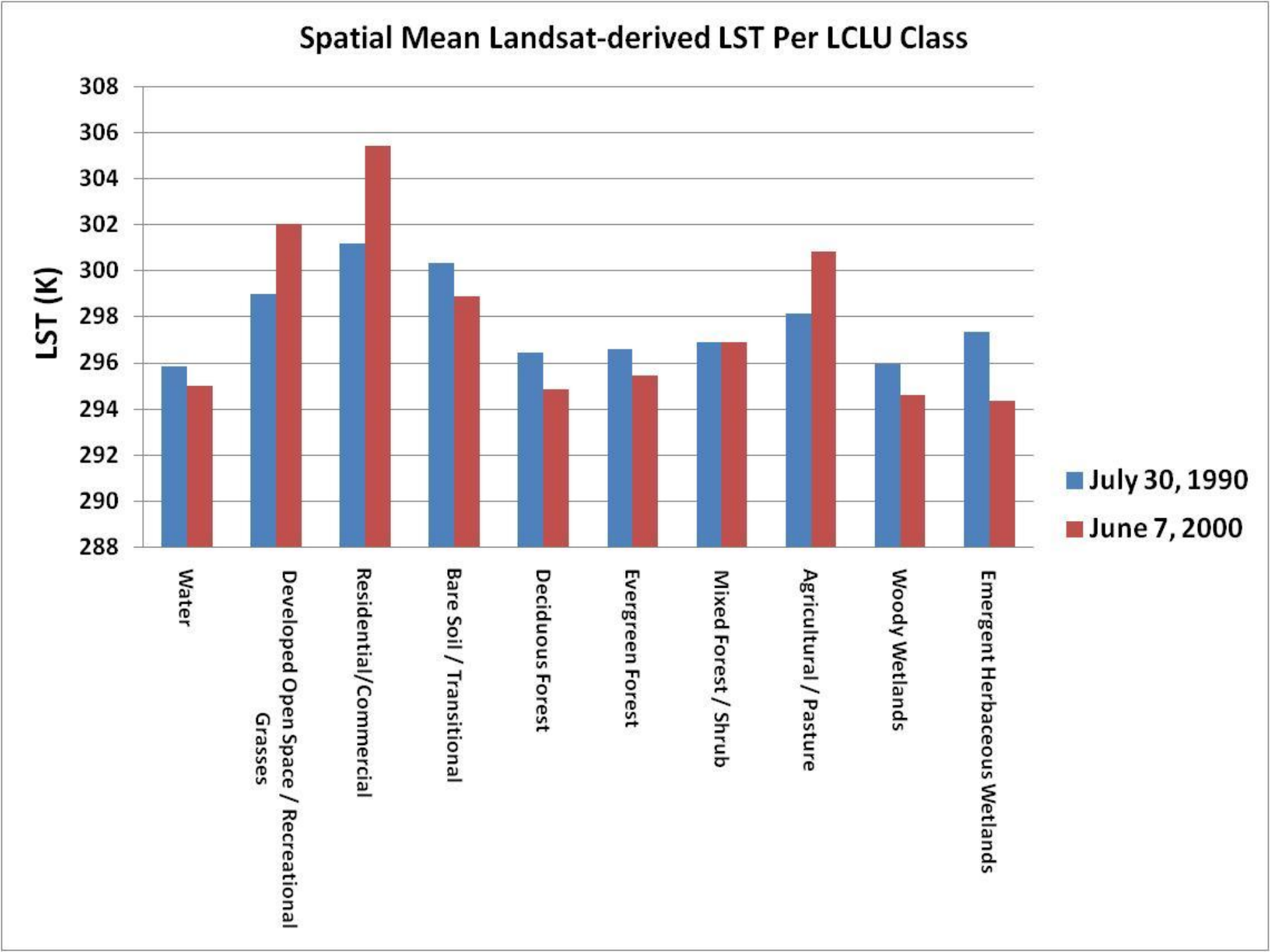
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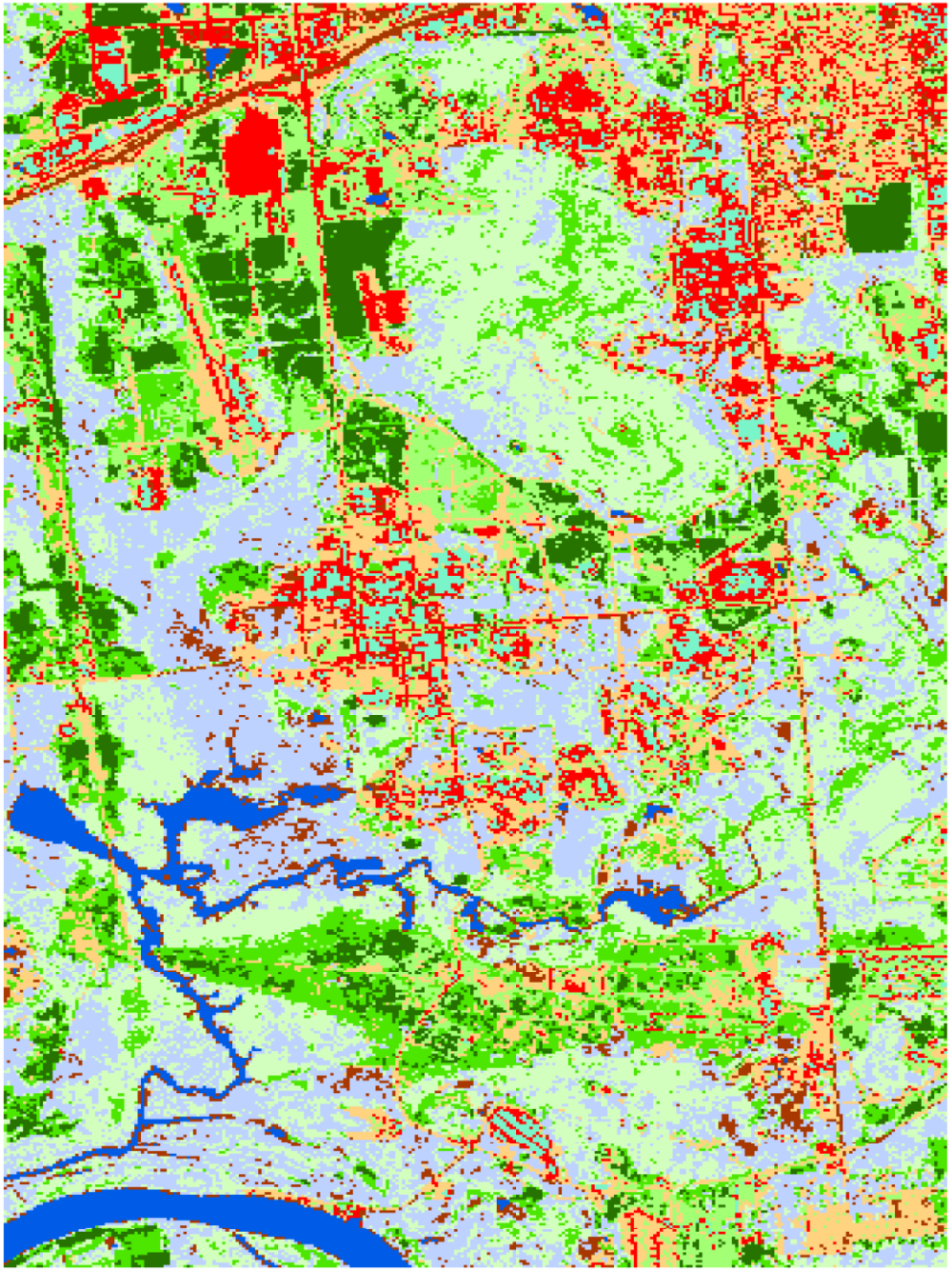
July 30, 1990
June 7, 2000

Weather Data Huntsville International Airport

Date	Min (F)	Max (F)	Precip. (inches)	Temp@10am (F)	RH@10am (%)
6/5/00	63	78	0.76		
6/6/00	56	74	0.0		
6/7/00	53	80	0.0	69	51
7/28/90	68	91	0.0		
7/29/90	67	93	0.0		
7/30/90	69	94	0.07	83	68

ASTER LULC (AUG 21, 2001)



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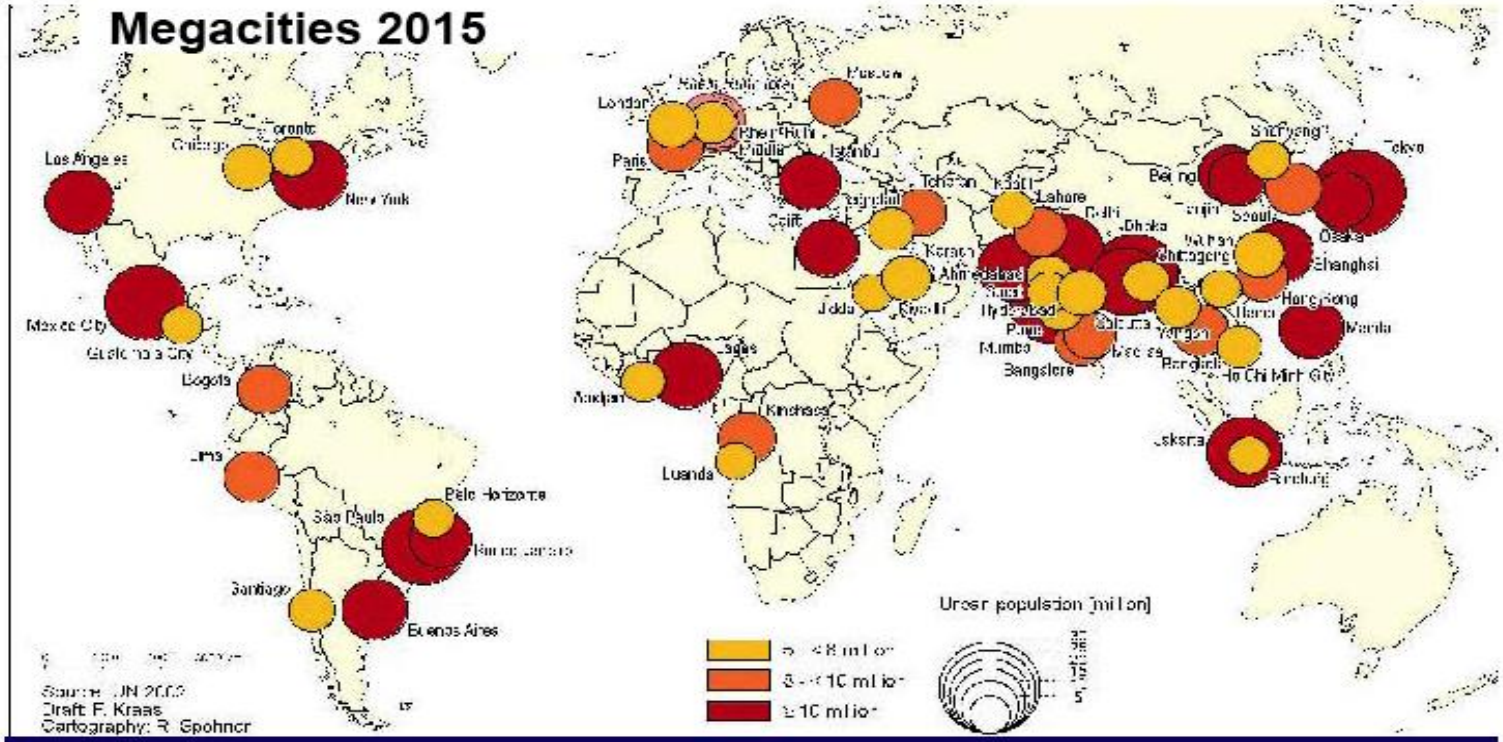
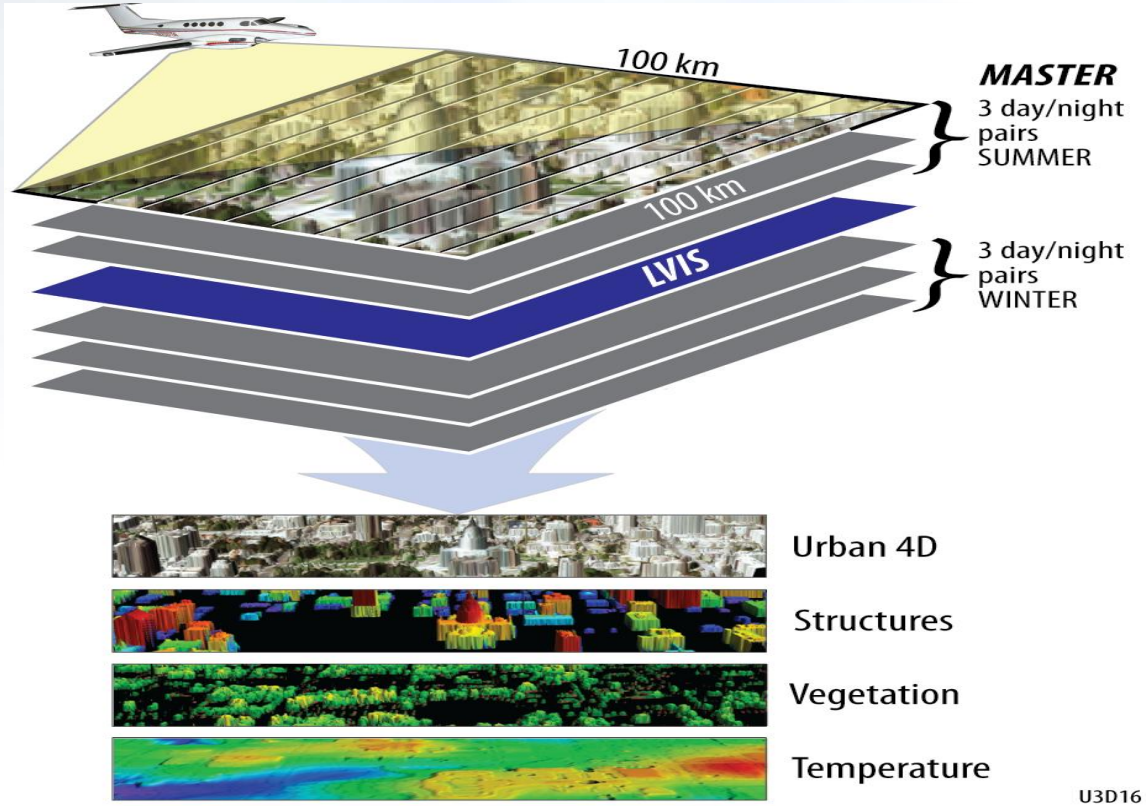
Growth of Global Megacities



- 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

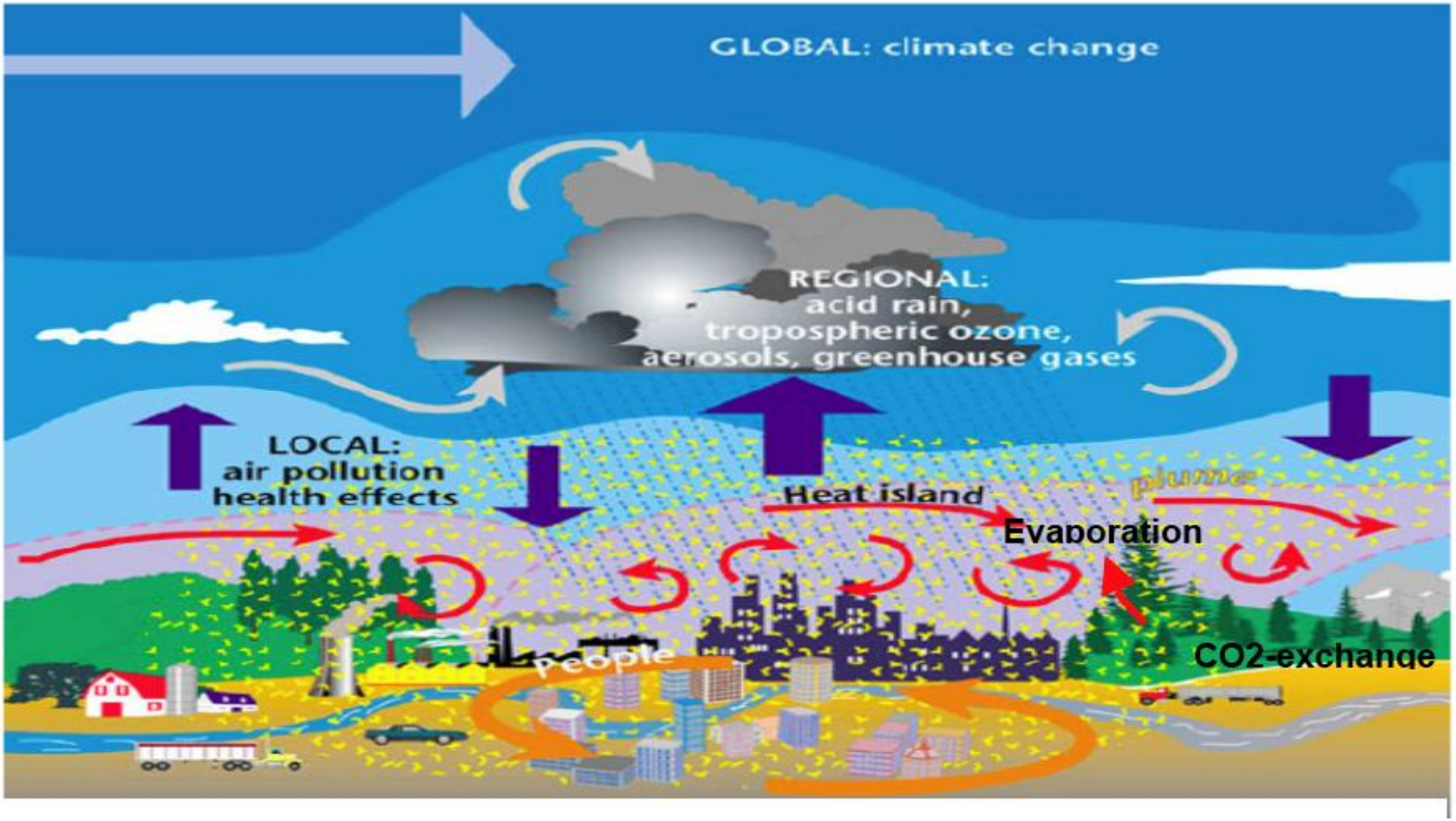
Urban Analysis with HyspIRI Data – Regional to Global Scales

- *Connecting urban environmental processes and climate*



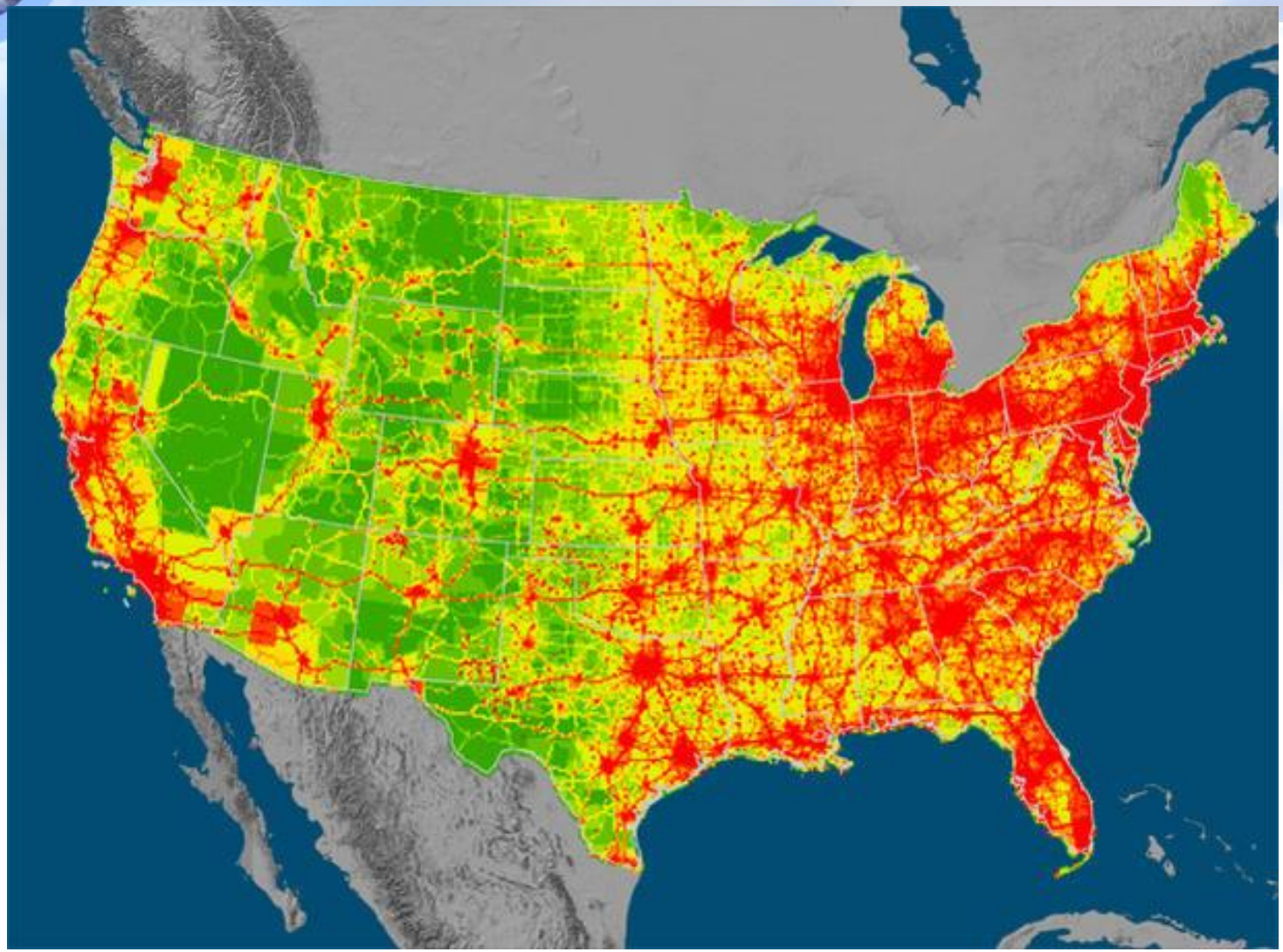
M. Imhoff – Goddard Space Flight Center

The Urban Dynamic



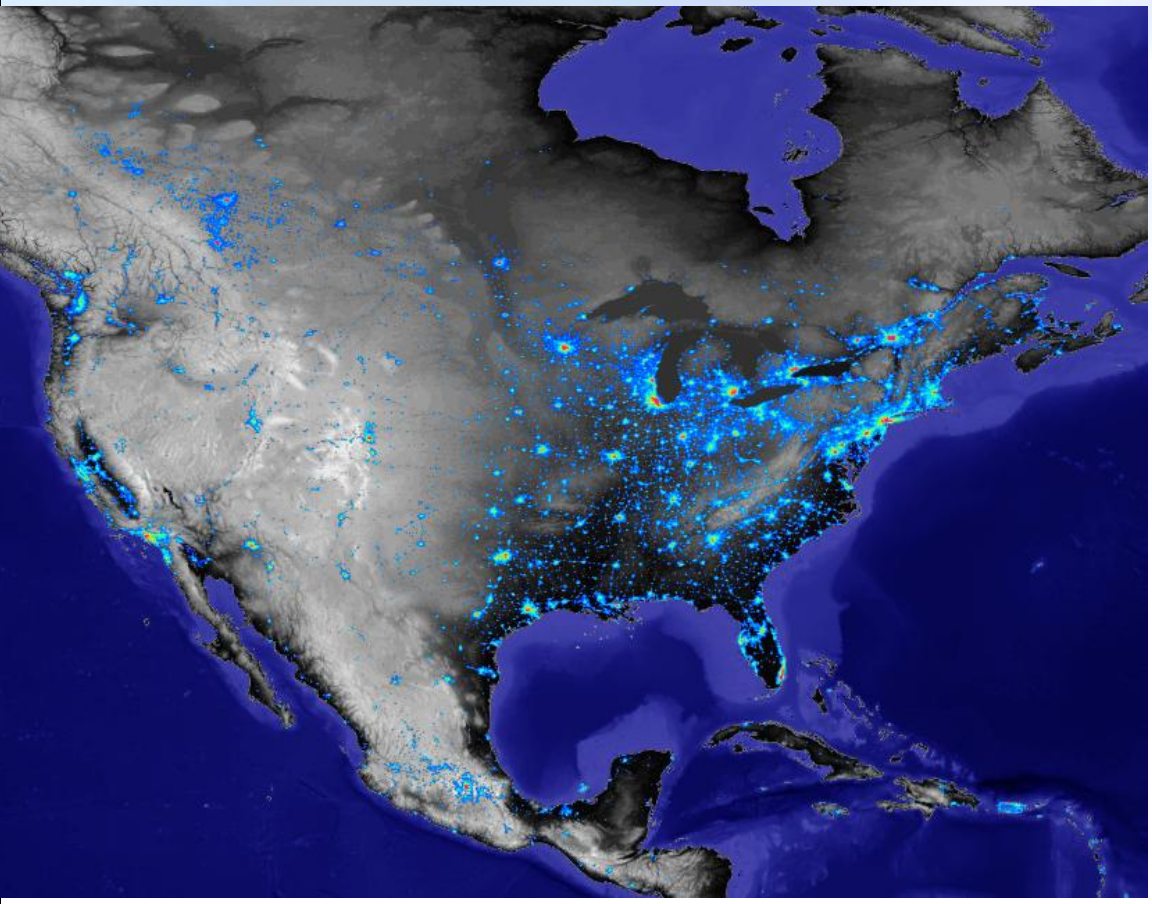
Seto and Shepherd (2009) originally in Hidalgo et al--38. Hidalgo J, Masson V, Baklanov A, Pigeon G, Gimenoa L: Advances in Urban Climate Modeling:Trends and Directions in Climate Research. *Annual New York Academy of Sciences* 2008, 1146.

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>*

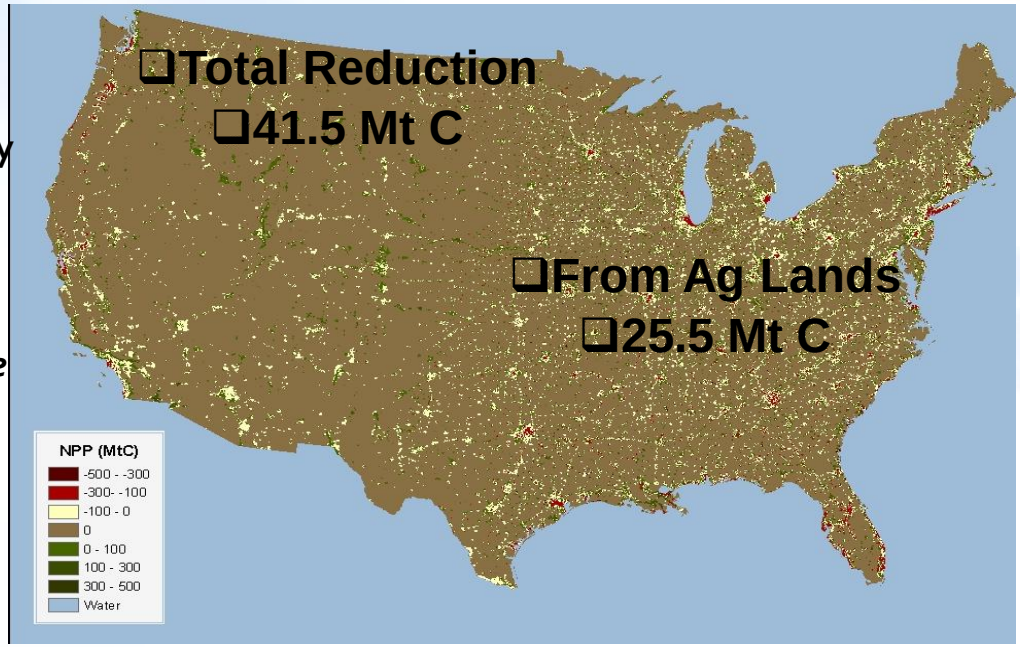
❑*Urbanization is taking place on the most fertile lands*

❑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

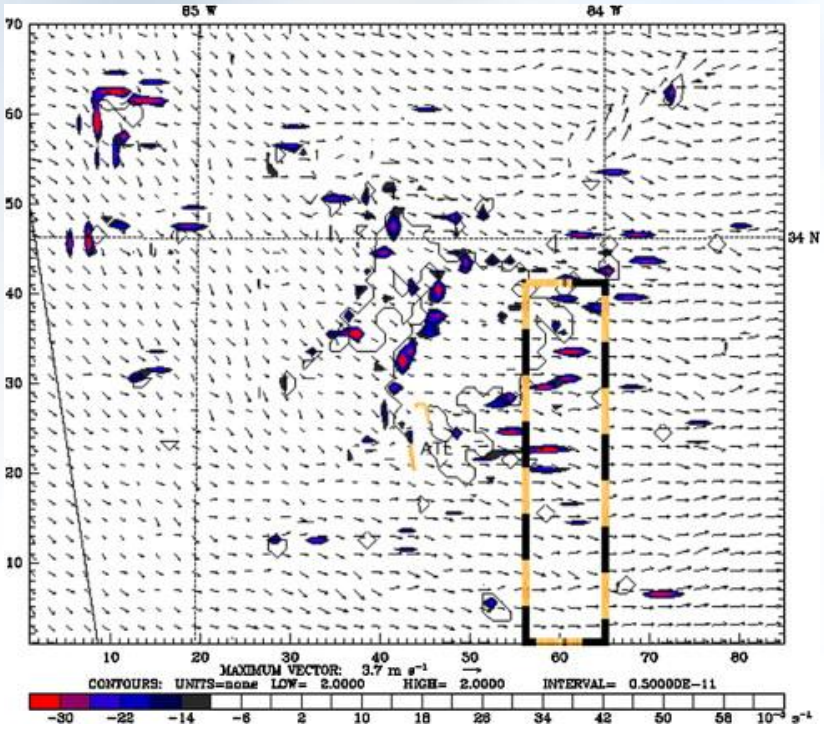


-Annual loss of food web energy 400 Trillion kilocalories

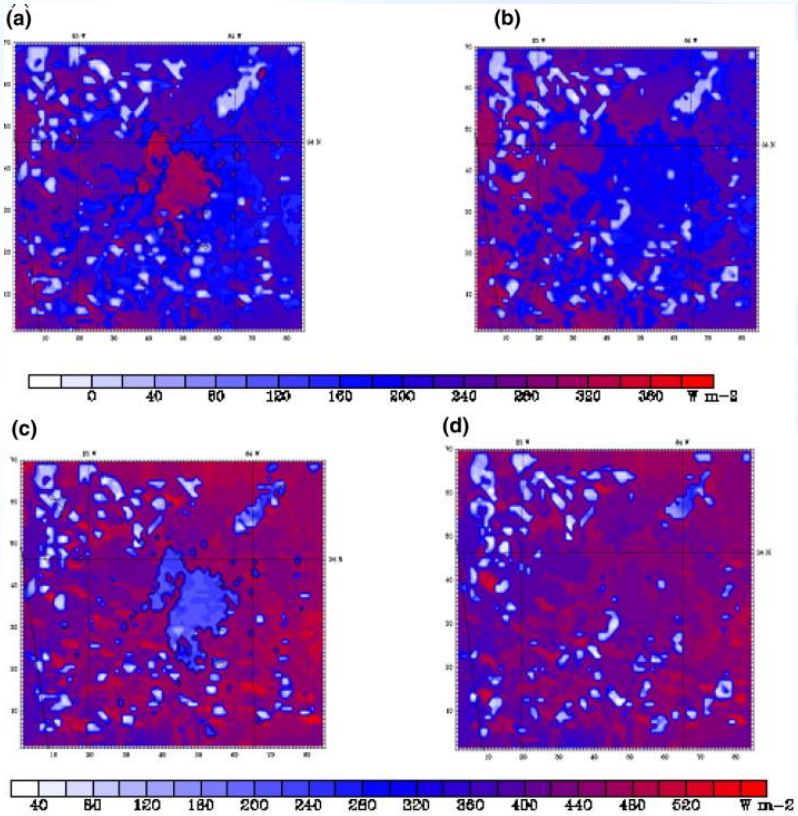
- ❑ (roughly equal to food energy requirement for 448 million people).
- Reduction of actual food products equivalent to needs of 16.5 million persons annually
  - ❑ (about 6% of US population).

Mechanisms: Convergence and Fluxes?

❑Difference in Divergence (Atlanta - No Atlanta

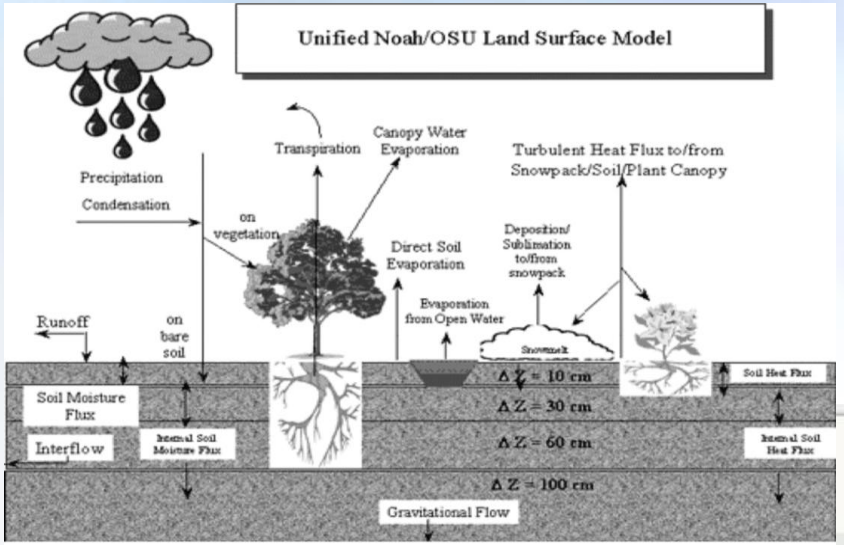


❑Atlanta No Atlanta

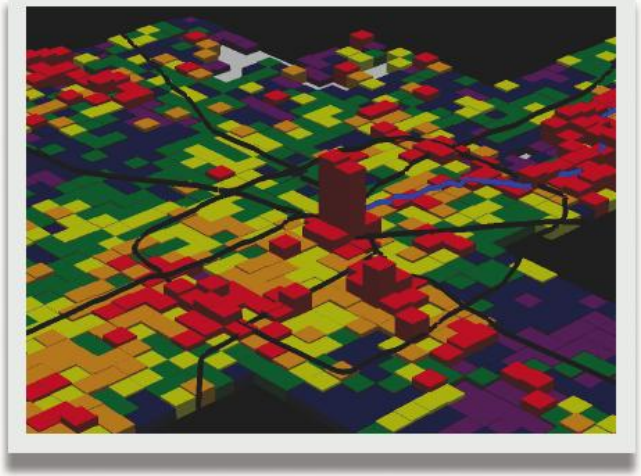


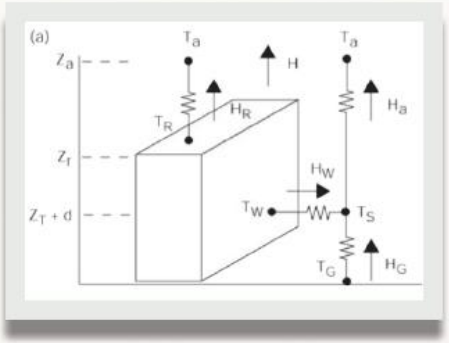
- Shem and Shepherd (2009) found that Atlanta can initiate or enhance pre-existing convection through enhanced convergence (left) and sensible heat flux (right and top)

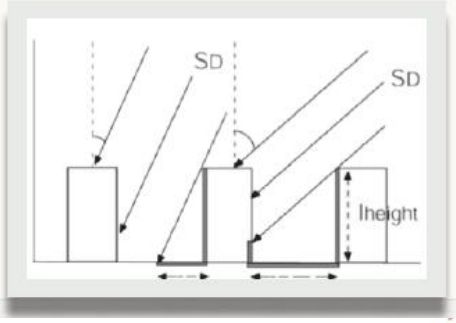
Urban surfaces and morphological parameters are still poorly represented in most studies of urban effects



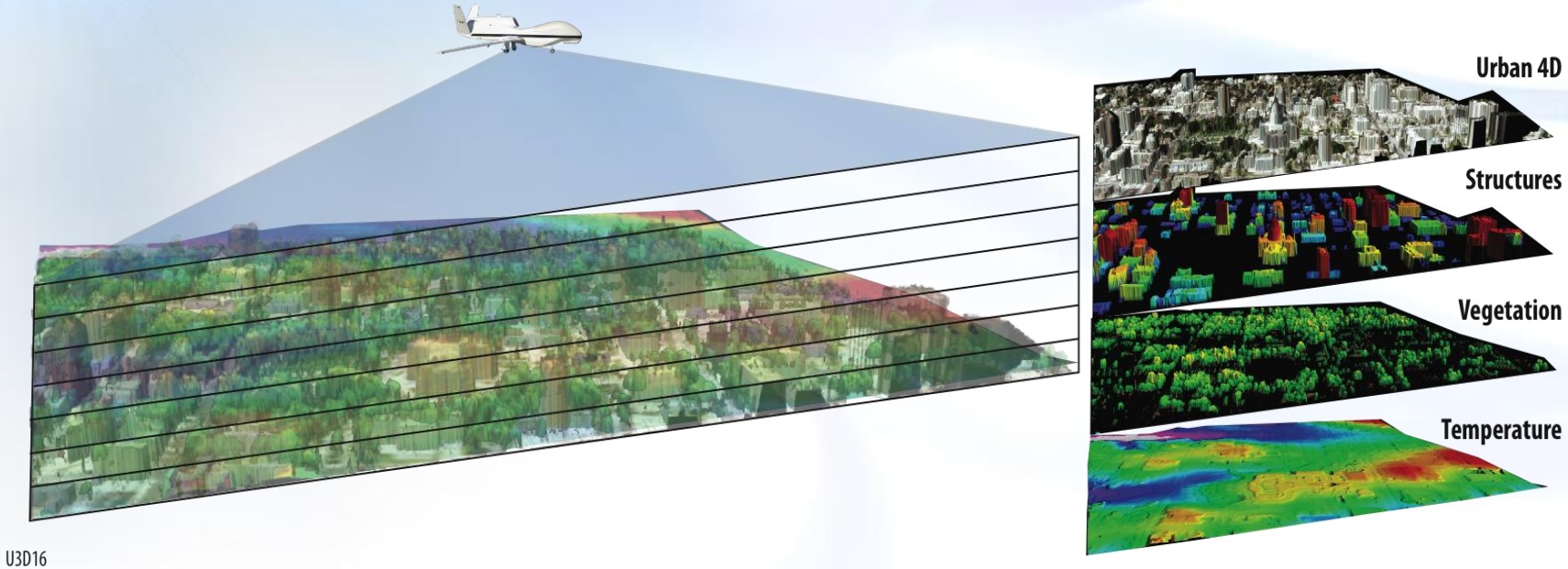
- Shepherd, Burian, and colleagues (2009) have used lidar derived urban canopy parameters and an Urban Canopy Model embedded in WRF NOAH.





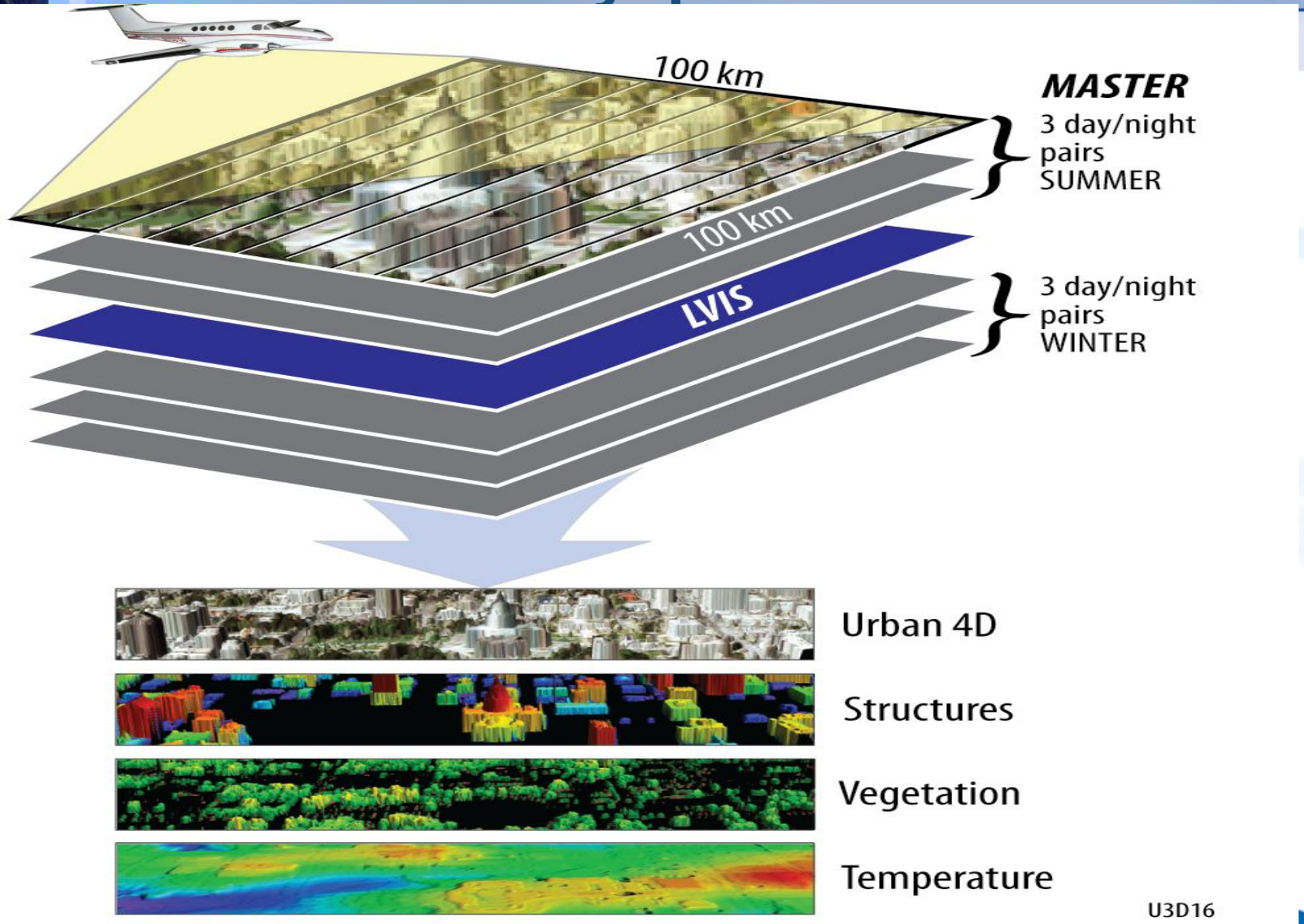


Science Overview – The Need for HyspIRI Data

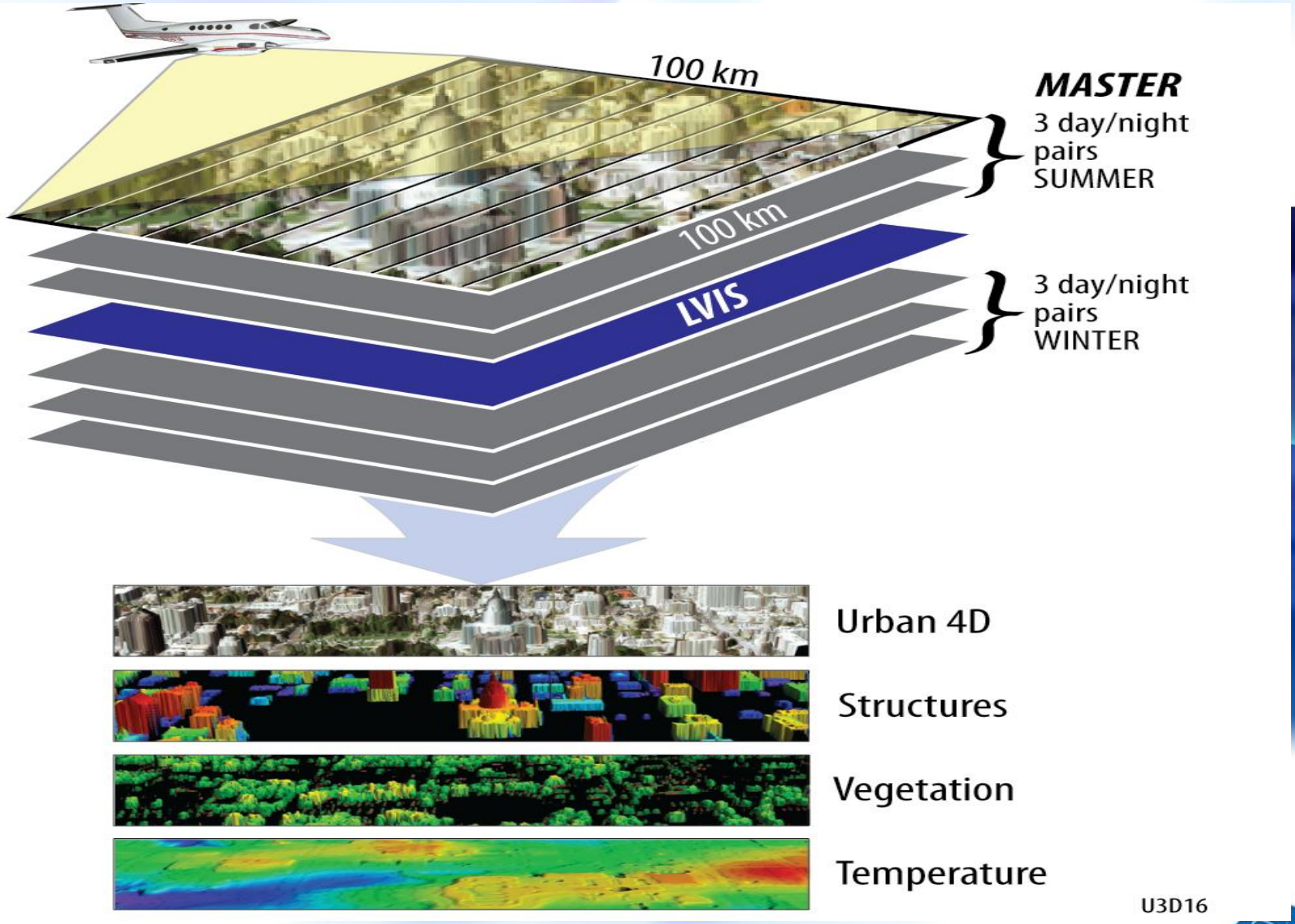


- Time series of airborne lidar, multispectral, and thermal sensors to provide the 4-dimensional (space and time) observations required to parameterize, test, and further develop models that explain and predict the influence of urbanization on earth system processes at the local, regional, and global 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

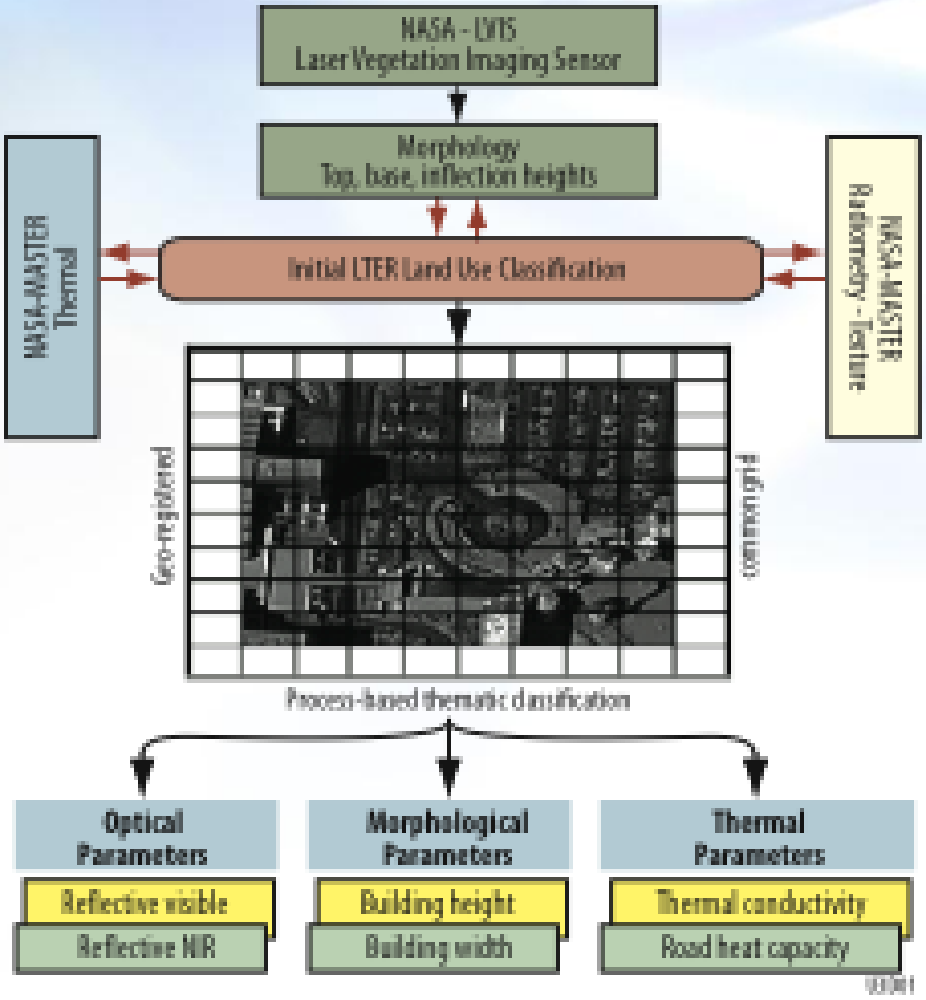


The Need for HyspIRI Data

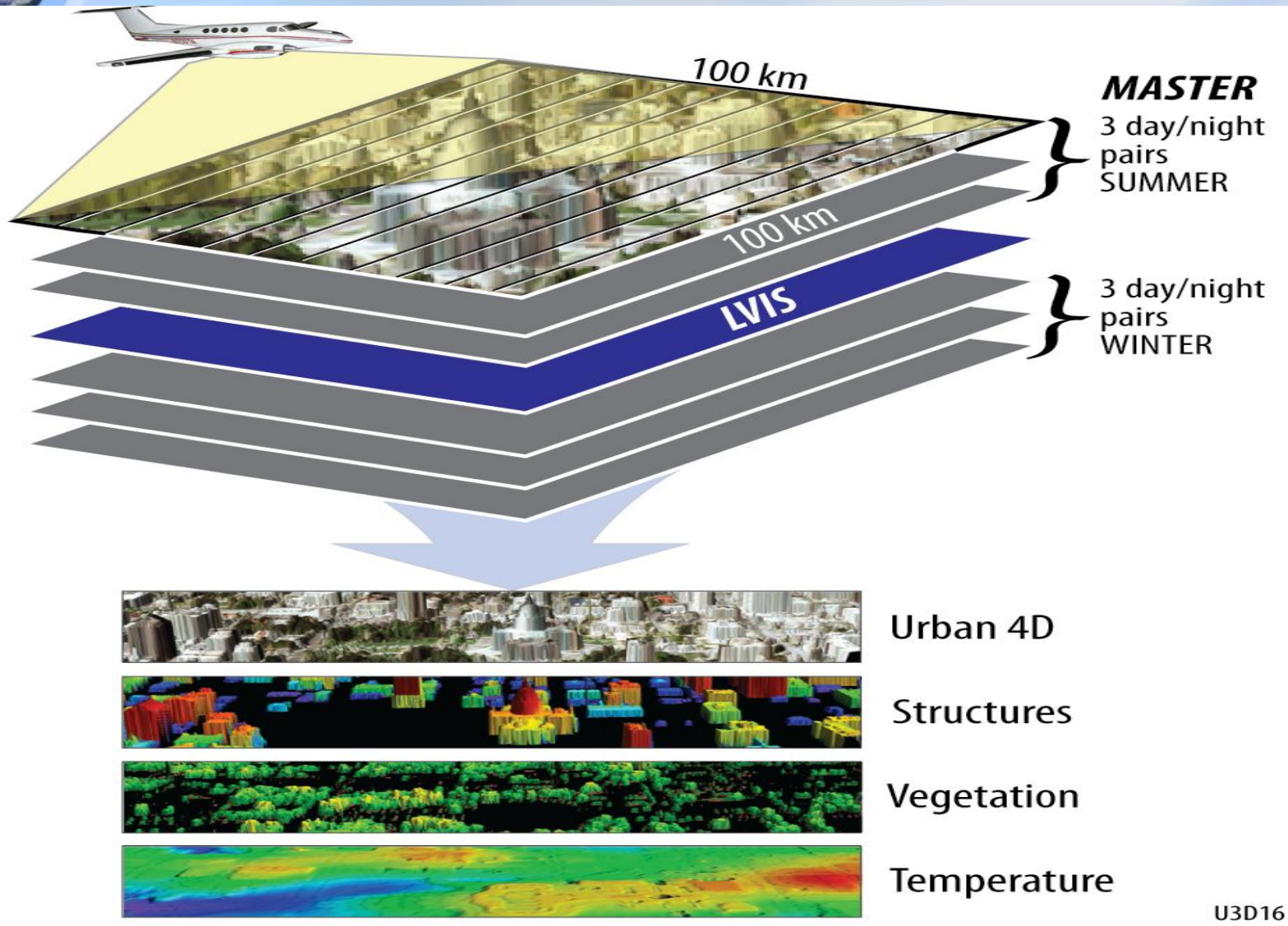


The Need for HyspIRI Data

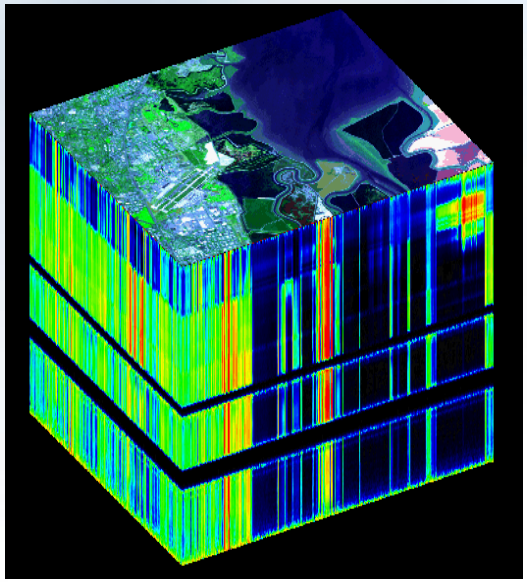
Multi-scale Combined Classification



The Need for HyspIRI Data



HyspIRI Combined Composite Data Set Advanced Product for Urban Ecosystems Analysis

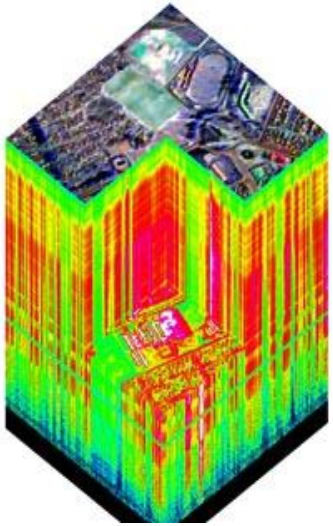


HyspIRI Hyperspectral VSWIR Level II Product
(NDVI, fPAR, surface reflectance characteristics)

+

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

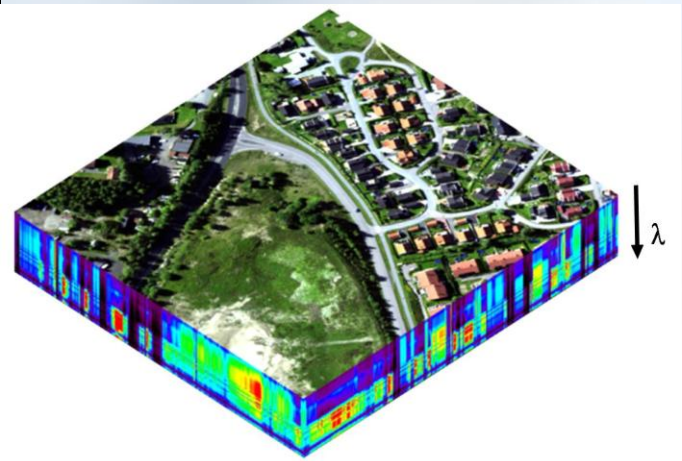
=



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

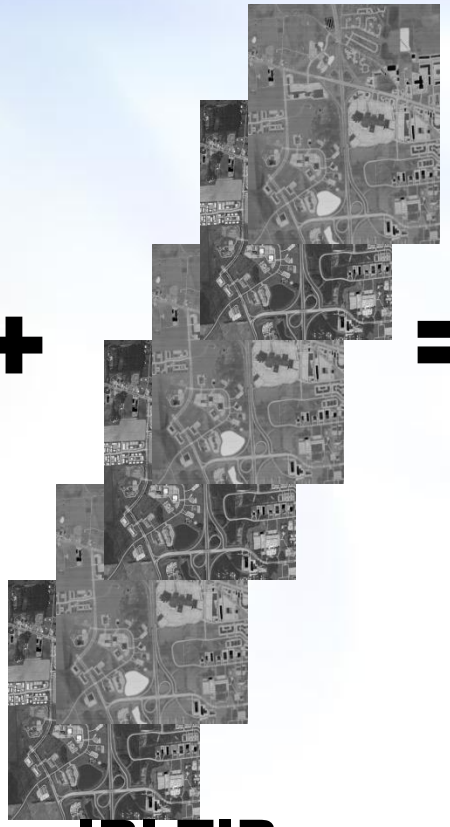
Through Time



HyspIRI Hyperspectral VSWIR Level II Product

(NDVI, fPAR, surface reflectance characteristics)

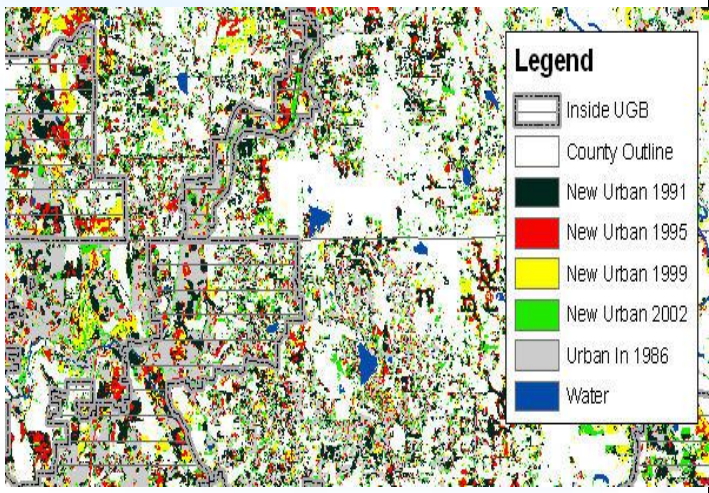
+



HyspIRI TIR multispectral Level II product (8 TIR Bands)

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

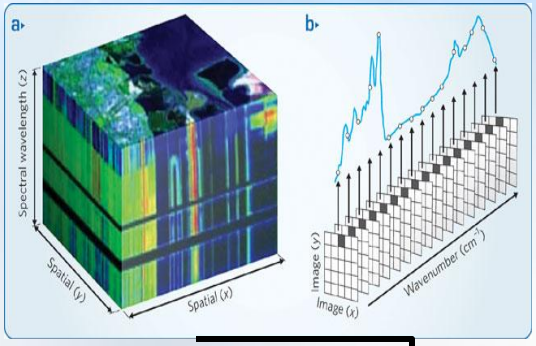
=



HyspIRI VSWIR/TIR composite land cover change data set

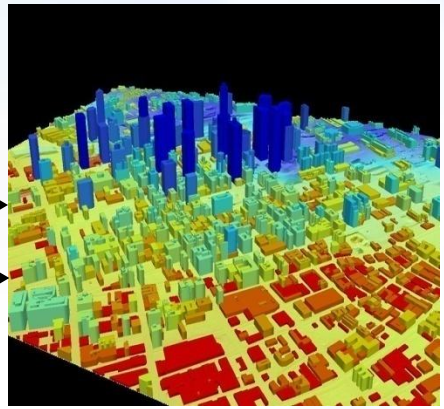
(quantitative integrative measurement of urban surface reflectances, temperatures, and emissivity across the urban ecosystem as they change through time)

HyspIRI Combined "Integrated" Advanced Product for Urban Ecosystems Analysis



HyspIRI Hyperspectral VSWIR Level II Product

(NDVI, fPAR, surface reflectance characteristics)



Lidar Data

=

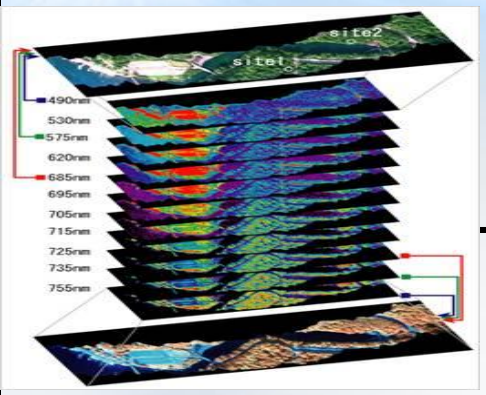
HyspIRI VSWIR/TIR and Lidar composite data set

(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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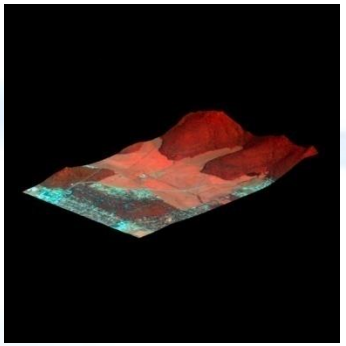

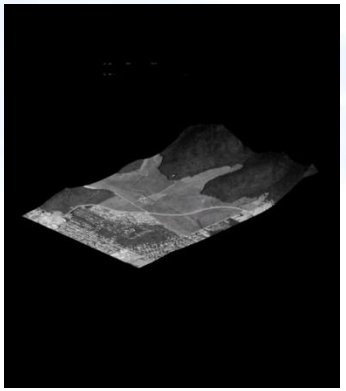

HyspIRI VSWIR/TIR and DEM composite data set

(hyperspctral/day/night TIR digital elevation model data sets))

HyspIRI TIR multispectral Level II product (8 TIR Bands)

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