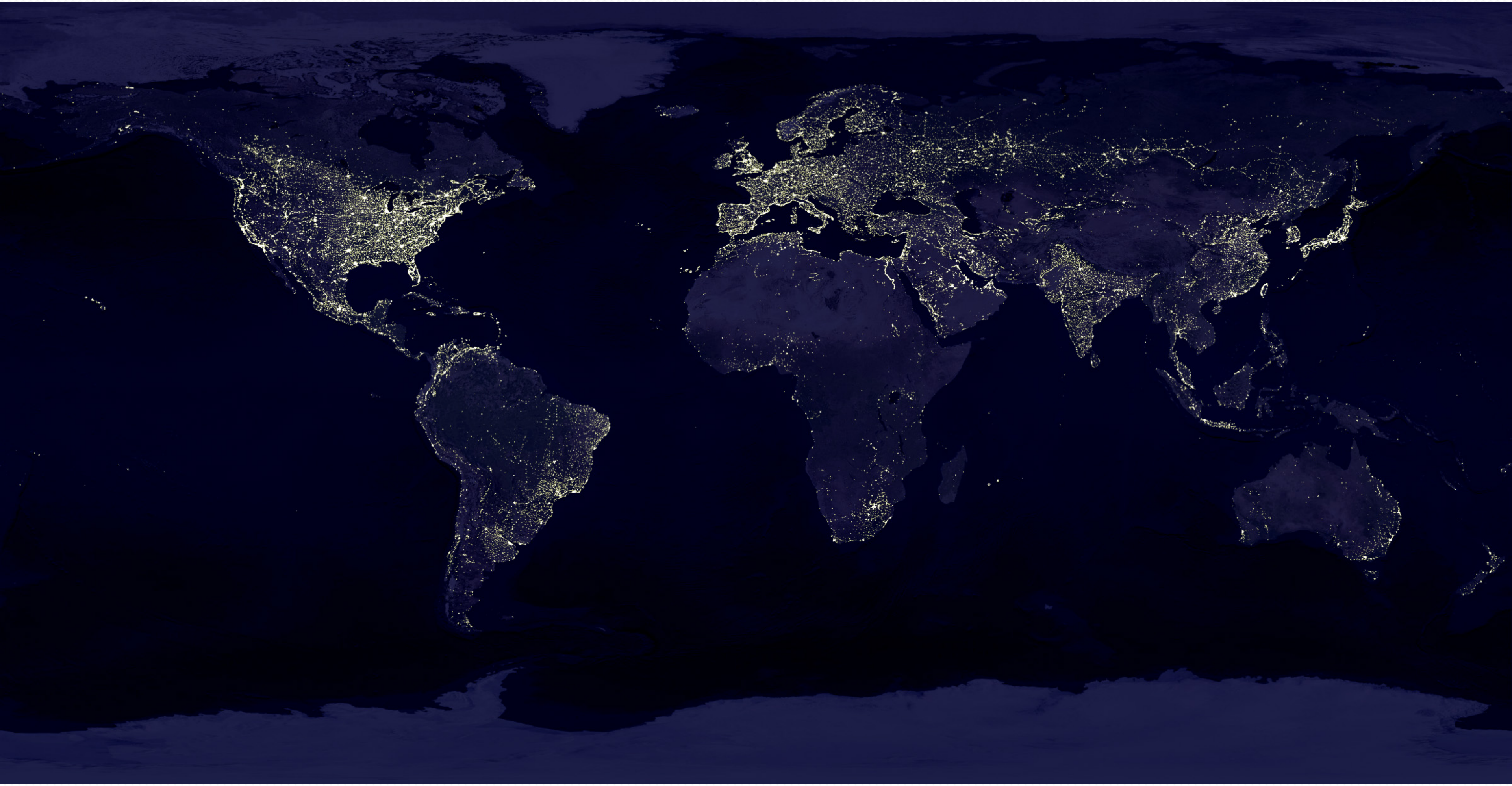
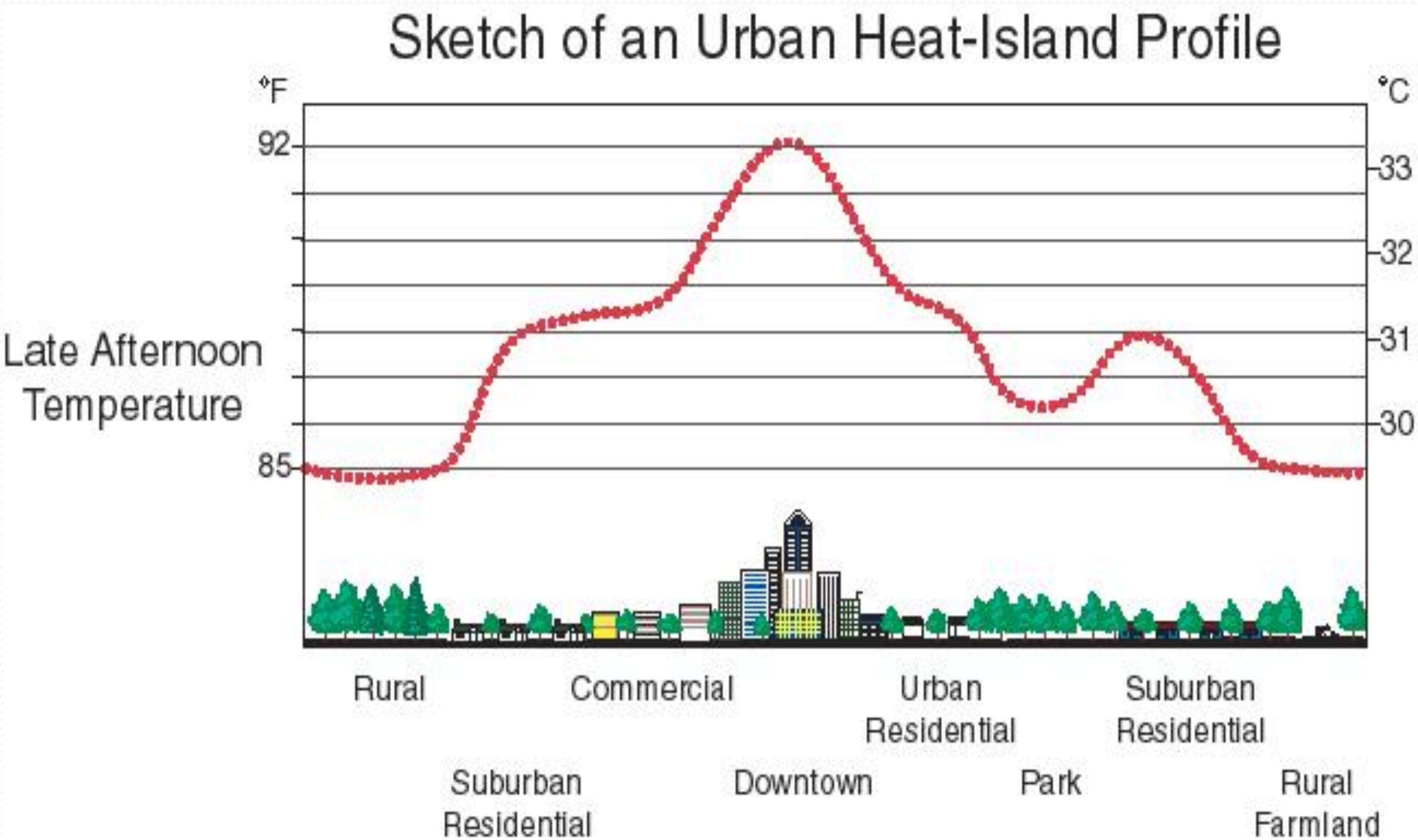
Potential for Improved Urban Land Surface Characterization and Land Surface Temperature Analysis Using HyspIRI Data: Previous ATLAS Studies in Puerto Rico



Jeffrey C. Luvall and Dale A. Quattrochi
NASA Marshall Space Flight Center



Sketch of an Urban Heat-Island Profile
°F
°C
92
85
33
32
31
30
Late Afternoon Temperature
Rural
Suburban Residential
Commercial
Downtown
Urban Residential
Park
Suburban Residential
Rural Farmland

TRMM Precipitation Radar Study of Urban-Induced Rainfall Featured in August 11th, 2003 Issue of TIME magazine

AUGUST 11, 2003

TIME

How Cities Make Their Own Weather

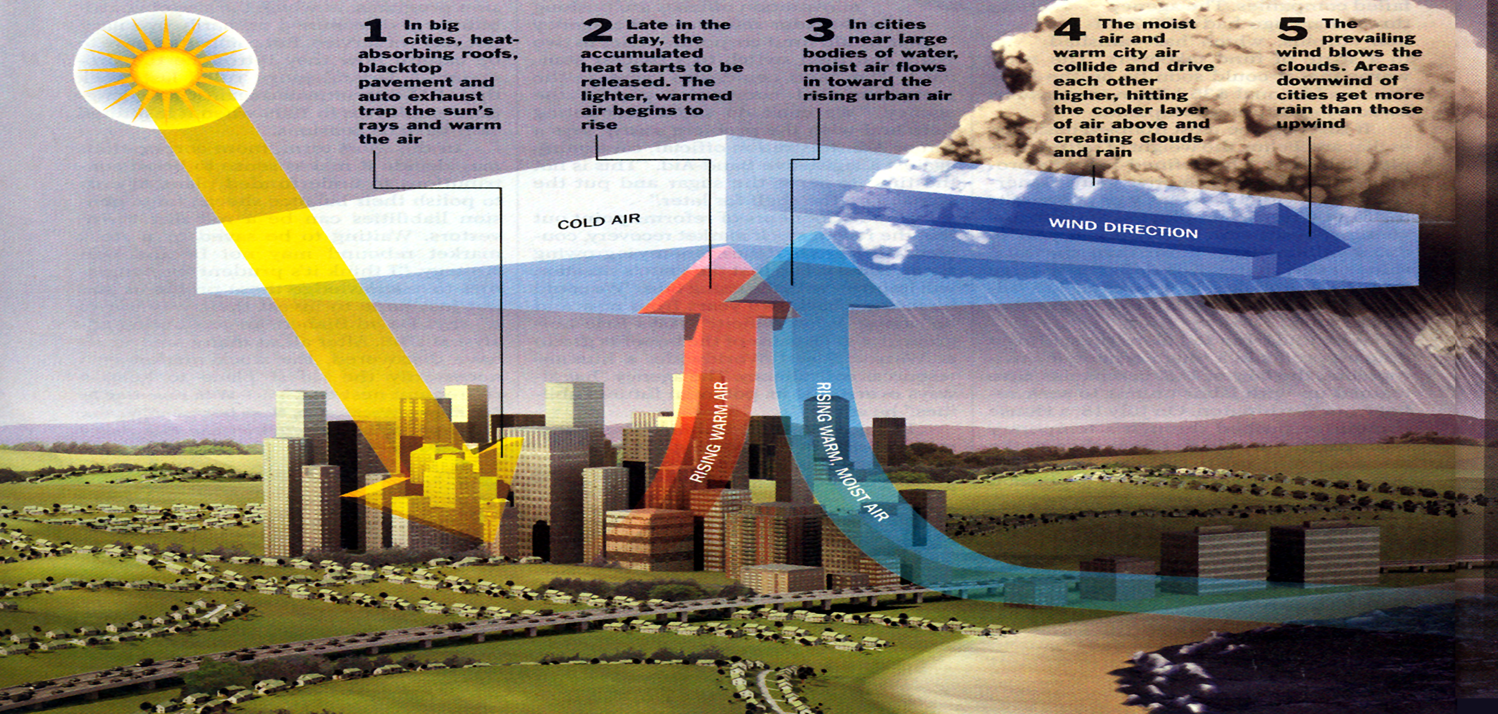
WHEN HOUSTON IS HIT BY A SUDden storm, the city may be partly to blame. Increasingly, urban centers don't merely endure bad weather; they help create it. Researchers believe the phenomenon may be more common now than ever before.

Scientists have known for 200 years that the temperature in a city can be higher than that in its environs—something they learned when an amateur weather watcher detected a 1.58°F temperature difference between London and its suburbs. Modern cities, with their cars and heat-trapping buildings, can create an even bigger temperature gap, sometimes as much as 10°F.

Islands of urban heat can do funny things with weather. Hot city air, like hot air anywhere else, rises—even more so because of the turbulence caused by tall buildings. When that air is damp enough and collides with colder layers above it, water can condense out as a sudden burst of rain, especially if there are few frontal systems to disrupt the layers, as in summer. In a spot storm above a city or just downwind of it, it's likely that nature alone isn't behind the downpour.

NASA and the University of Arkansas have been using satellite mapping and ground-based temperature readings … termine how widespread this phenon … is. This spring researchers got a su … when they turned their attention to Houston. Because it's near a coast and sea breezes tend to cool and disperse hot air, Houston was thought to be comparatively safe from homemade rain. Now it appears that the opposite may be true. "The sea breeze may exacerbate the rainfall," says research meteorologist Marshall Shepherd of NASA's Goddard Space Flight Center. The warm air and sea air collide, he explains, and "move straight up like the front ends of two cars that hit head on, providing a pump of moist air that helps thunderstorms develop."

Hot, waterlogged cities can be cooled off in the usual ways—by limiting auto exhaust, for example. Using light-colored roofing and paving materials in place of black, heat-absorbing tar will also help. As a bonus, the cooler roof will reduce the need for air conditioning. —*By Jeffrey Kluger*

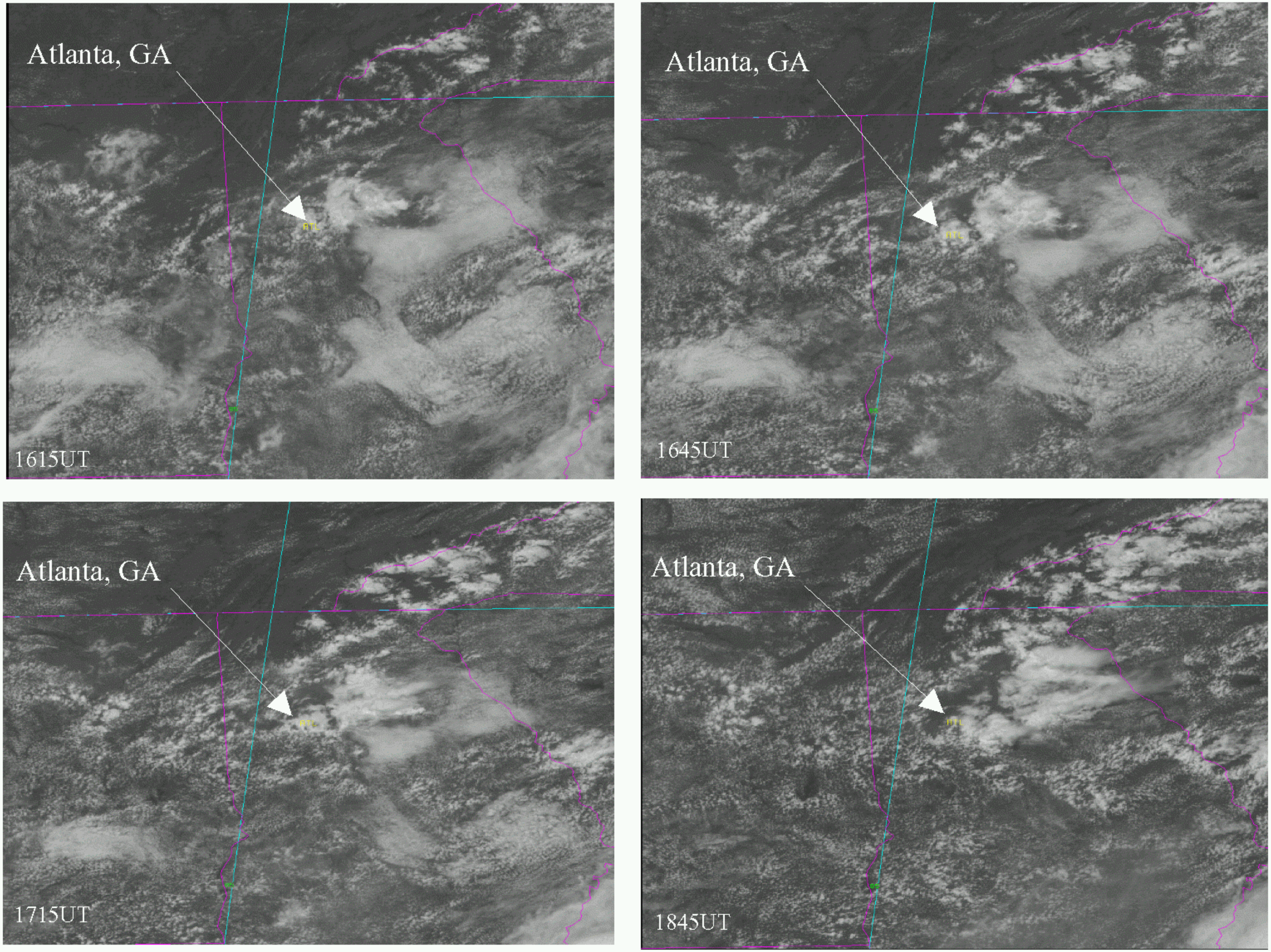


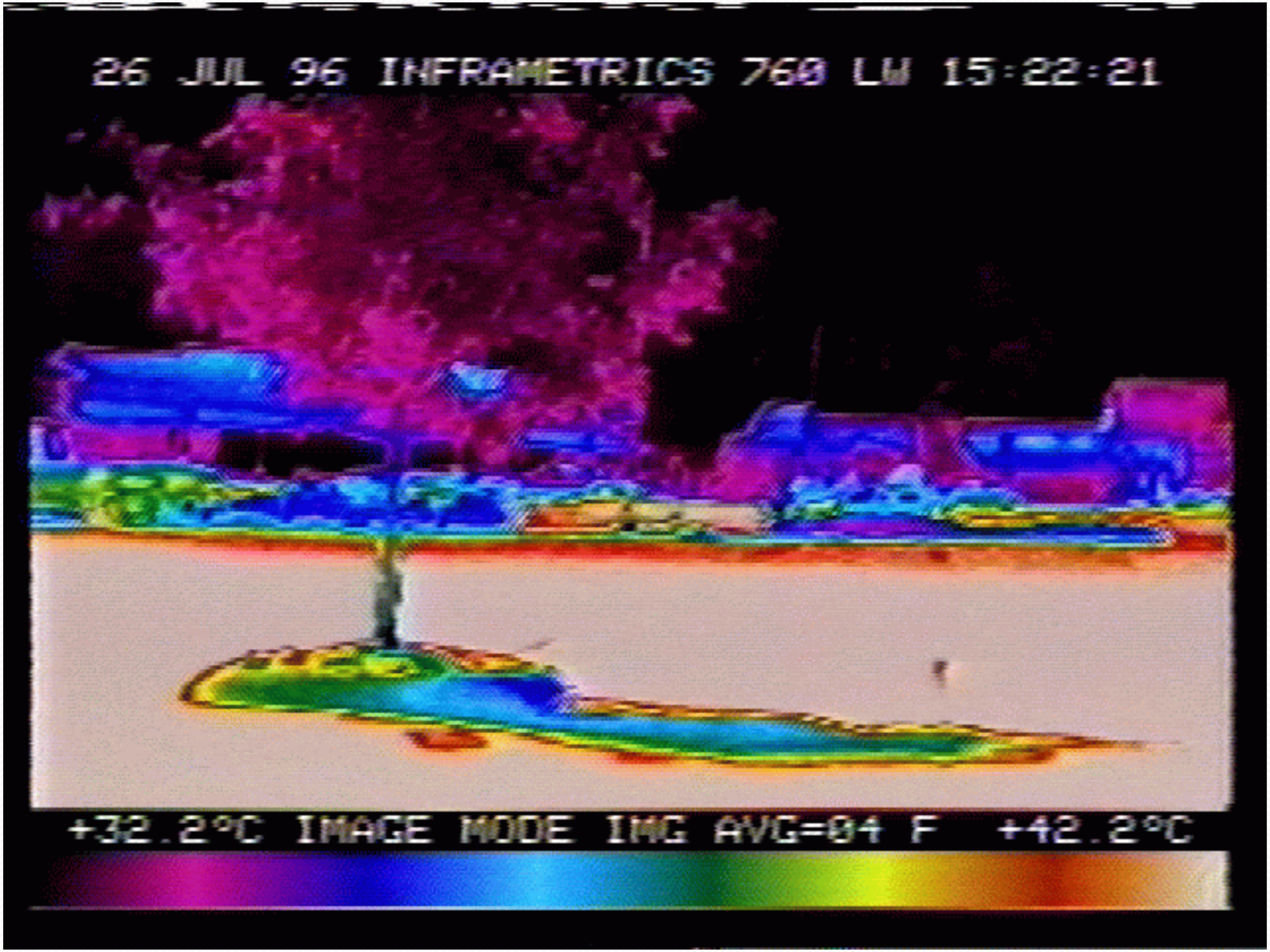
HOT ZONE

High concentrations of buildings, roads and other artificial structures retain heat, leading to warmer temperatures. A NASA snapshot of Houston taken one evening in August 2000 demonstrates this urban heat-island effect: the hot zone downtown stands in sharp contrast to the cooler suburbs to the south

70°F (21°C) — 90°F (32°C)

Source: NASA/Goddard Space Flight Center
TIME diagram by Joe Lertola


Atlanta, GA
1615UT
Atlanta, GA
1645UT
Atlanta, GA
1715UT
Atlanta, GA
1845UT



26 JUL 96 INFRAMETRICS 760 LW 15:22:21
+32.2°C IMAGE MODE IMG AVG=04 F +42.2°C

Surface Radiation Budget

$$Q^* = (K_{in} + K_{out}) + (L_{in} + L_{out})$$

Q^* = Net Radiation

K_{in} = Incoming Solar

K_{out} = Reflected Solar

L_{in} = Incoming Longwave

L_{out} = Emitted Longwave

Surface Energy Budget

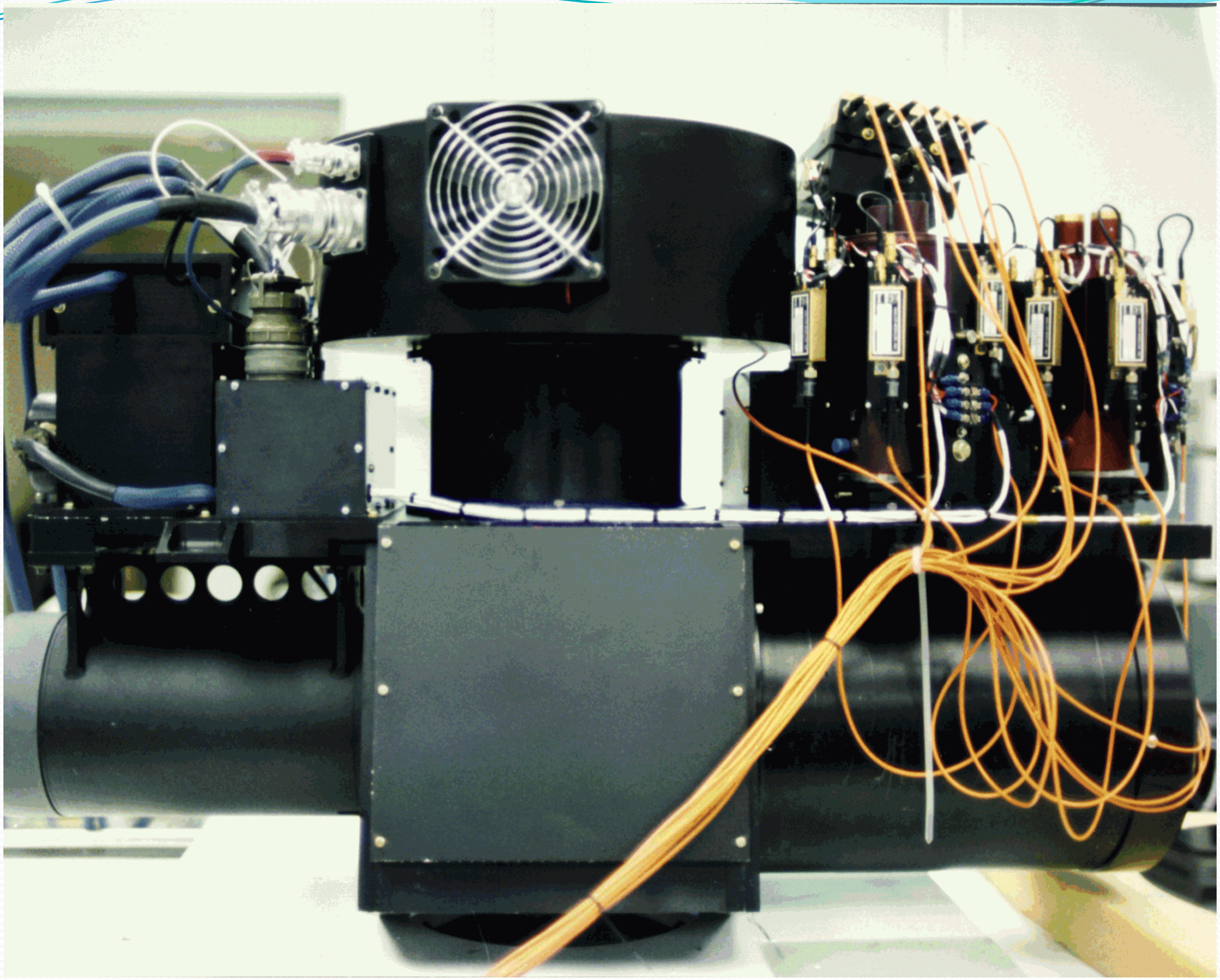
$$Q^* = H + LE + G$$

H = Sensible Heat Flux

LE = Latent Heat Flux

G = Storage (maybe + or -)

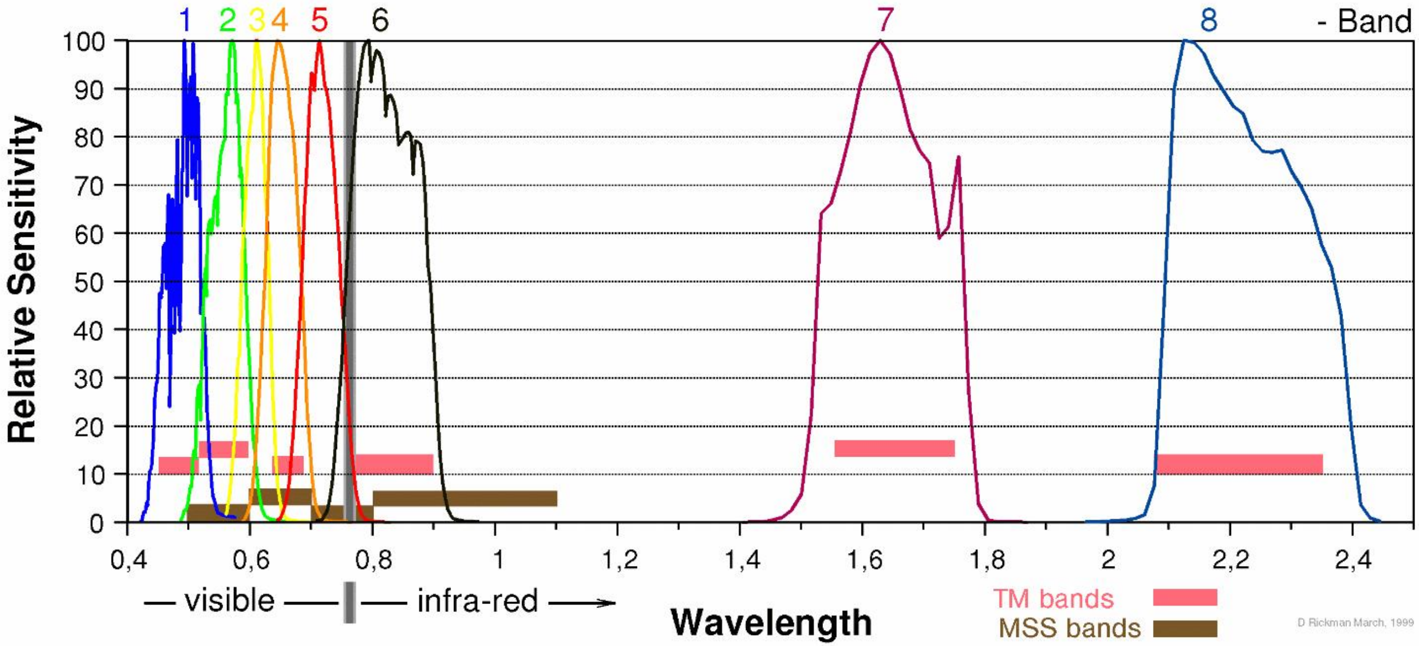

NASA
N933NA



ATLAS

Typical Spectral Response Curves

Reflected Bands

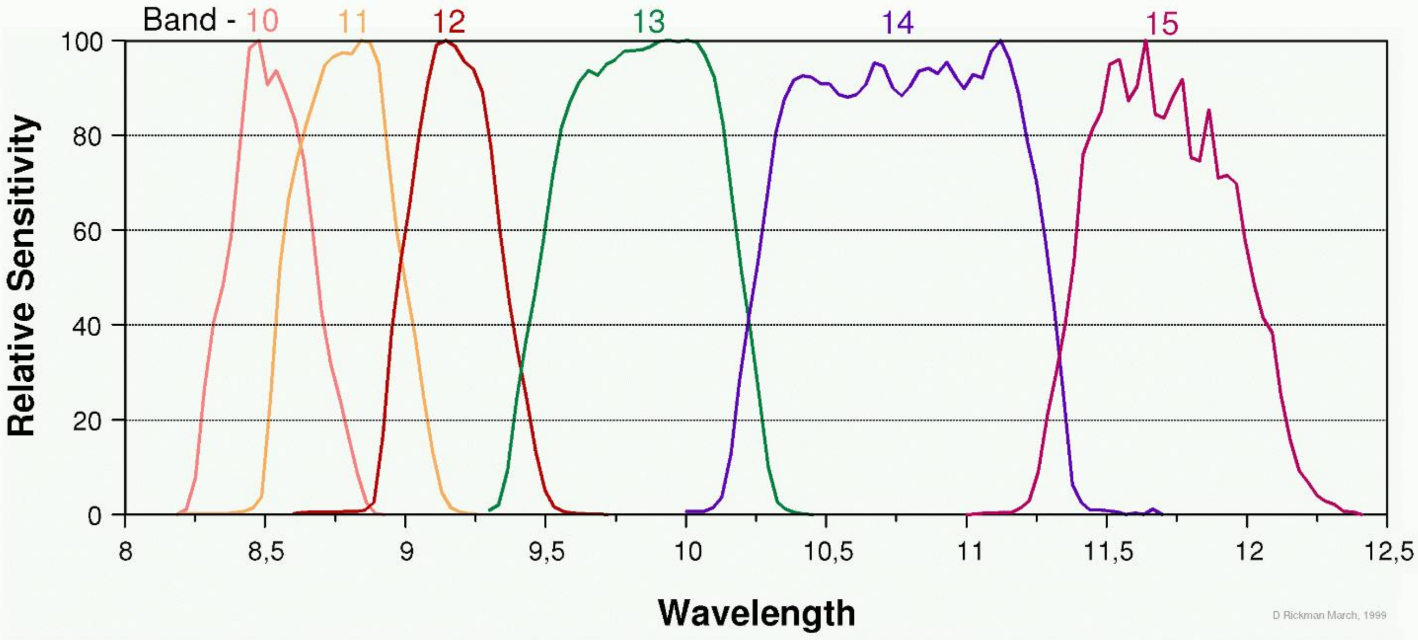


D. Rickman, et al., Nov. 9,1999

ATLAS

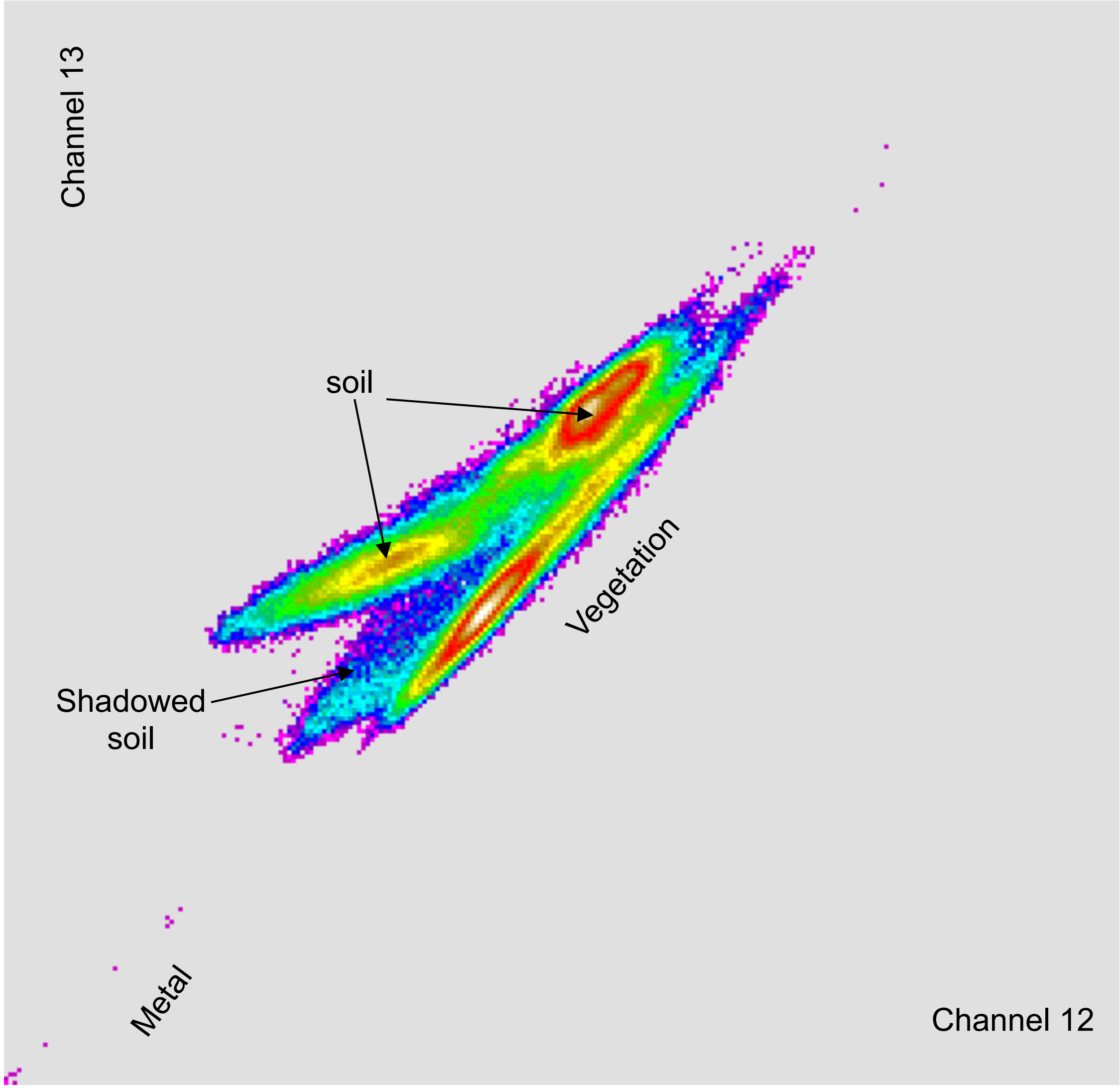
Typical Spectral Response Curves

Thermal Bands



D. Rickman, et al., Nov. 9,1999

Emissivity Differences in Natural Surfaces



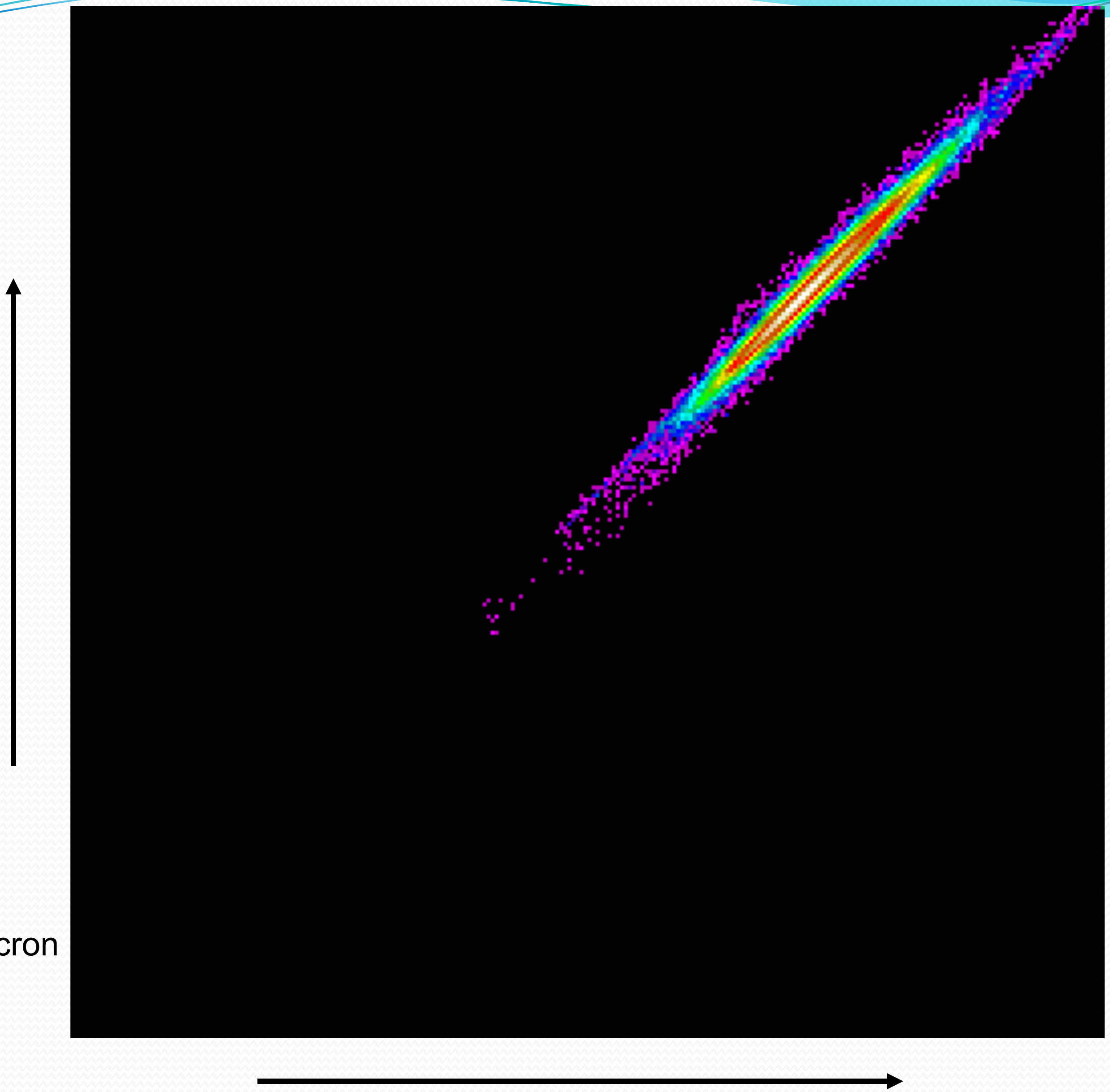
W m^{-2} micron^{-1} sr^{-1}

W m^{-2} micron^{-1} sr^{-1}

Increasing energy

San Juan

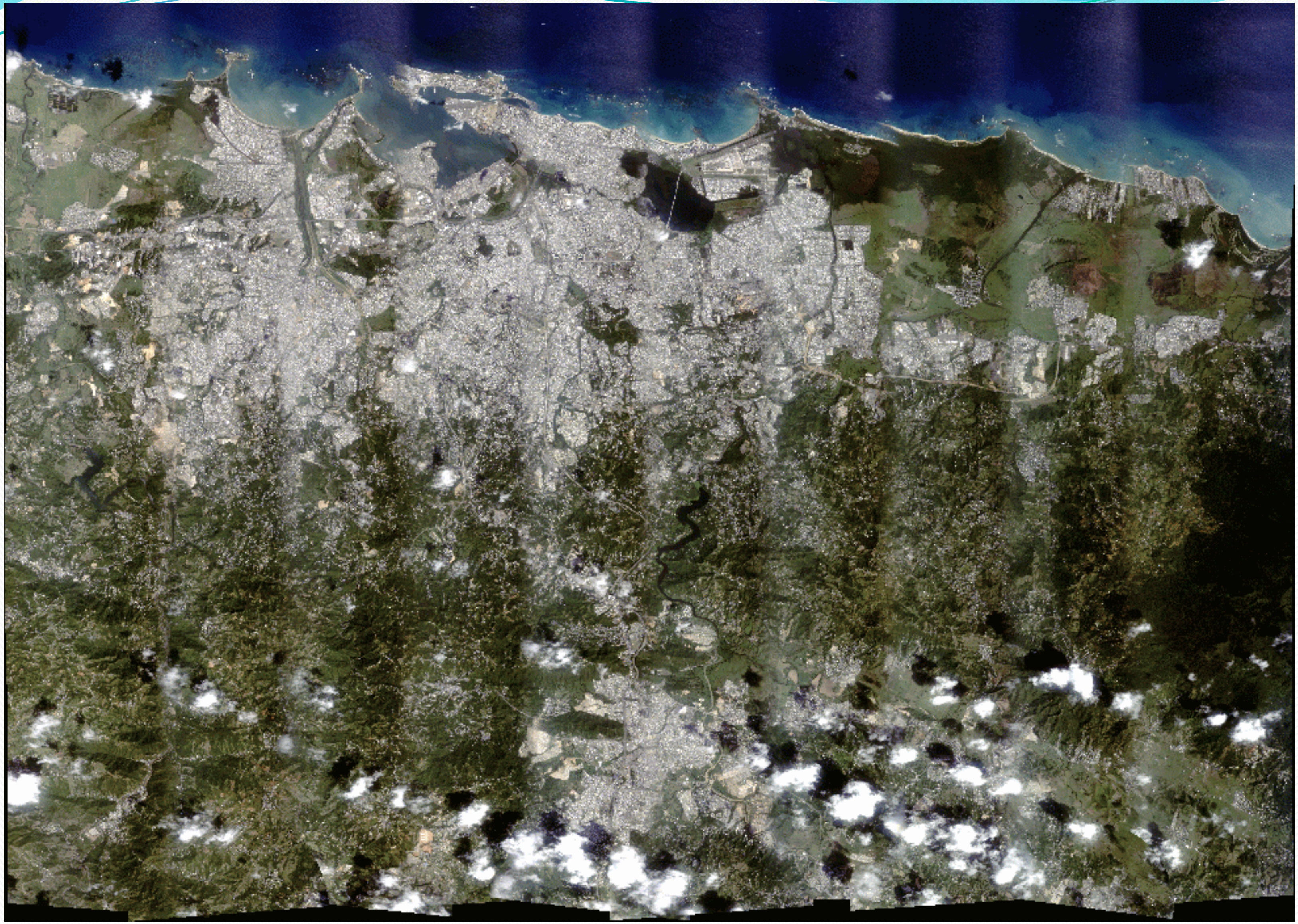
CH 10 vs CH 11



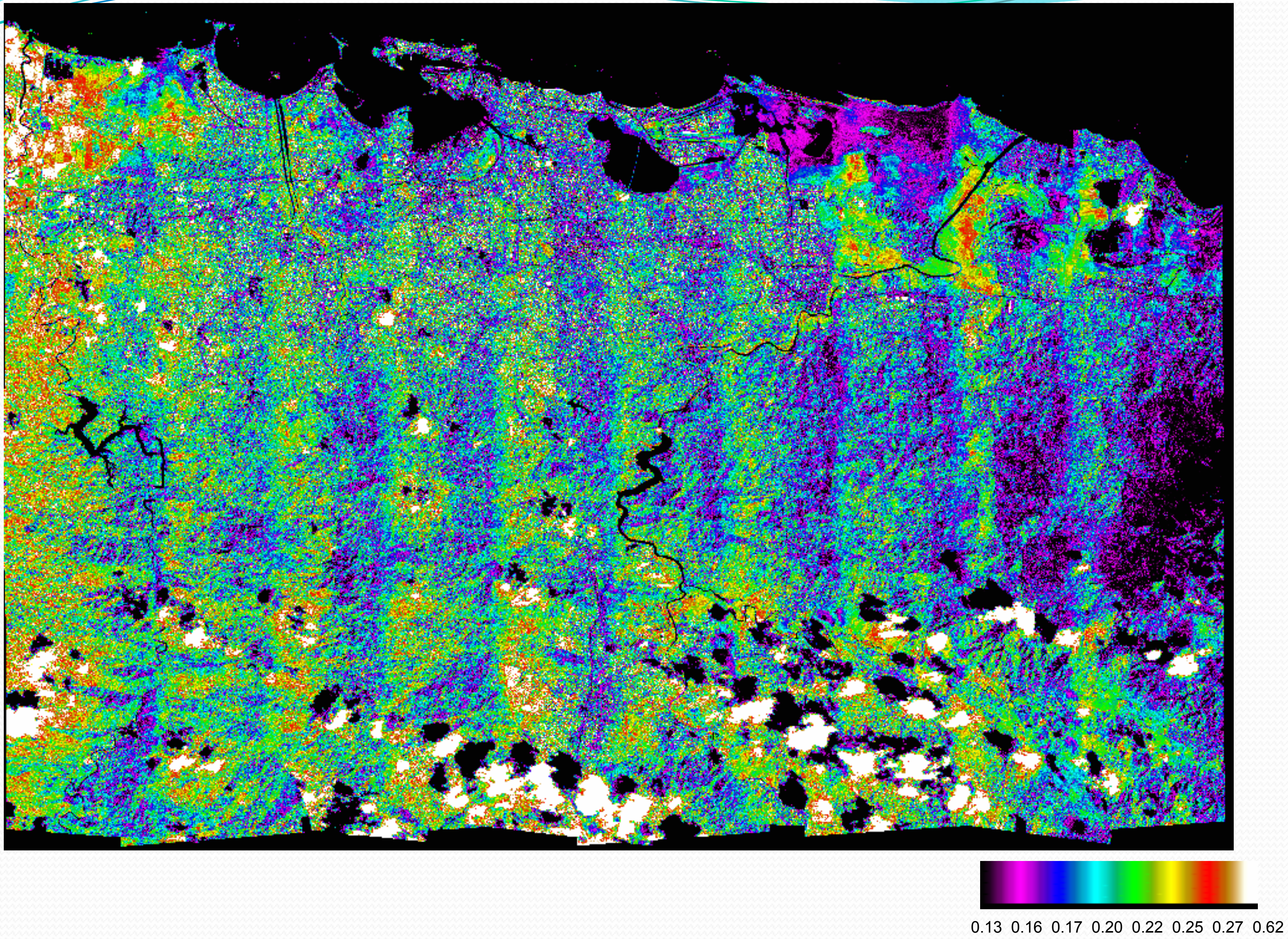
Energy

W m-2 sr-1 micron

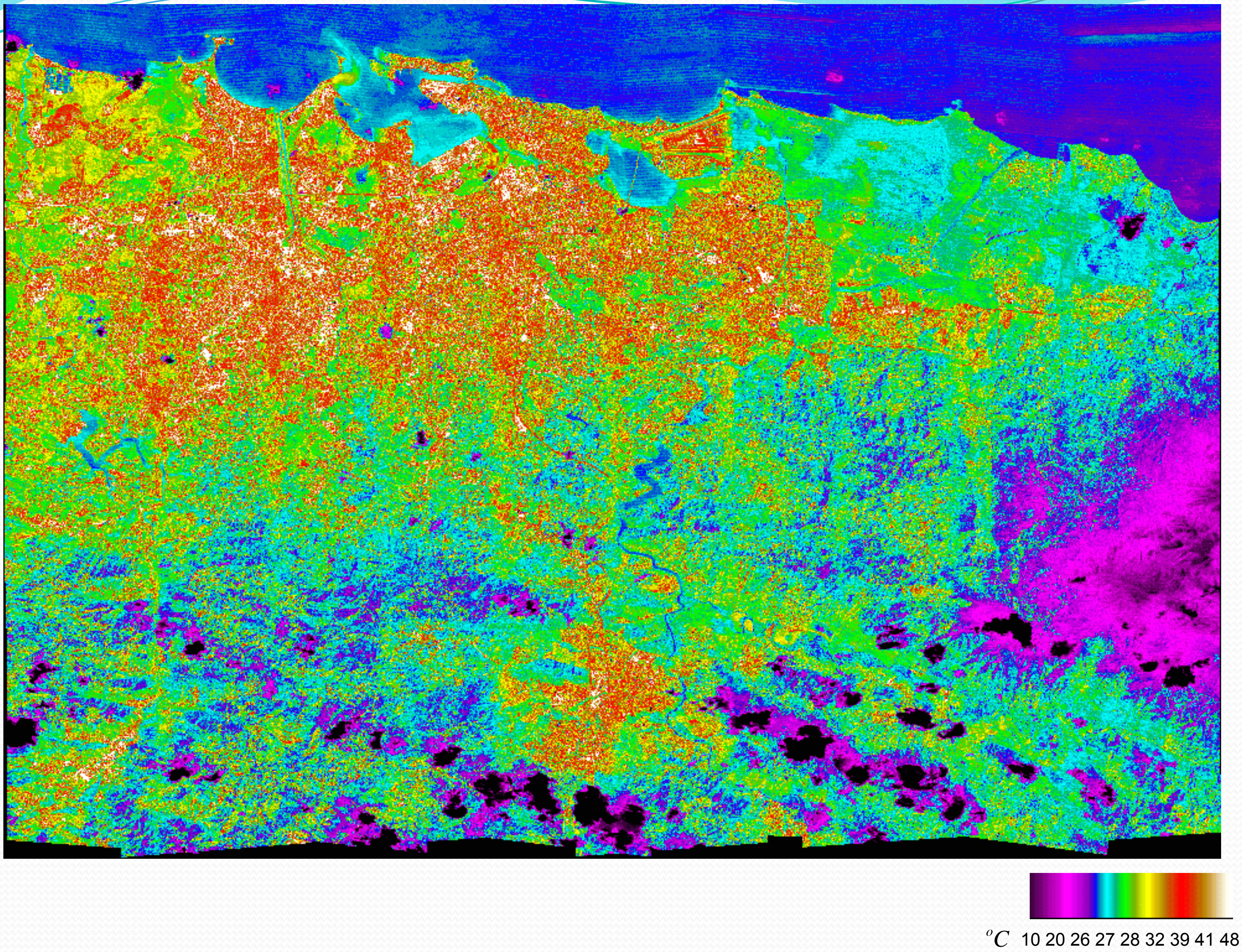
San Juan F5 Mosaic True Color

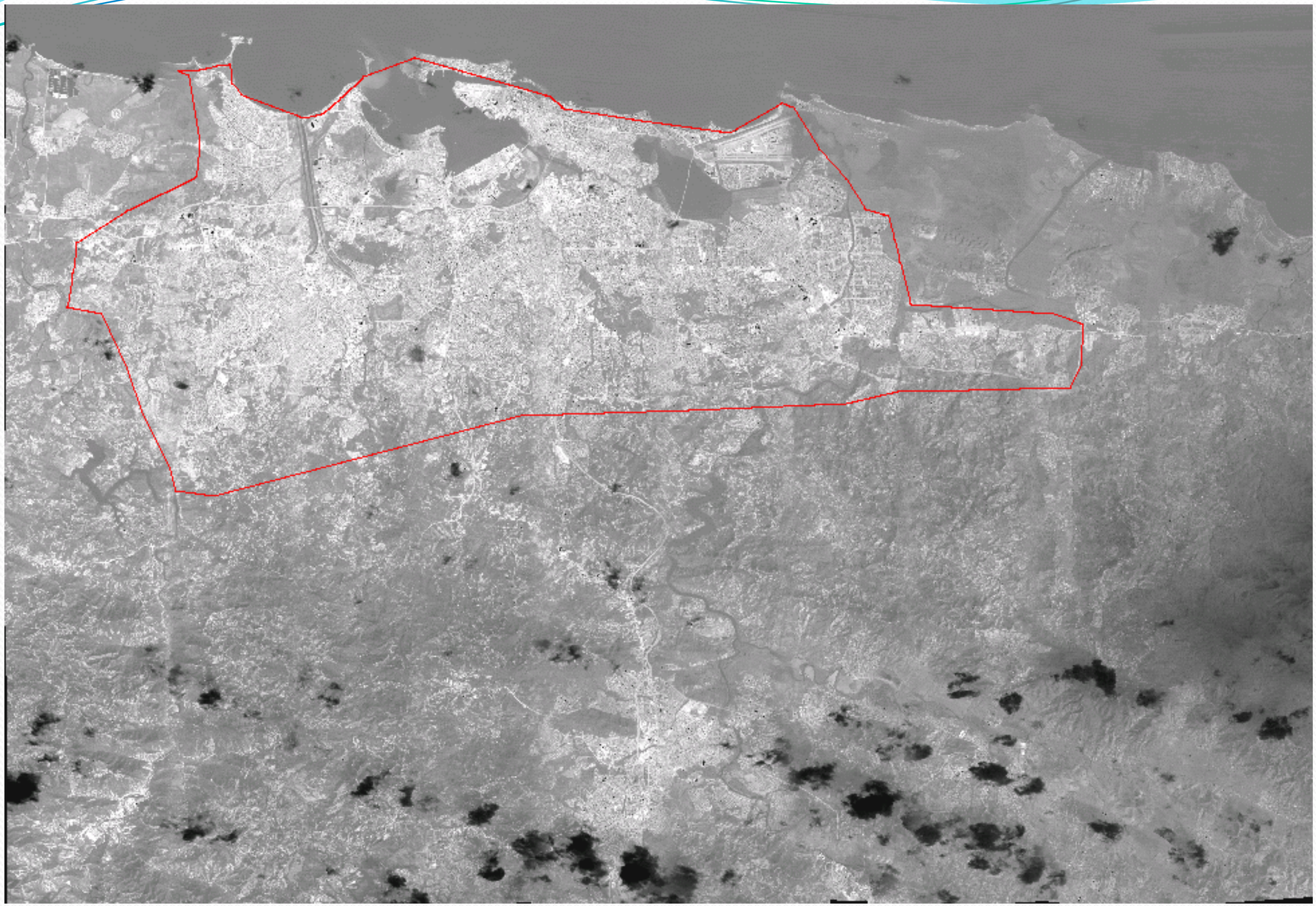


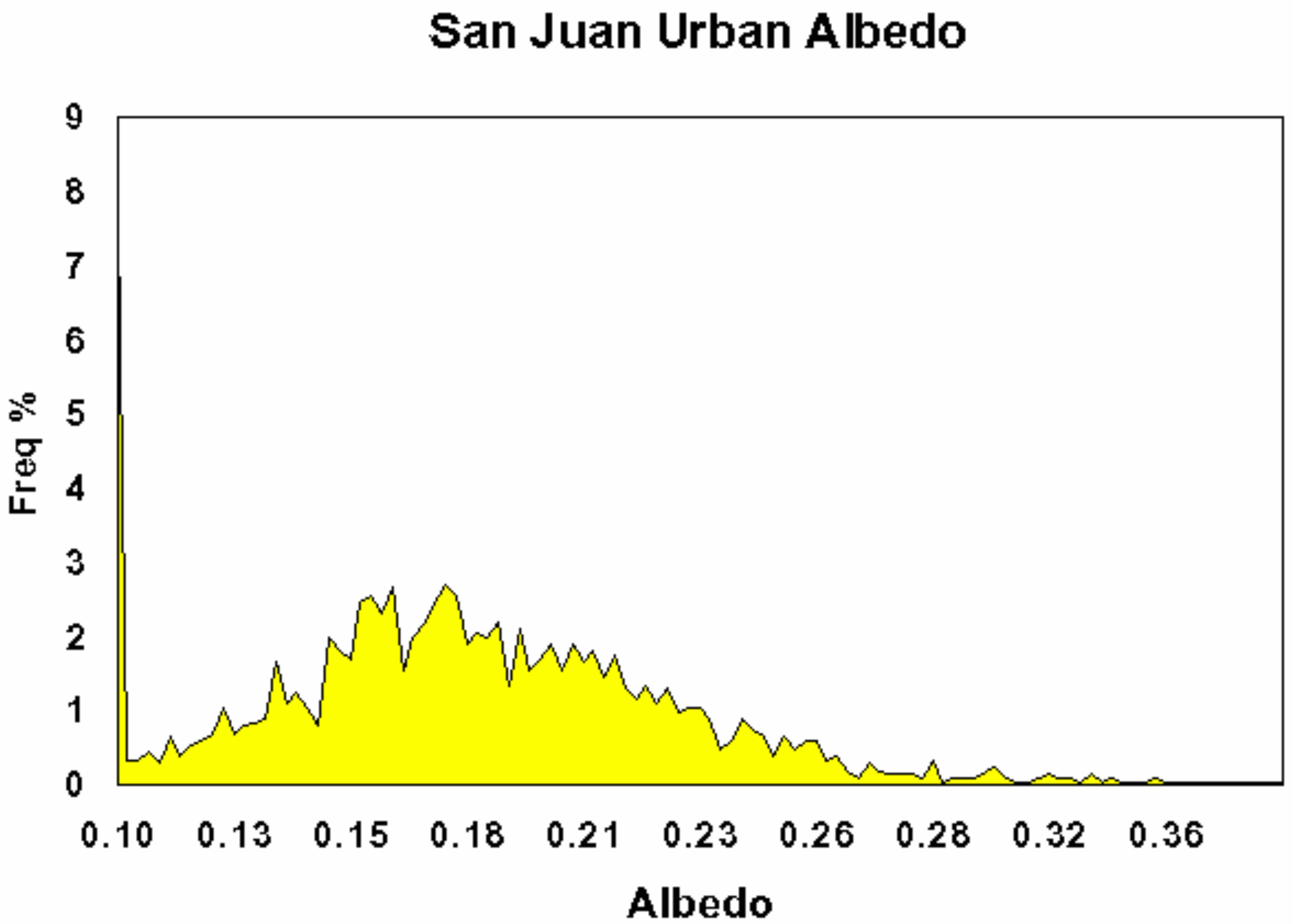
San Juan F5 Mosaic Albedo

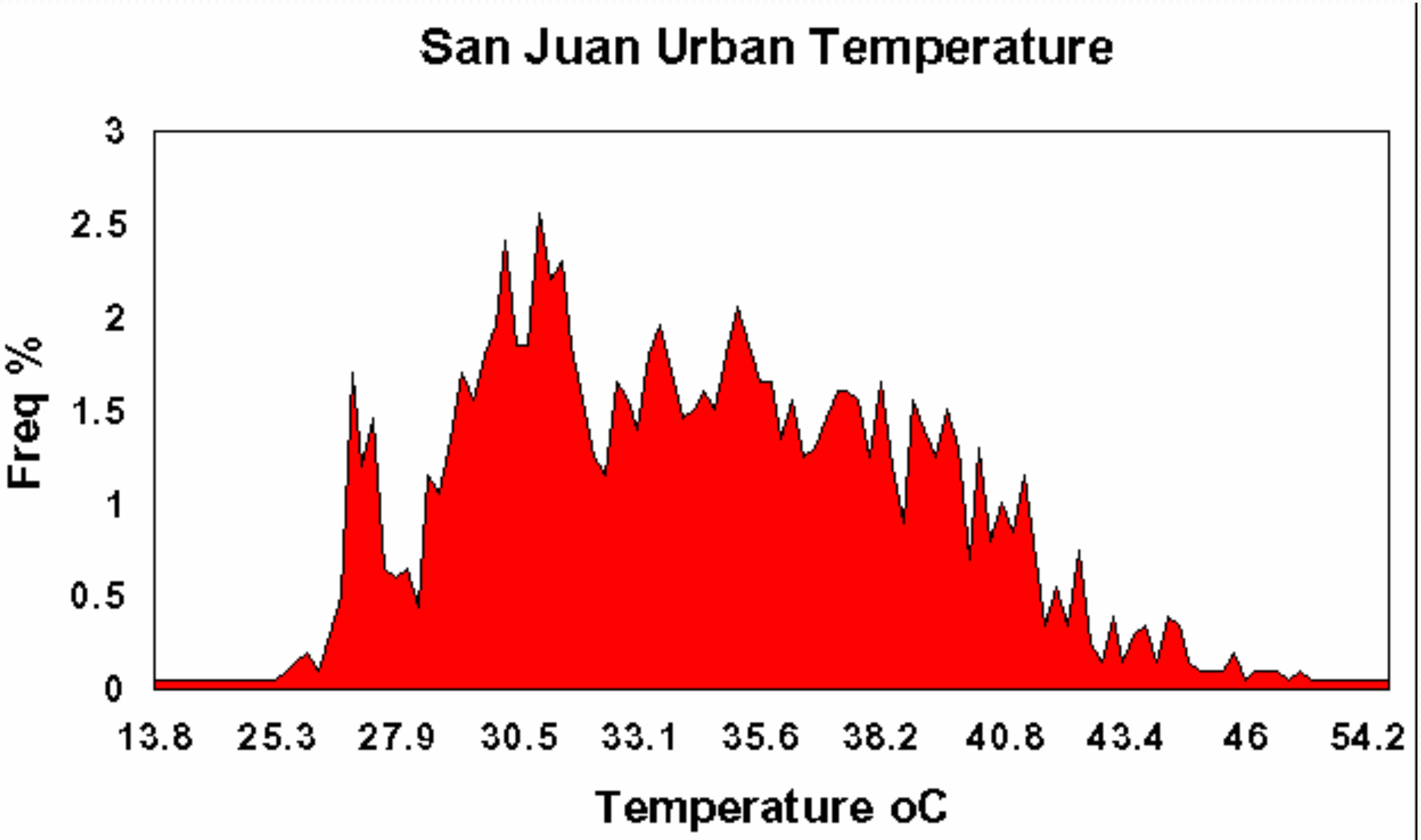


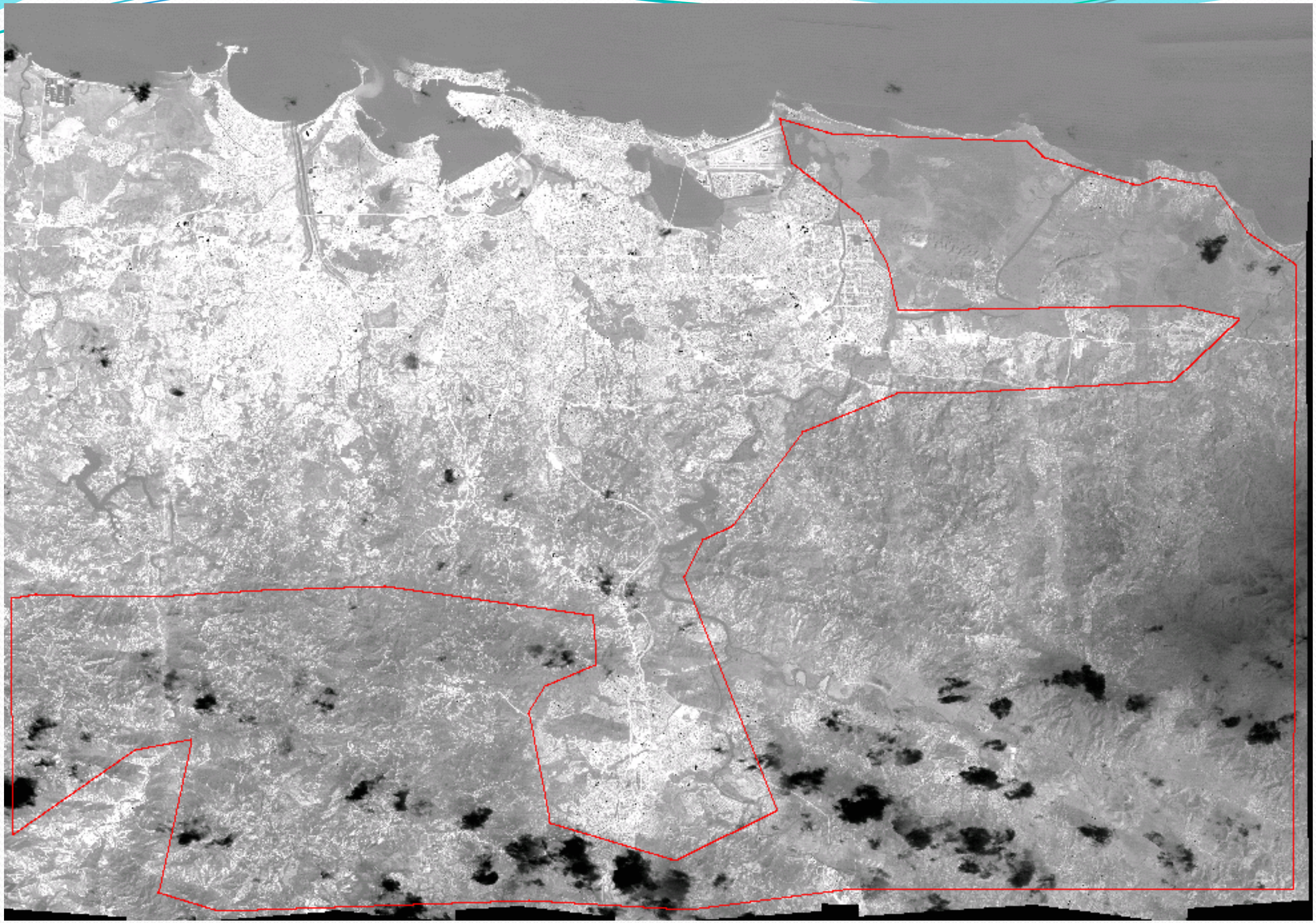
San Juan F5 Mosaic Temperature

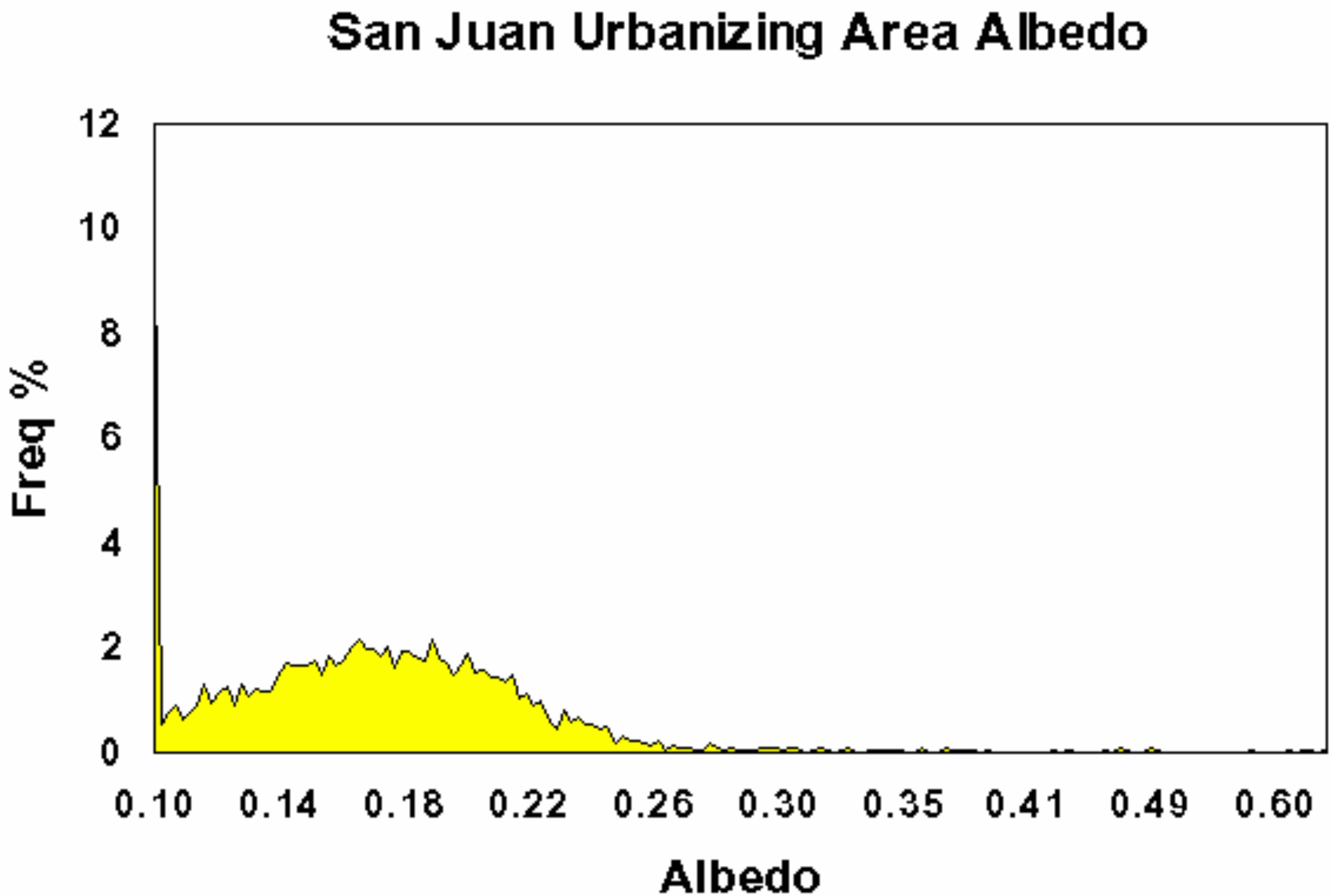


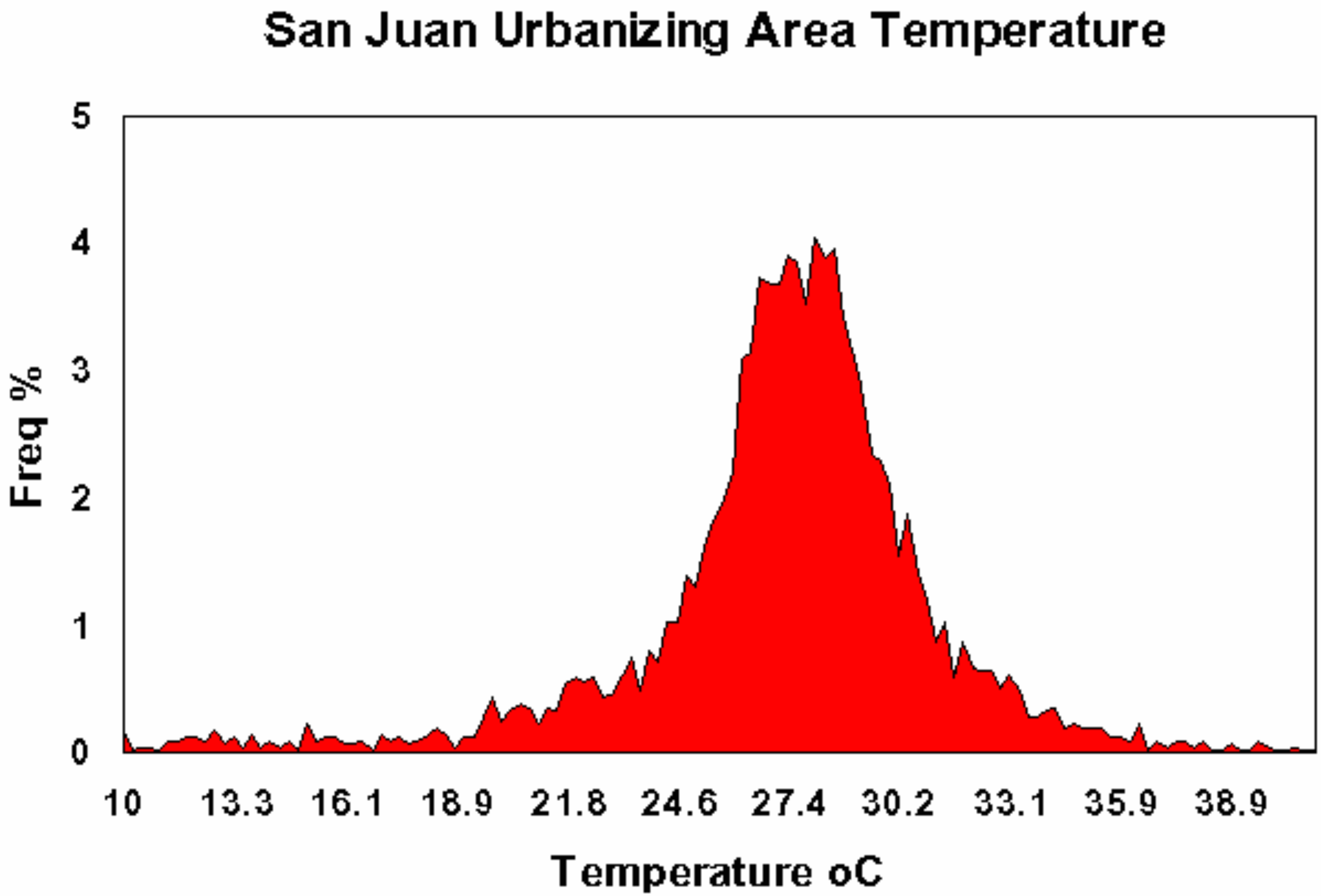



San Juan Urban Albedo
Freq %
9
8
7
6
5
4
3
2
1
0
0.10
0.13
0.15
0.18
0.21
0.23
0.26
0.28
0.32
0.36
Albedo

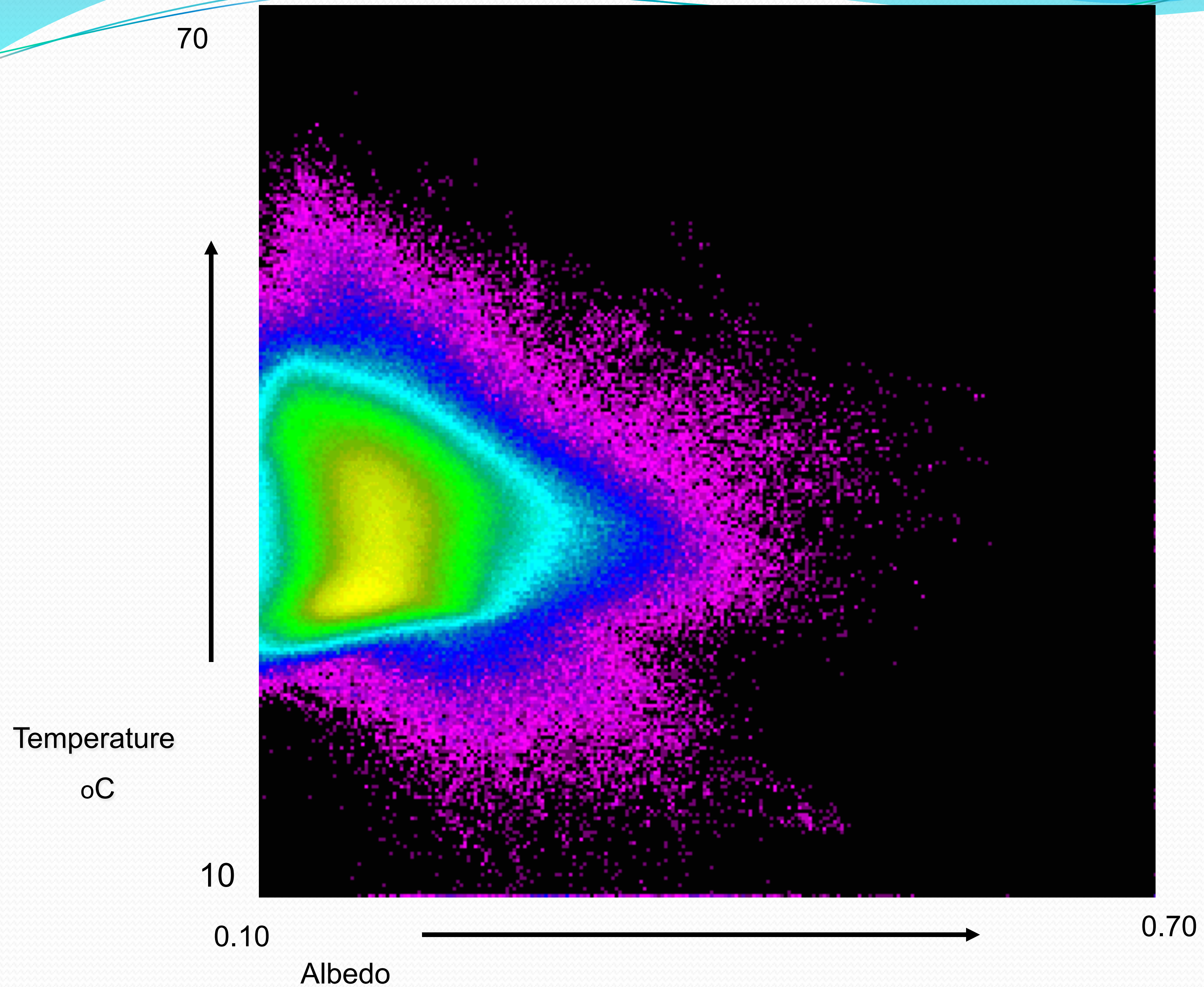

San Juan Urban Temperature
3
2.5
2
1.5
1
0.5
0
Freq %
13.8
25.3
27.9
30.5
33.1
35.6
38.2
40.8
43.4
46
54.2
Temperature oC



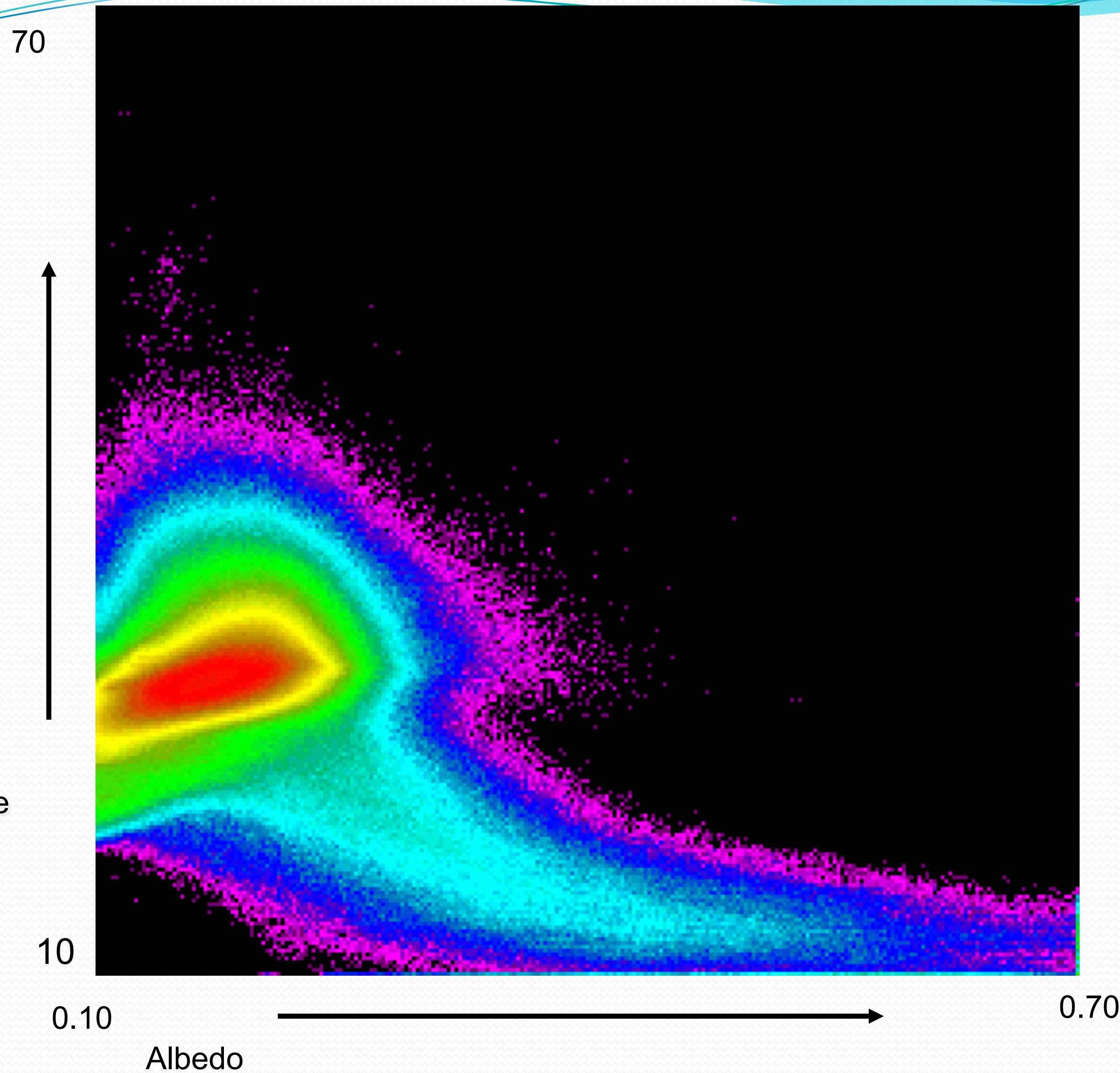

San Juan Urbanizing Area Albedo
12
10
8
6
4
2
0
Freq %
0.10
0.14
0.18
0.22
0.26
0.30
0.35
0.41
0.49
0.60
Albedo


San Juan Urbanizing Area Temperature
Freq %
0
1
2
3
4
5
10
13.3
16.1
18.9
21.8
24.6
27.4
30.2
33.1
35.9
38.9
Temperature oC

San Juan Puerto Rico
Albedo vs Temperature

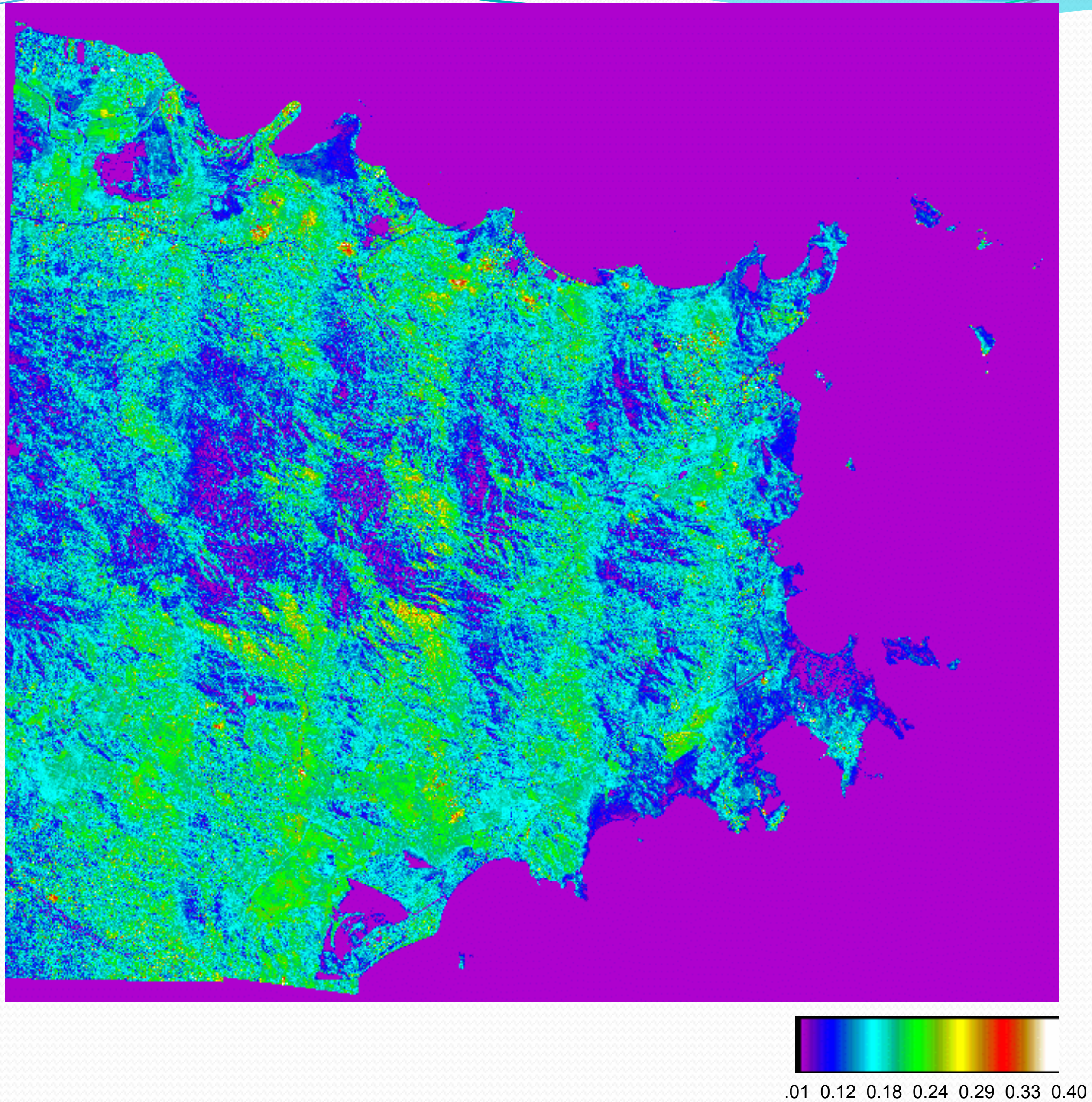


San Juan Puerto Rico Urbanizing Area
Albedo vs Temperature

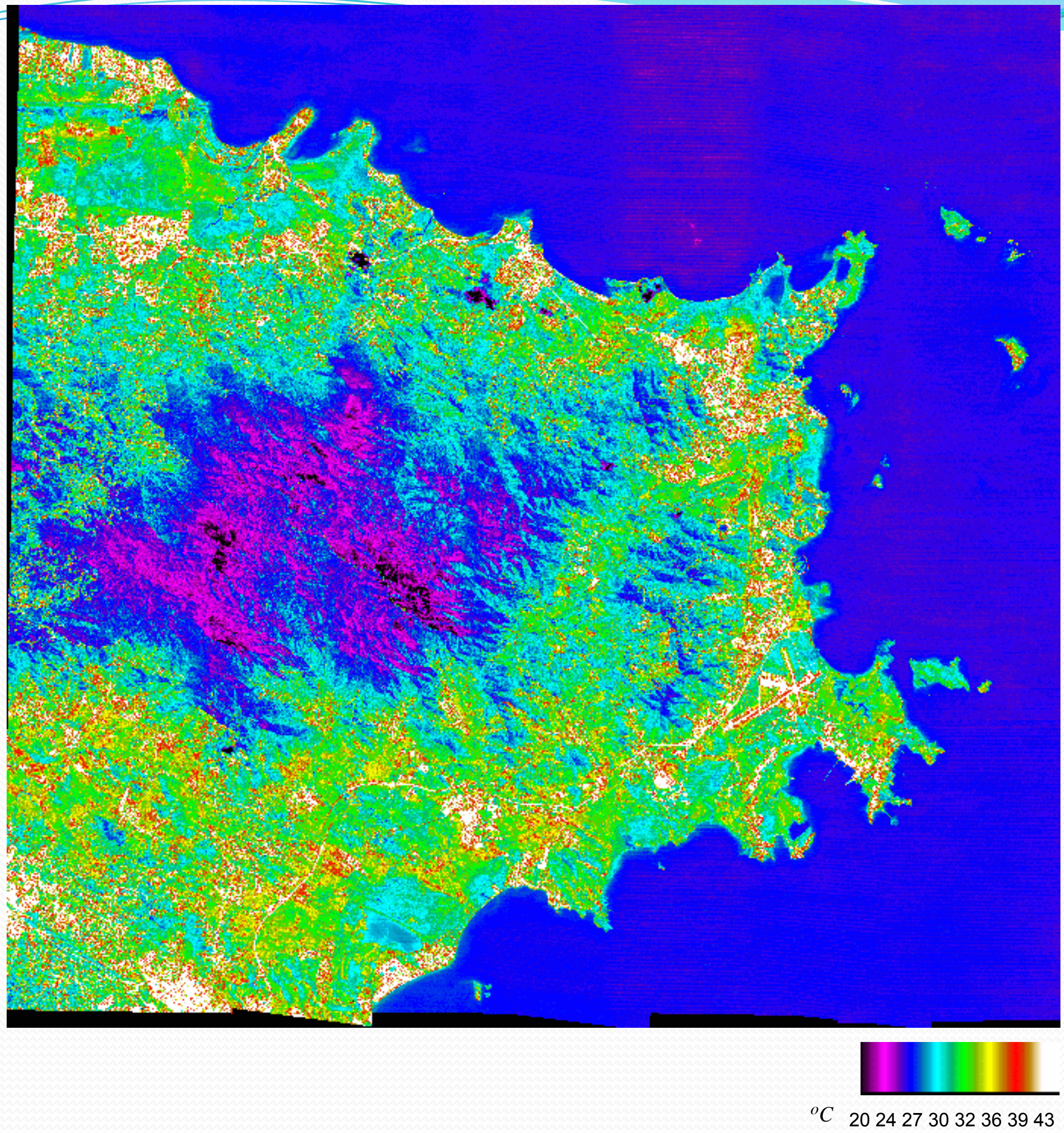


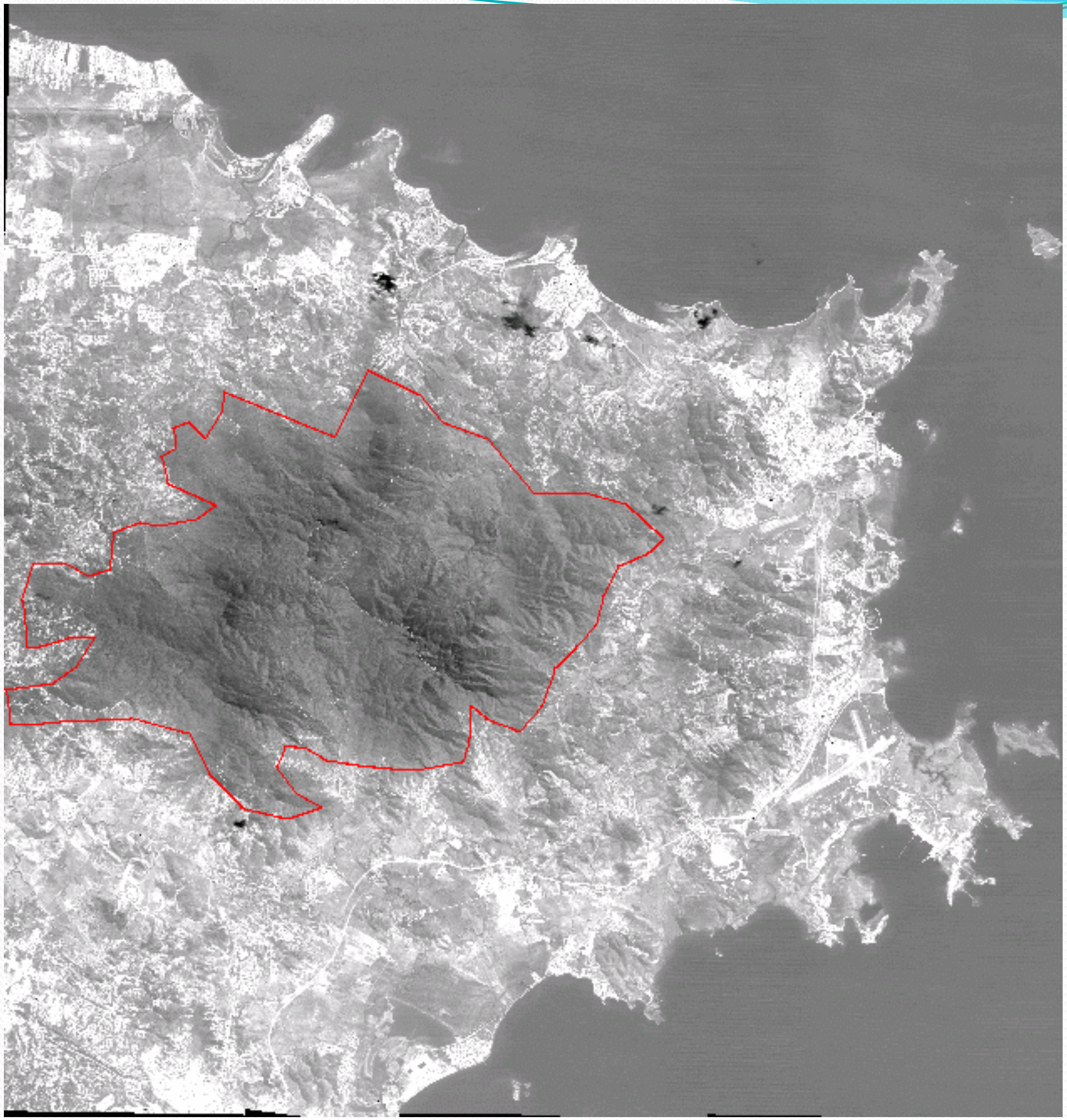
El Yunque F4 Mosaic True Color

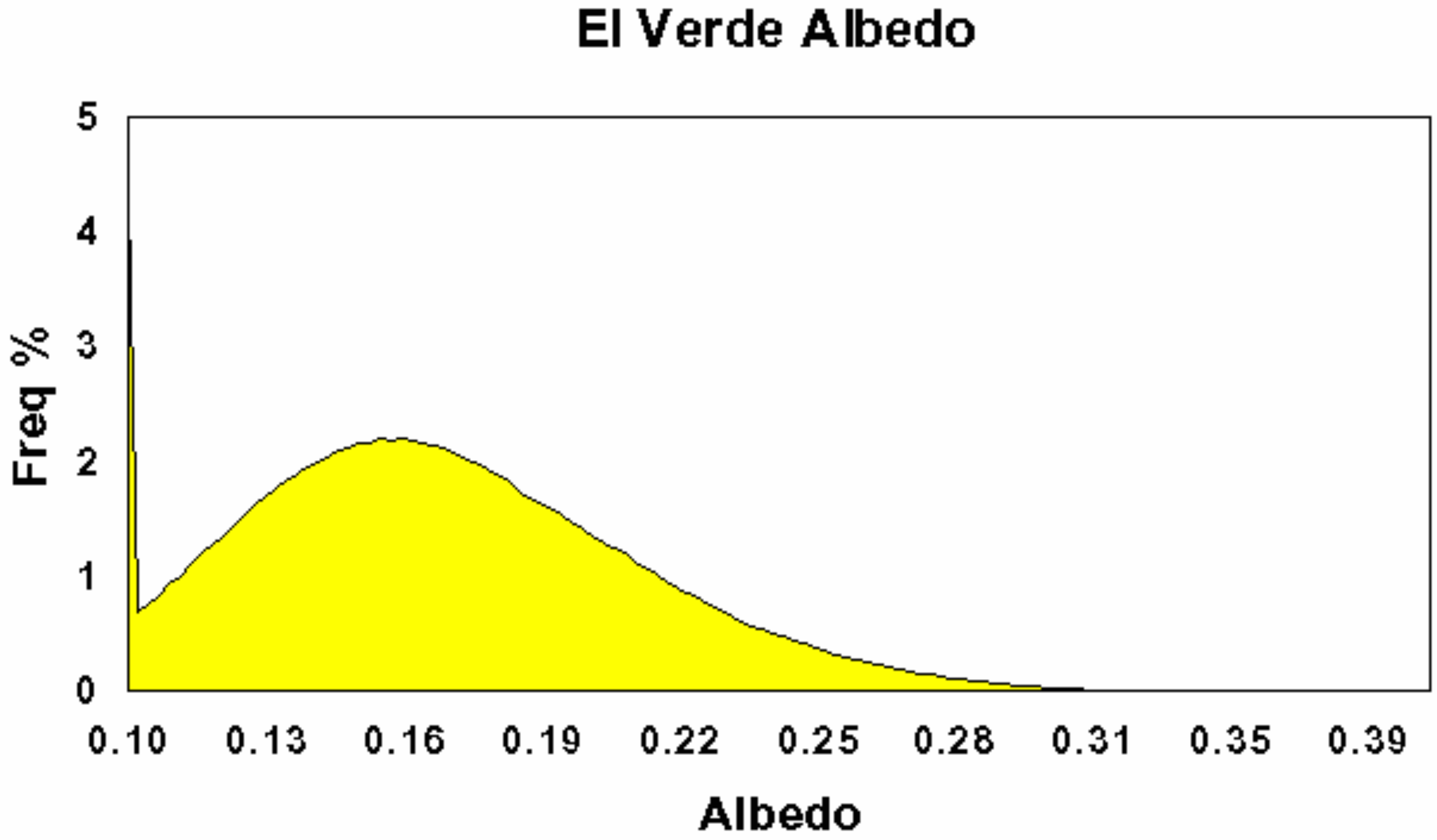
El Yunque F4 Mosaic Albedo

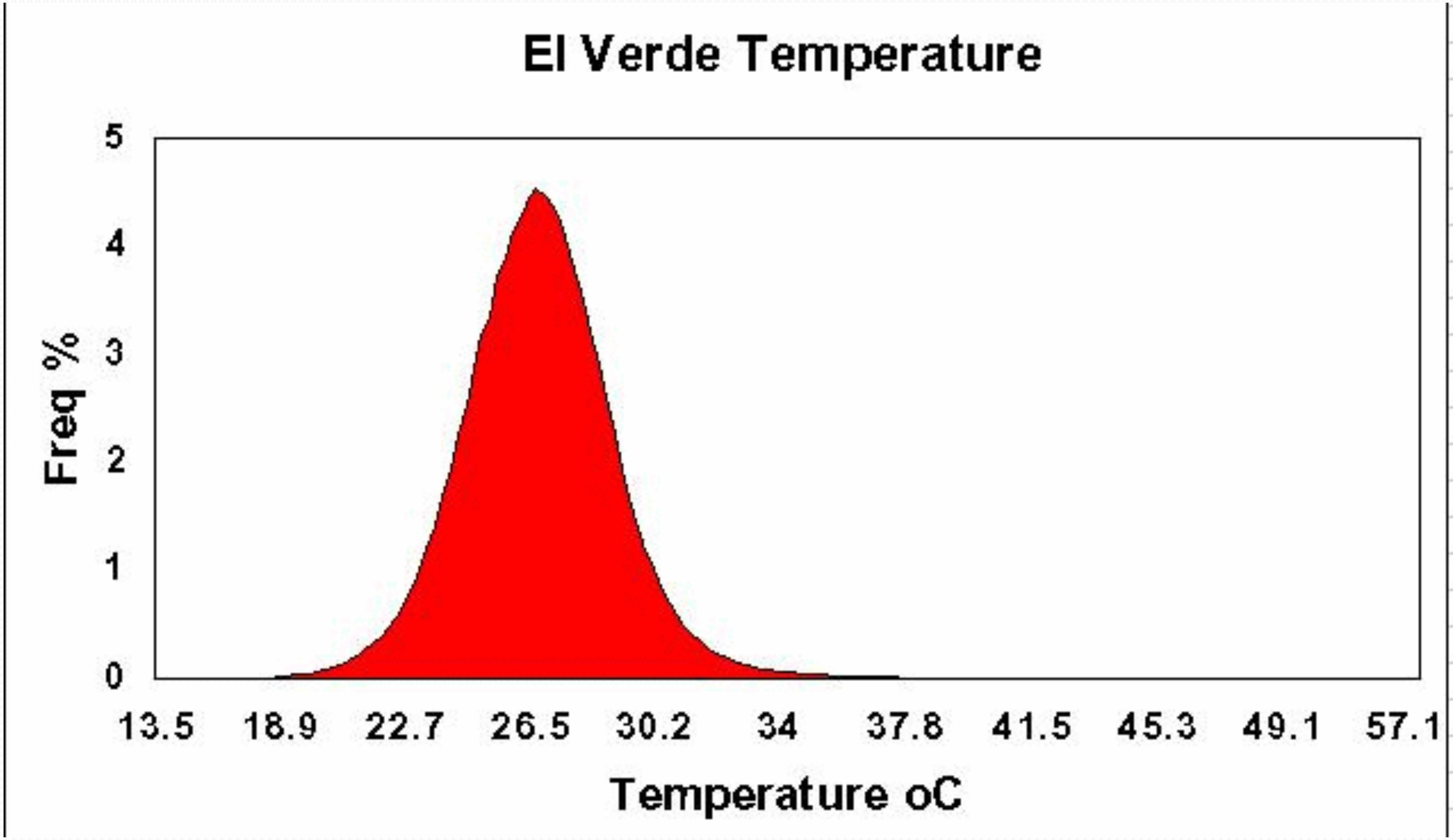


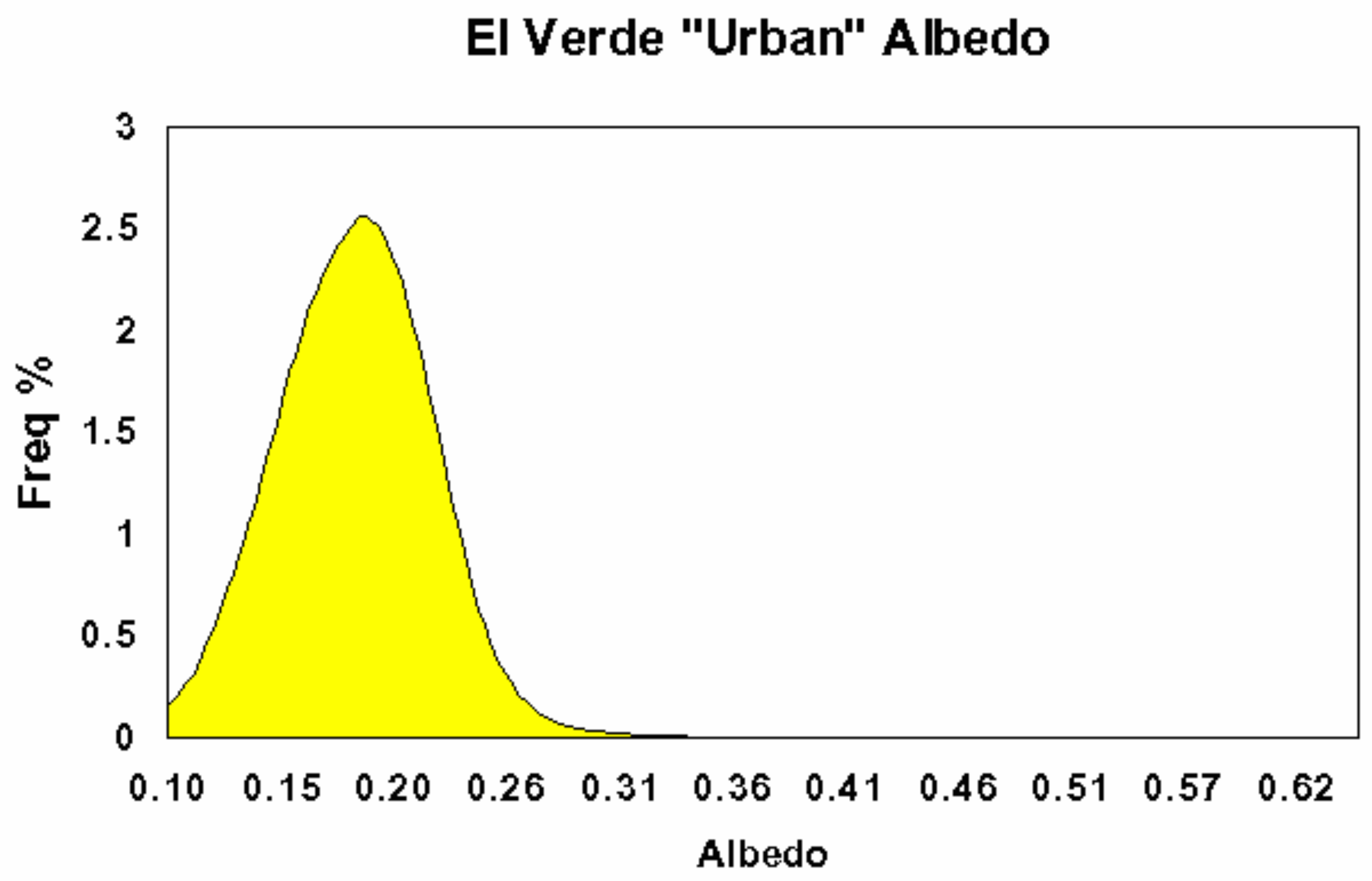
El Yunque F4 Mosaic Temperature

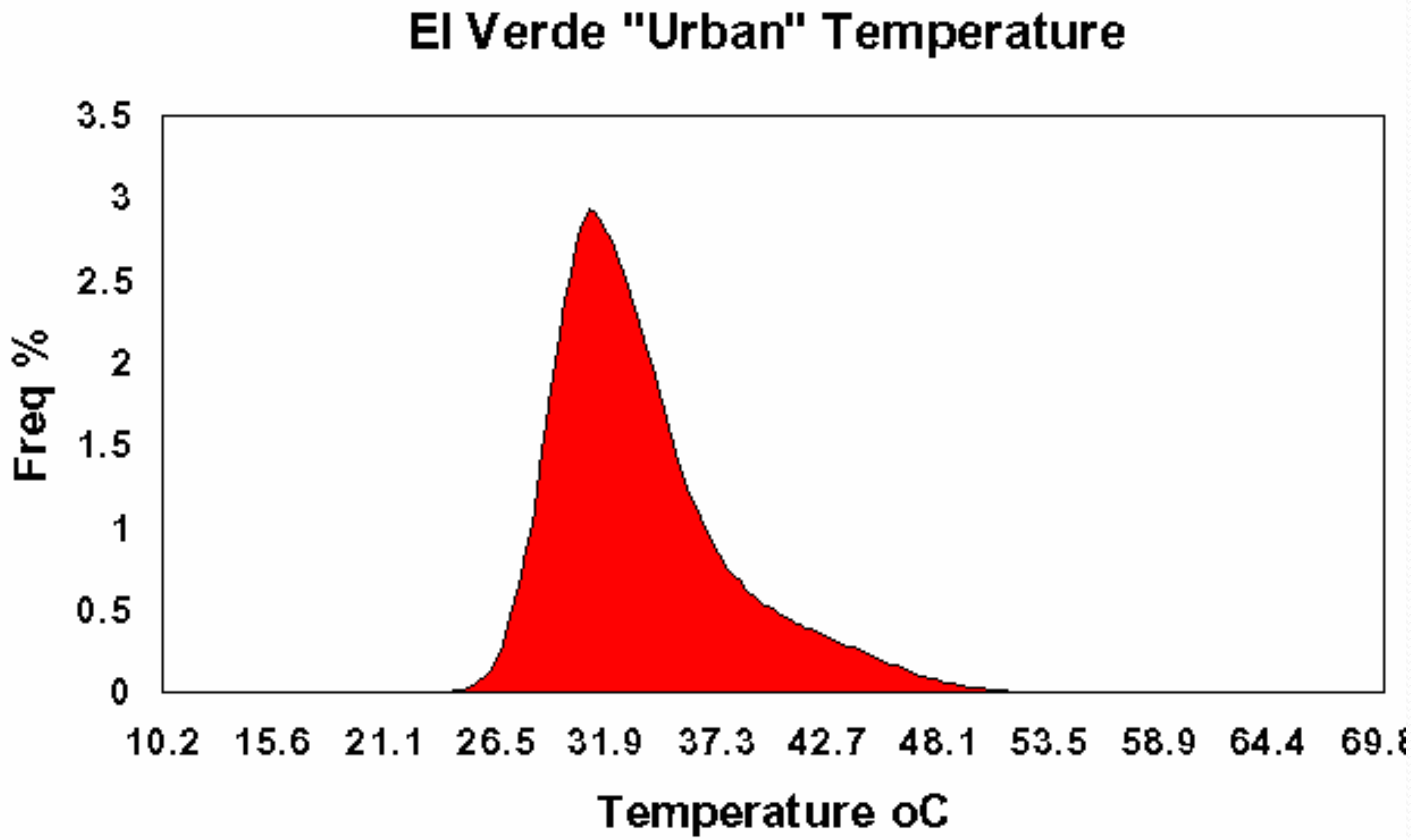




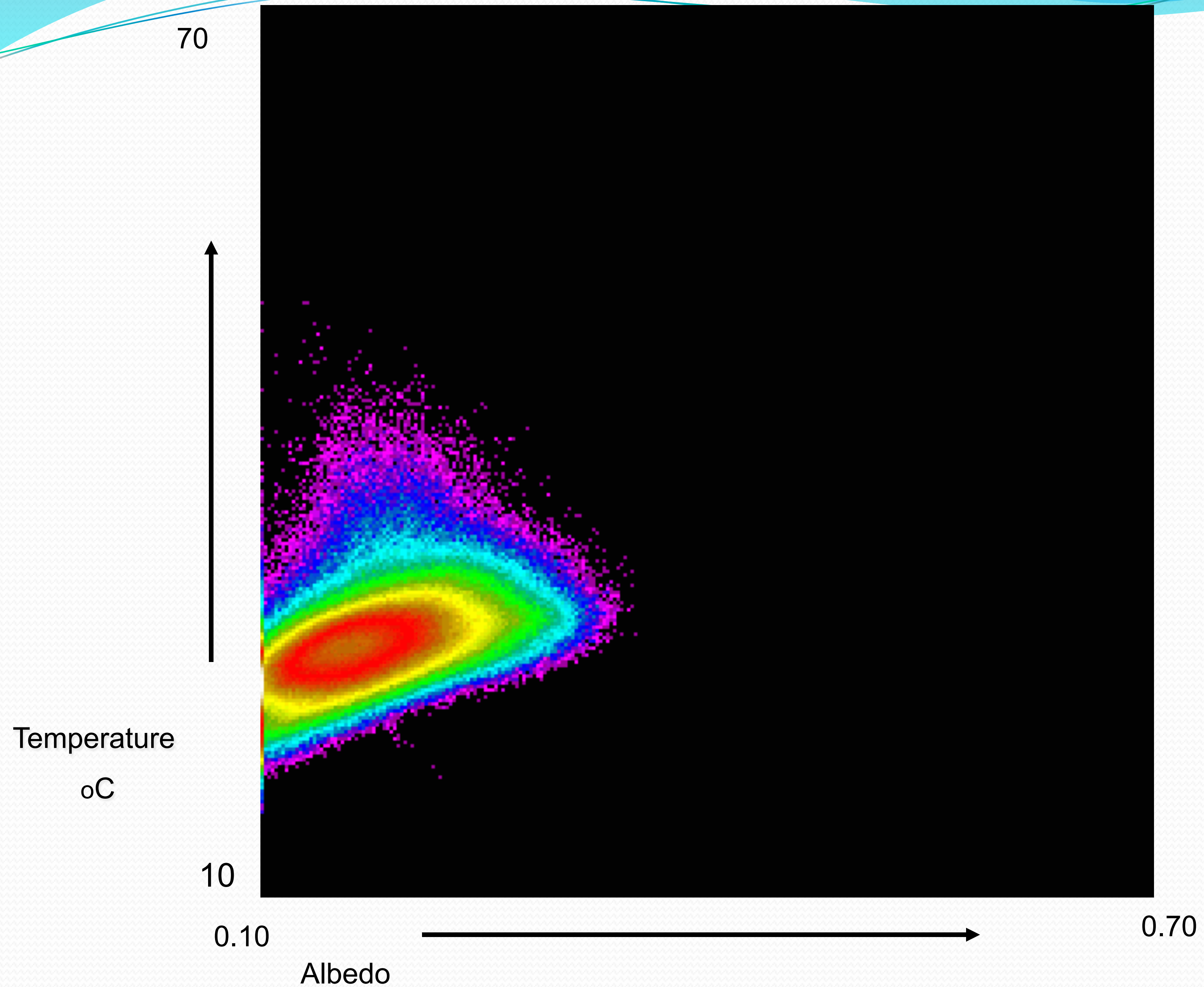

El Verde Albedo
5
4
3
2
1
0
Freq %
0.10
0.13
0.16
0.19
0.22
0.25
0.28
0.31
0.35
0.39
Albedo


El Verde Temperature
Freq %
5
4
3
2
1
0
13.5
18.9
22.7
26.5
30.2
34
37.8
41.5
45.3
49.1
57.1
Temperature oC


El Verde "Urban" Albedo
Freq %
3
2.5
2
1.5
1
0.5
0
0.10
0.15
0.20
0.26
0.31
0.36
0.41
0.46
0.51
0.57
0.62
Albedo


El Verde "Urban" Temperature
Freq %
3.5
3
2.5
2
1.5
1
0.5
0
10.2
15.6
21.1
26.5
31.9
37.3
42.7
48.1
53.5
58.9
64.4
Temperature oC

El Yunque
Albedo vs Temperature



Urban Heat Island Mitigation Pilot Project

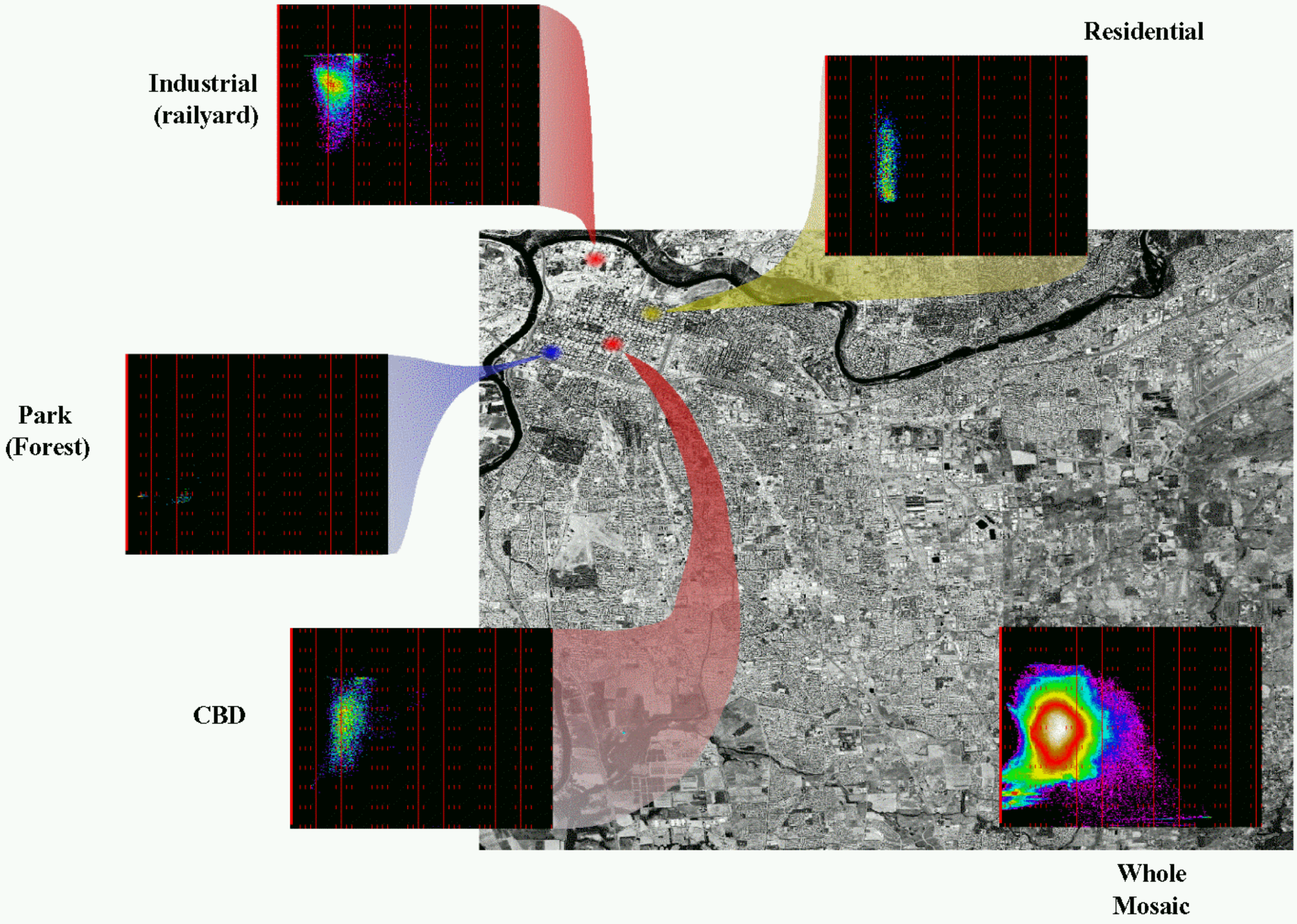
EPA/NASA Marshall Space Flight Center

Jeffrey C. Luvall
Dale Quattrochi
Maury Estes
Doug Rickman

Urban Heat Island Mitigation Strategies

- Albedo Modification
  - Lighter colored roofs and pavements
  - New materials/coatings
- Plant trees and increase green space
  - Shade buildings, rooftops, parking lots and roads
  - Cool the air through transpiration
- Rooftop gardens
  - Keep roofs cool by shading and/or transpiration
  - storm water reduction

Sacramento Skattergrams
Albedo vs Temperature



Climate Impacts of Land Cover and Land Use Changes in Tropical Islands under Conditions of Global Climate Change. Daniel E. Comarazamy, J. E. González, J.C. Luvall, D. L. Rickman, & R. D. Bornstein. *In Press*

A Land–Atmospheric Interaction Study in the Coastal Tropical City of San Juan, Puerto Rico

Daniel E. Comarazamy, J. E. González, J. C. Luvall, D. L. Rickman, and P. J. Mulero

Earth Interactions

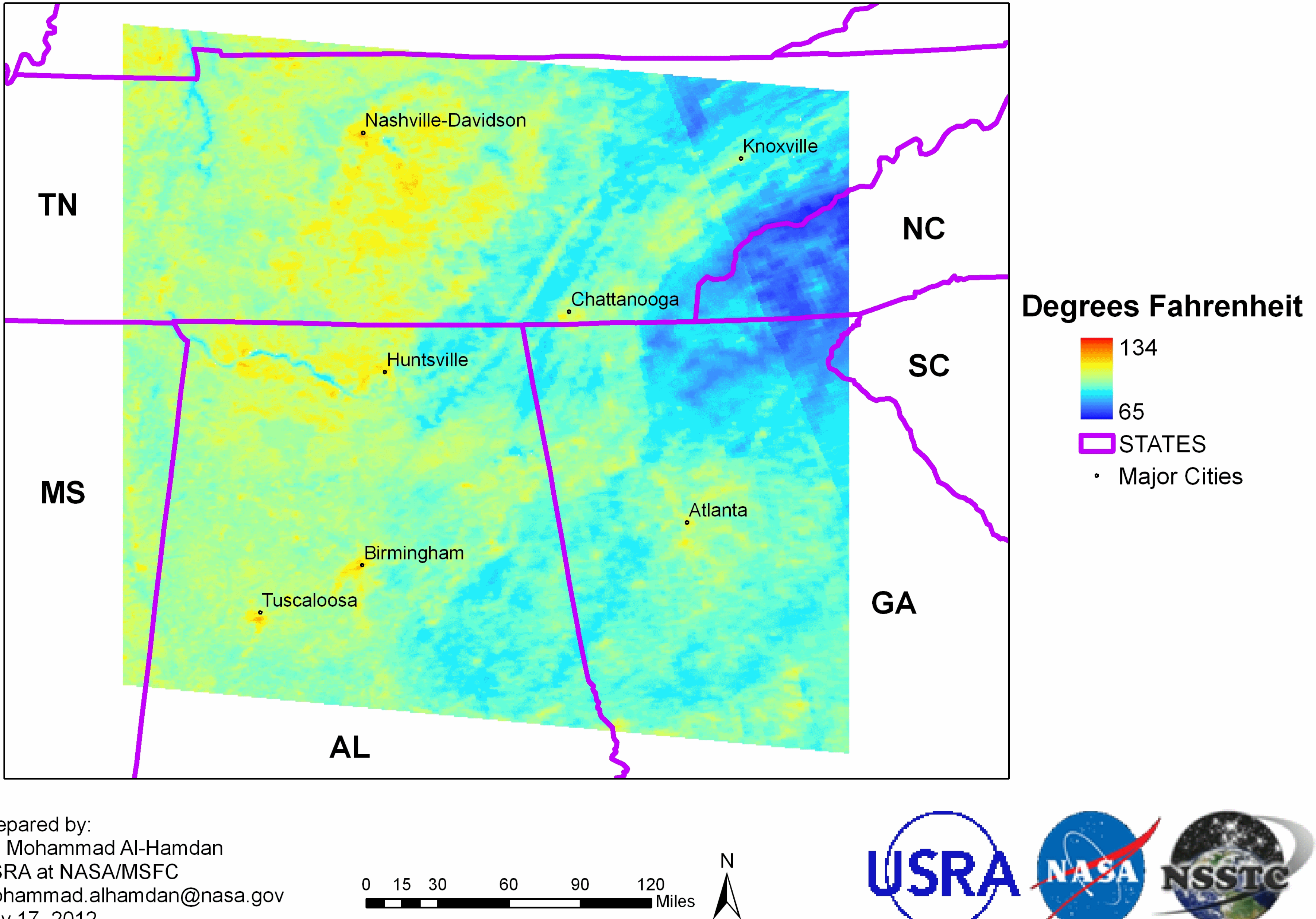
Volume 14, Issue 16 (November 2010) pp. 1-24

What can HyspIRI data provide for urban heat island research and applications ?

- Scale consistent with complex urban surfaces
- Well calibrated data allows quantifiable radiative & energy budgets:
    - Analysis of albedo
    - Analysis of surface temperature
    - Analysis of emissivity
- Scale consistent to plan alteration of the urban fabric to mitigate the urban heat island
- Swath width scale for urban climatology studies - urbanization of RAMS.
- Global cities.
- Only mutispectral thermal at 60 m
- 5 day repeat for thermal for short & long term trend analysis
- Allow for functional classification of urban surfaces

Thanks

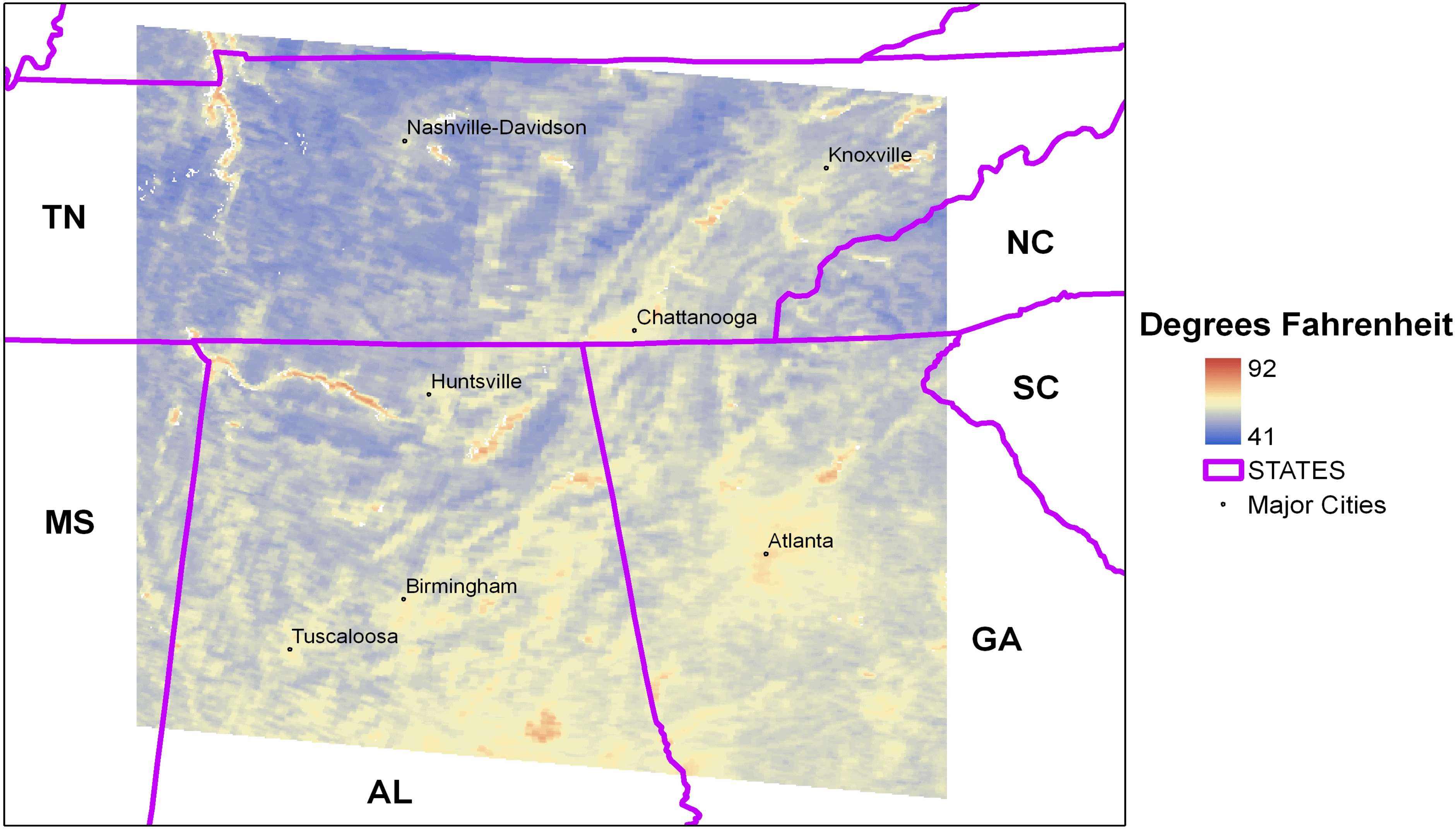
NASA/MODIS Land Surface Temperature at 1:30 PM (June 27, 2012)



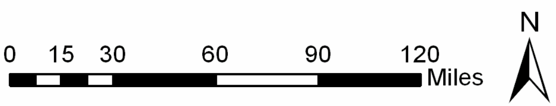
Prepared by:
Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC
mohammad.alhamdan@nasa.gov

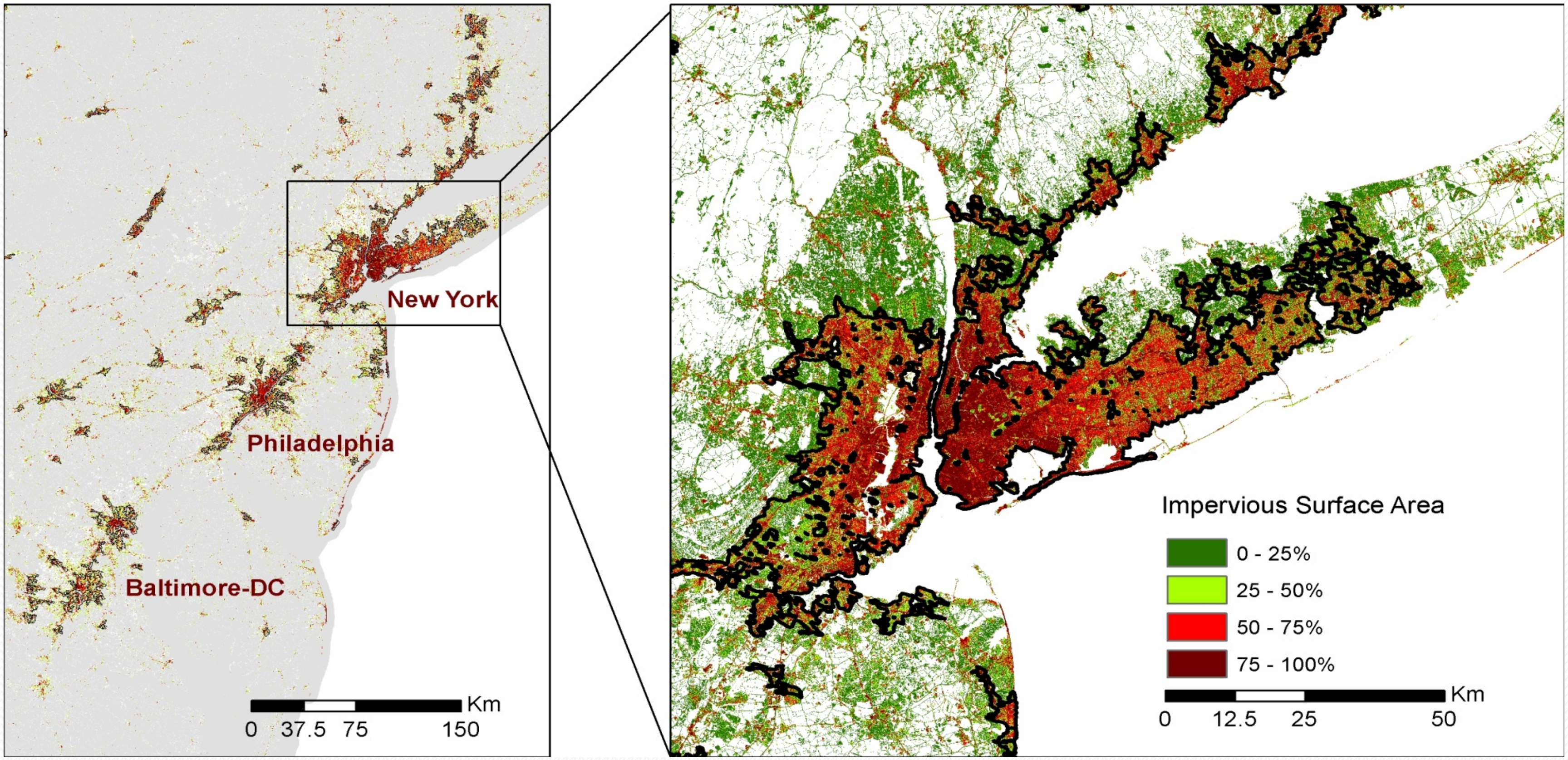
July 17, 2012

NASA/MODIS Land Surface Temperature at 1:30 AM
(June 27, 2012)



epared by:
r. Mohammad Al-Hamdan
SRA at NASA/MSFC
ohammad.alhamdan@nasa.gov
ly 17, 2012

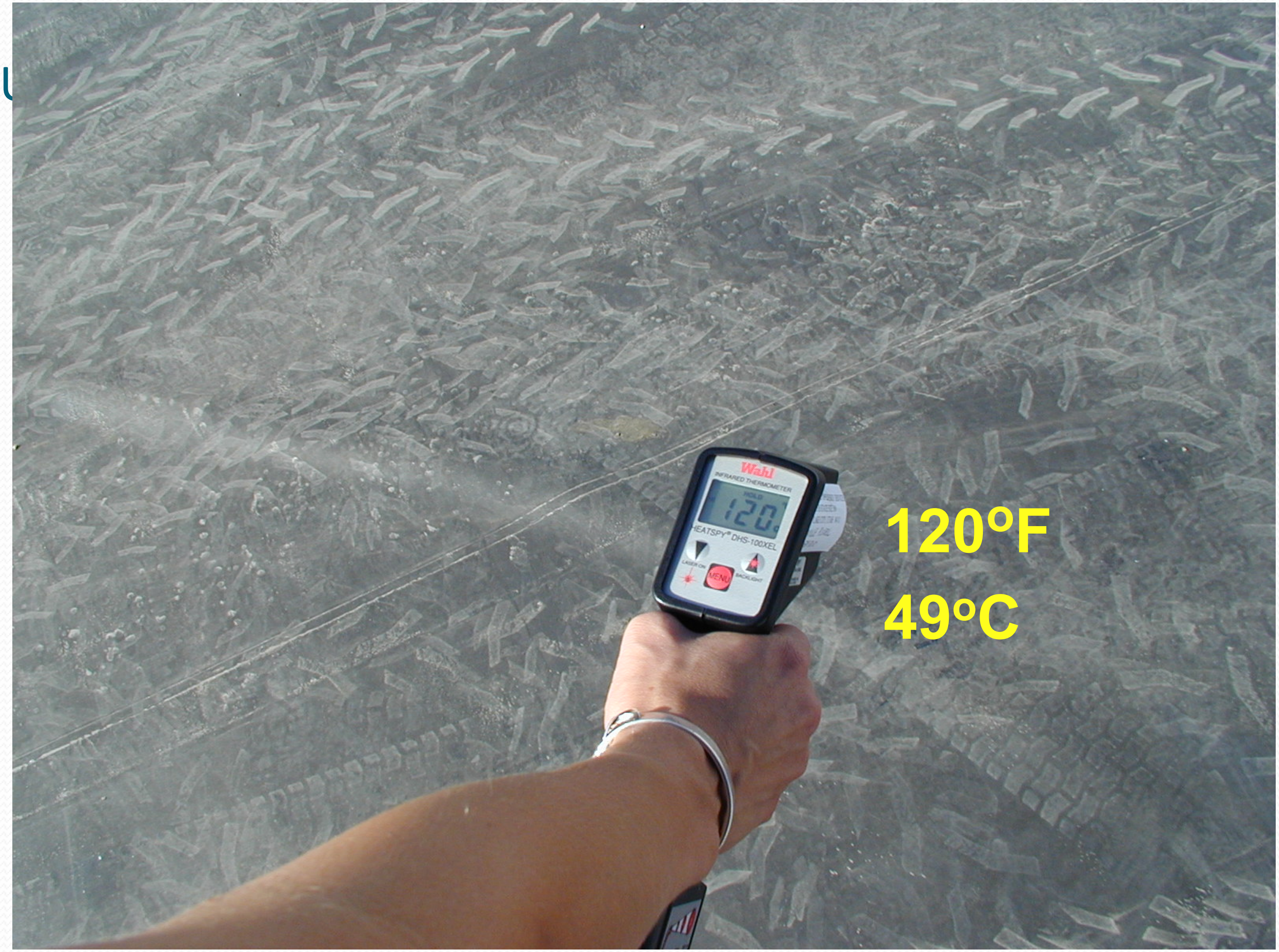




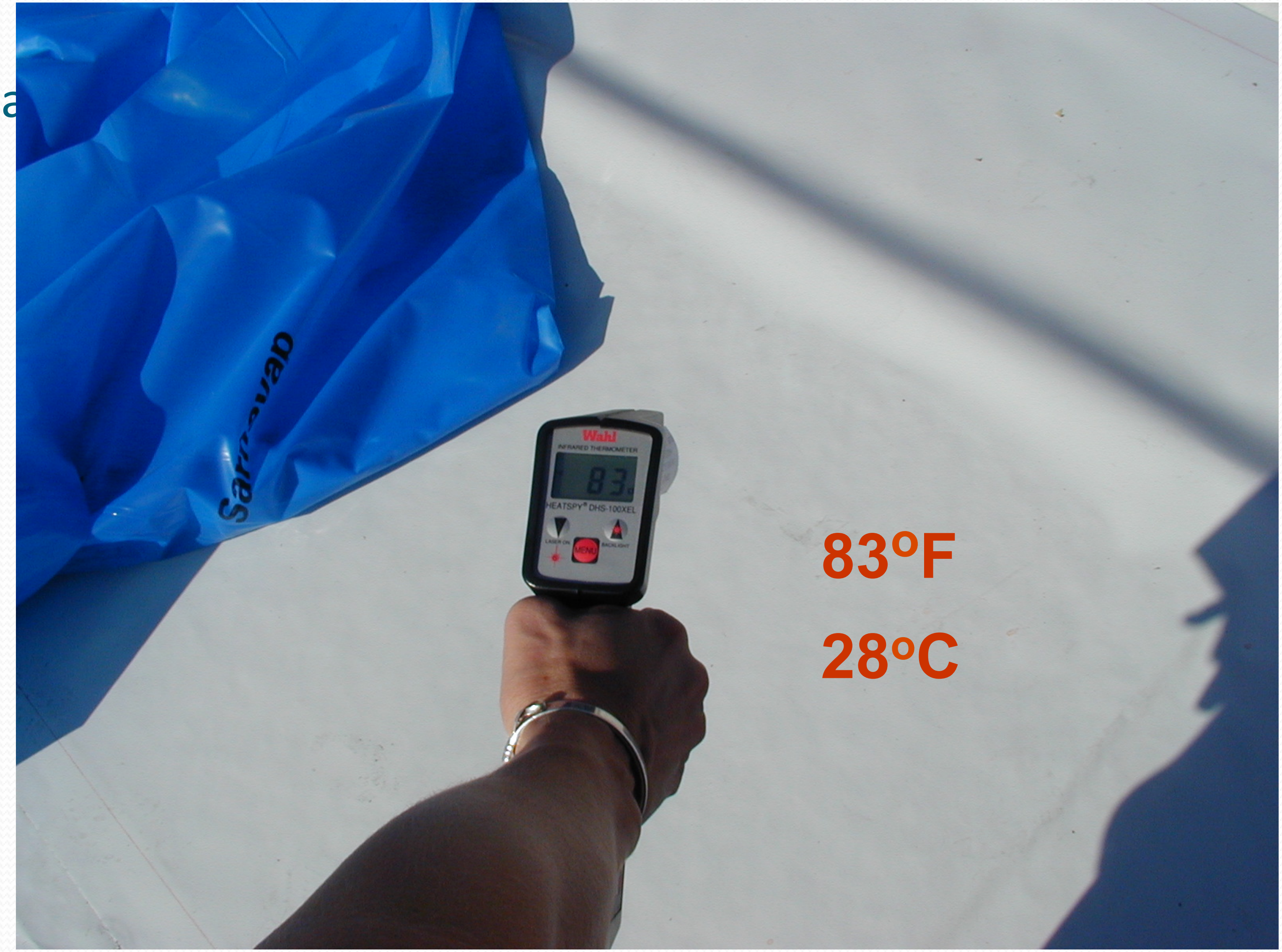
New York
Philadelphia
Baltimore-DC
Km
0 37.5 75 150
Impervious Surface Area
0 - 25%
25 - 50%
50 - 75%
75 - 100%
Km
0 12.5 25 50

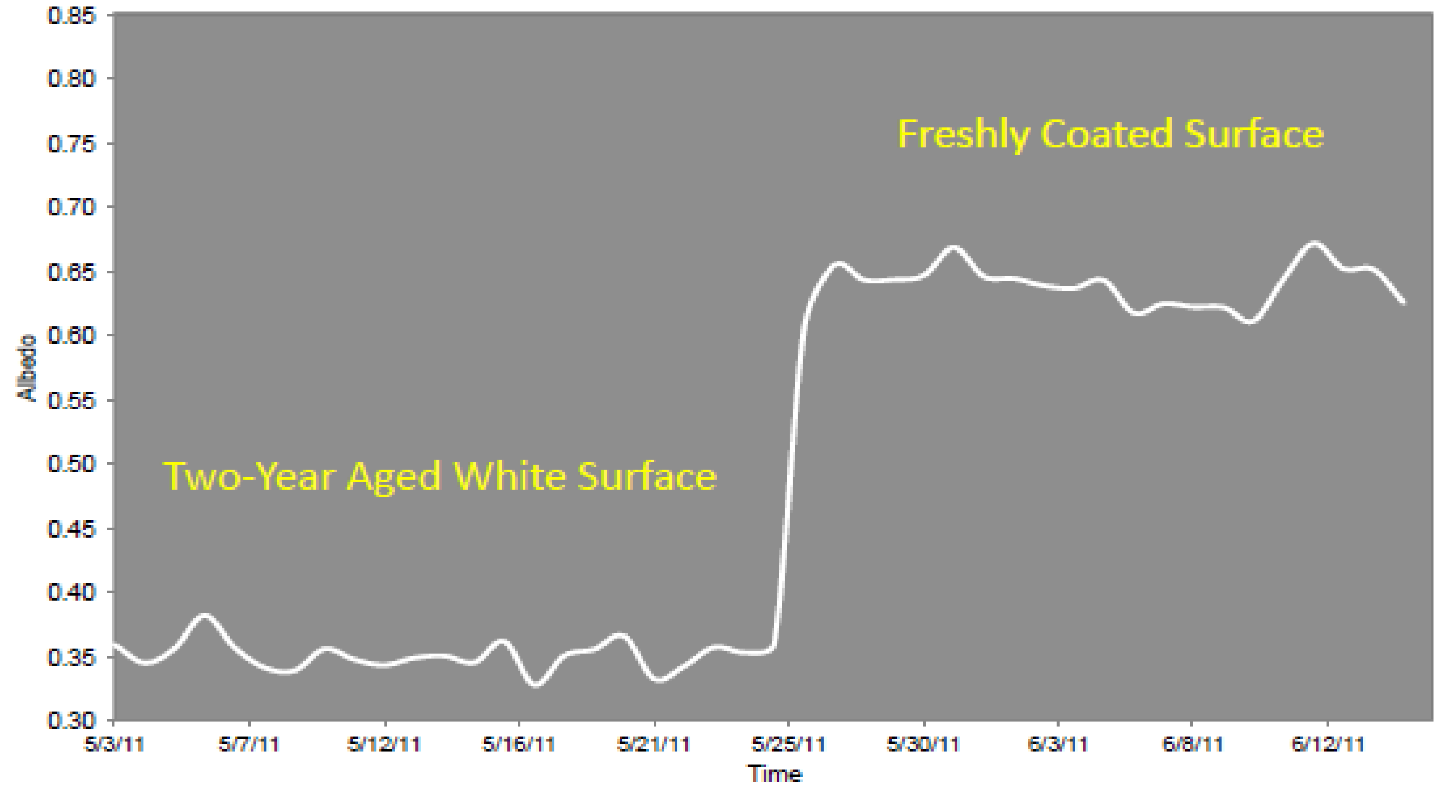
Urban Thermal Remote Sensing

Impervious Surfaces


Wahl
INFRARED THERMOMETER
HEATSPY® DHS-100XEL
MENU
120°F
49°C

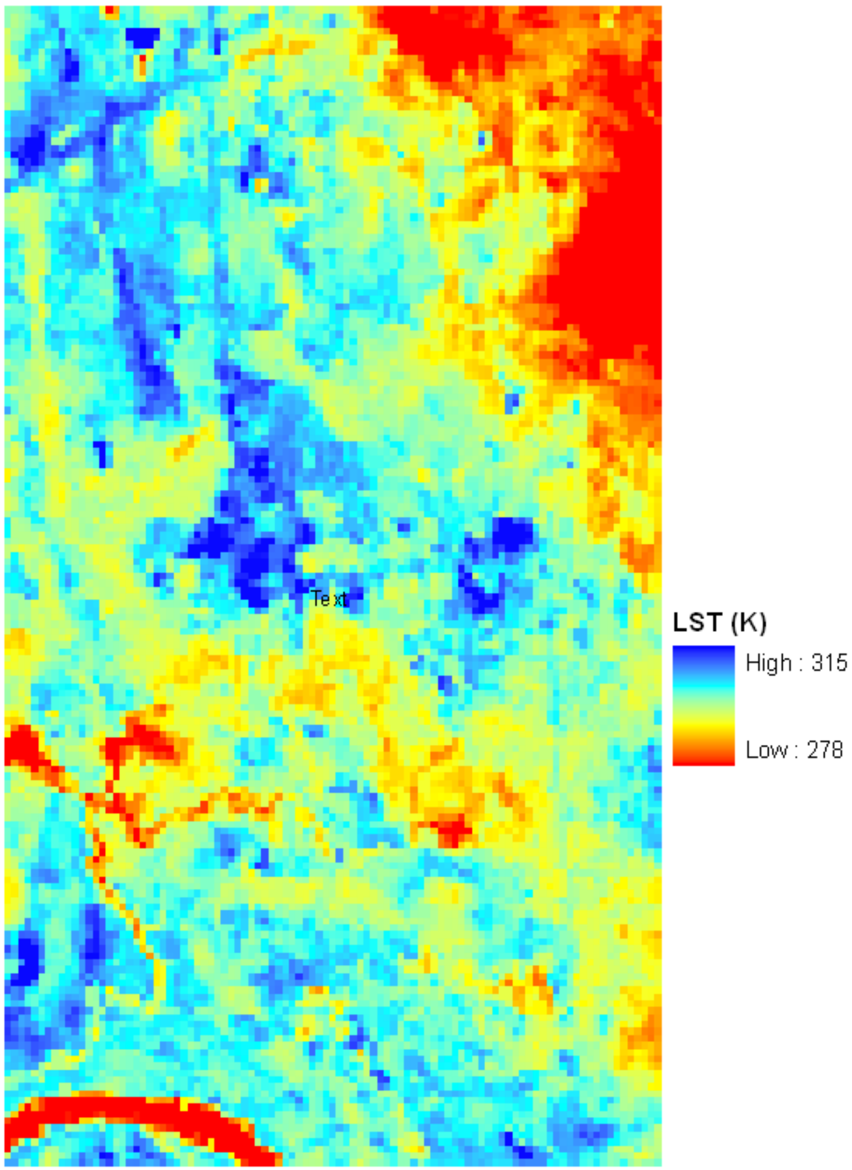
Urba


Wahl
INFRARED THERMOMETER
83
HEATSPY® DHS-100XEL
MENU
83°F
28°C

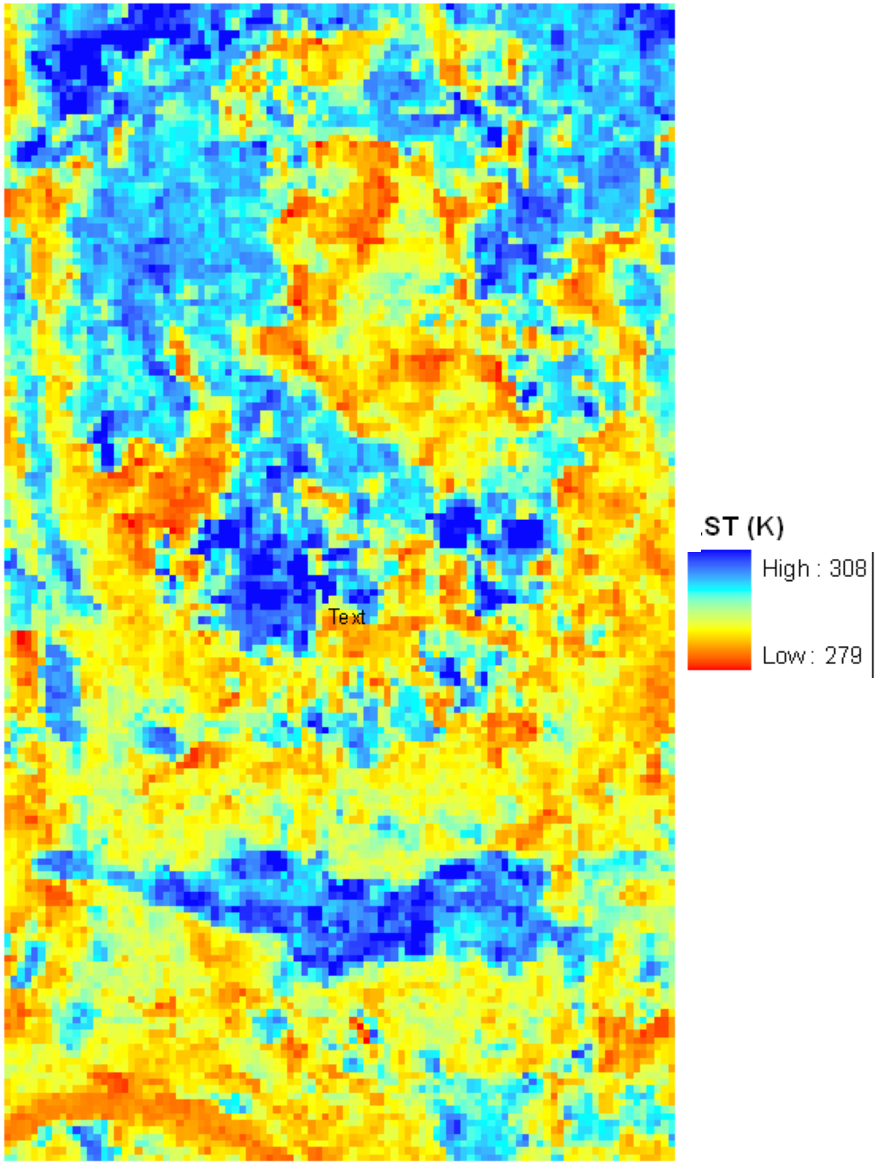


Freshly Coated Surface
Two-Year Aged White Surface
Albedo
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
5/3/11
5/7/11
5/12/11
5/16/11
5/21/11
5/25/11
5/30/11
6/3/11
6/8/11
6/12/11
Time

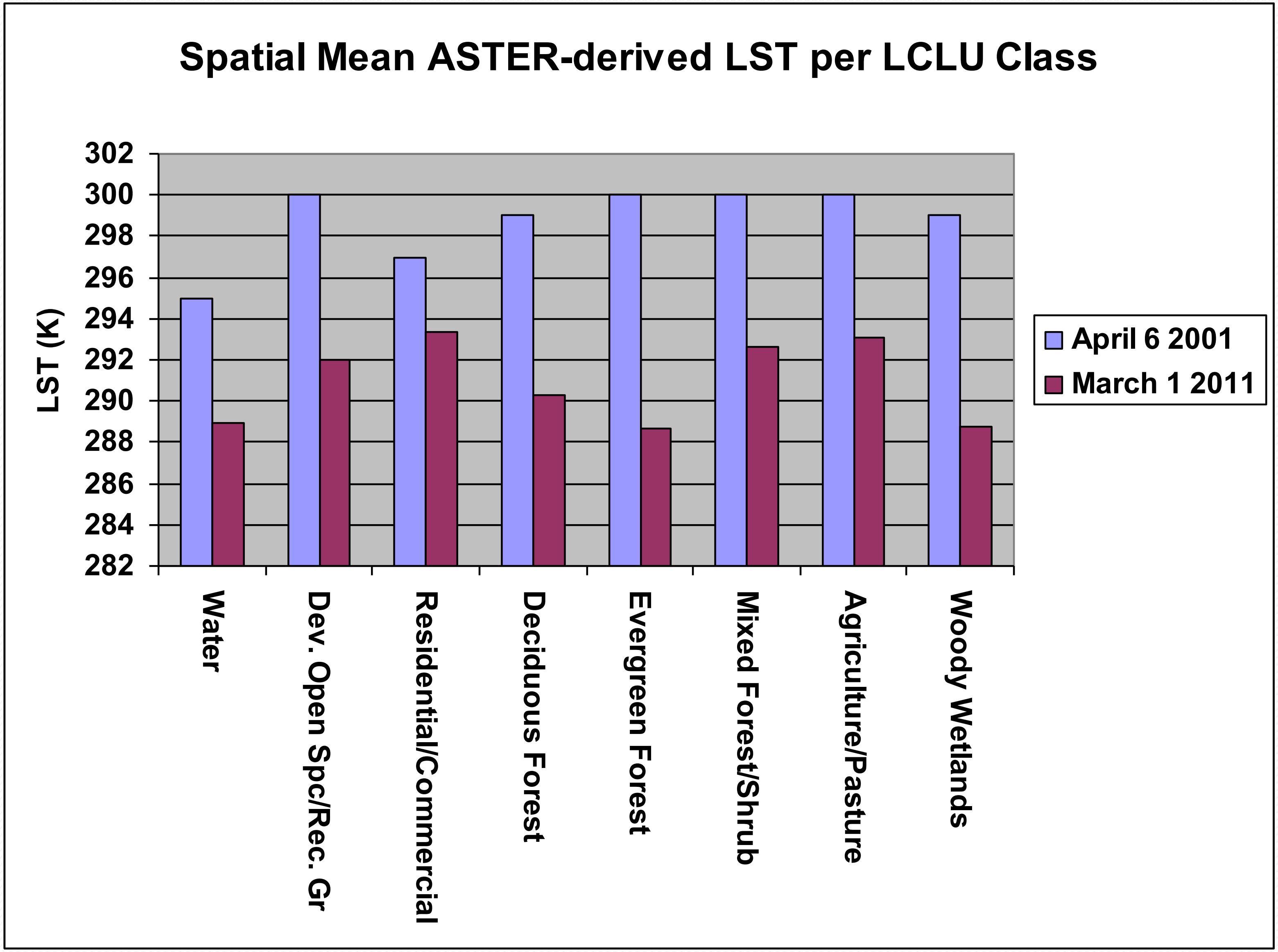
ASTER LST (K) (APR 6, 2001)



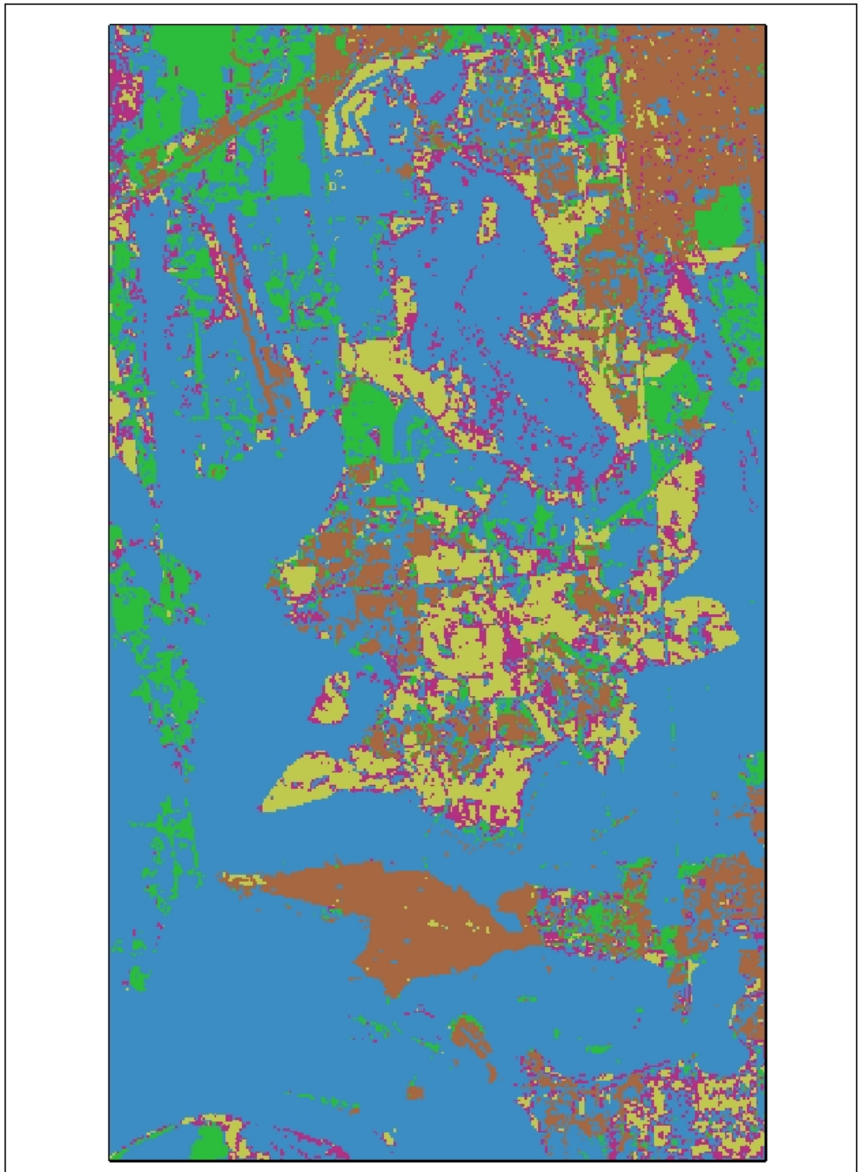
ASTER LST (K) (MAR 1, 2011)



Land Cover and Climate Change Impacts



Emissivity 1992

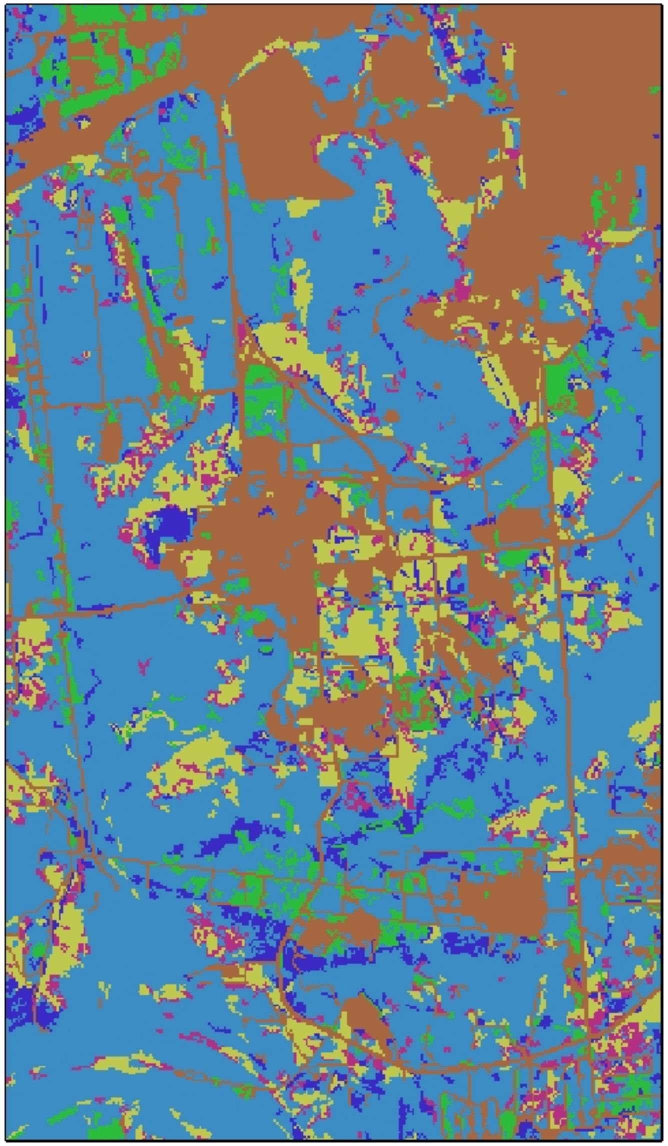


Emissivity

- 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



Emissivity

- 0.969 (Used for Bare Soil; and Developed Pixels)
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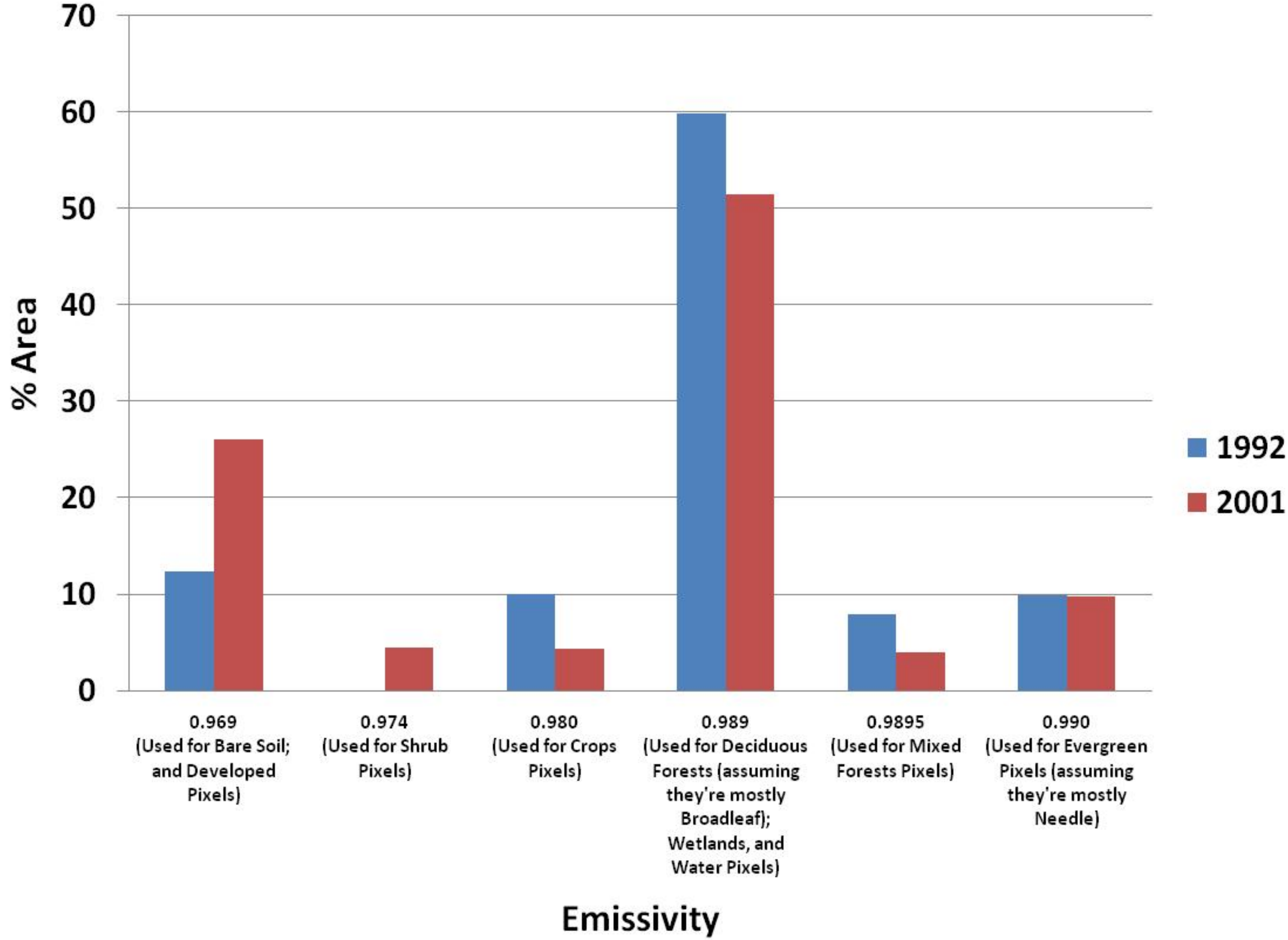
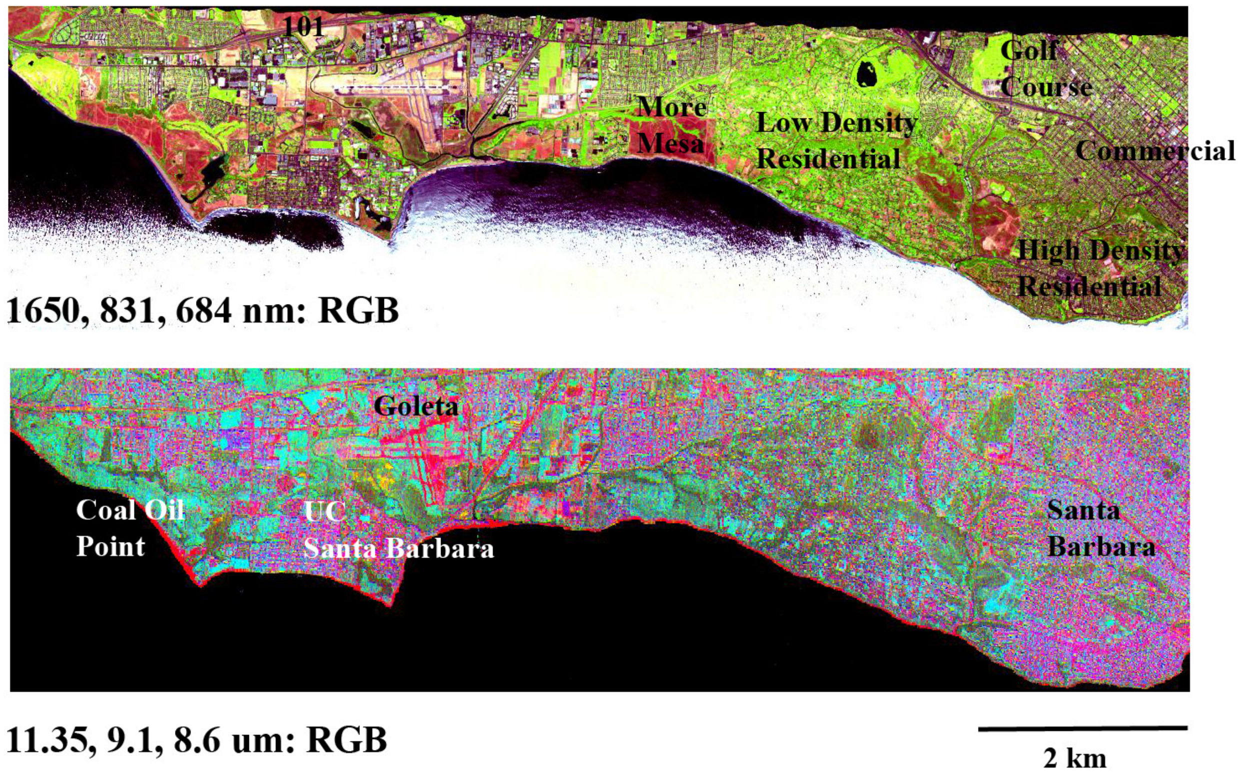


70
60
50
40
30
20
10
0
% Area
1992
2001
0.969 (Used for Bare Soil; and Developed Pixels)
0.974 (Used for Shrub Pixels)
0.980 (Used for Crops Pixels)
0.989 (Used for Deciduous Forests (assuming they're mostly Broadleaf); Wetlands, and Water Pixels)
0.9895 (Used for Mixed Forests Pixels)
0.990 (Used for Evergreen Pixels (assuming they're mostly Needle)
Emissivity

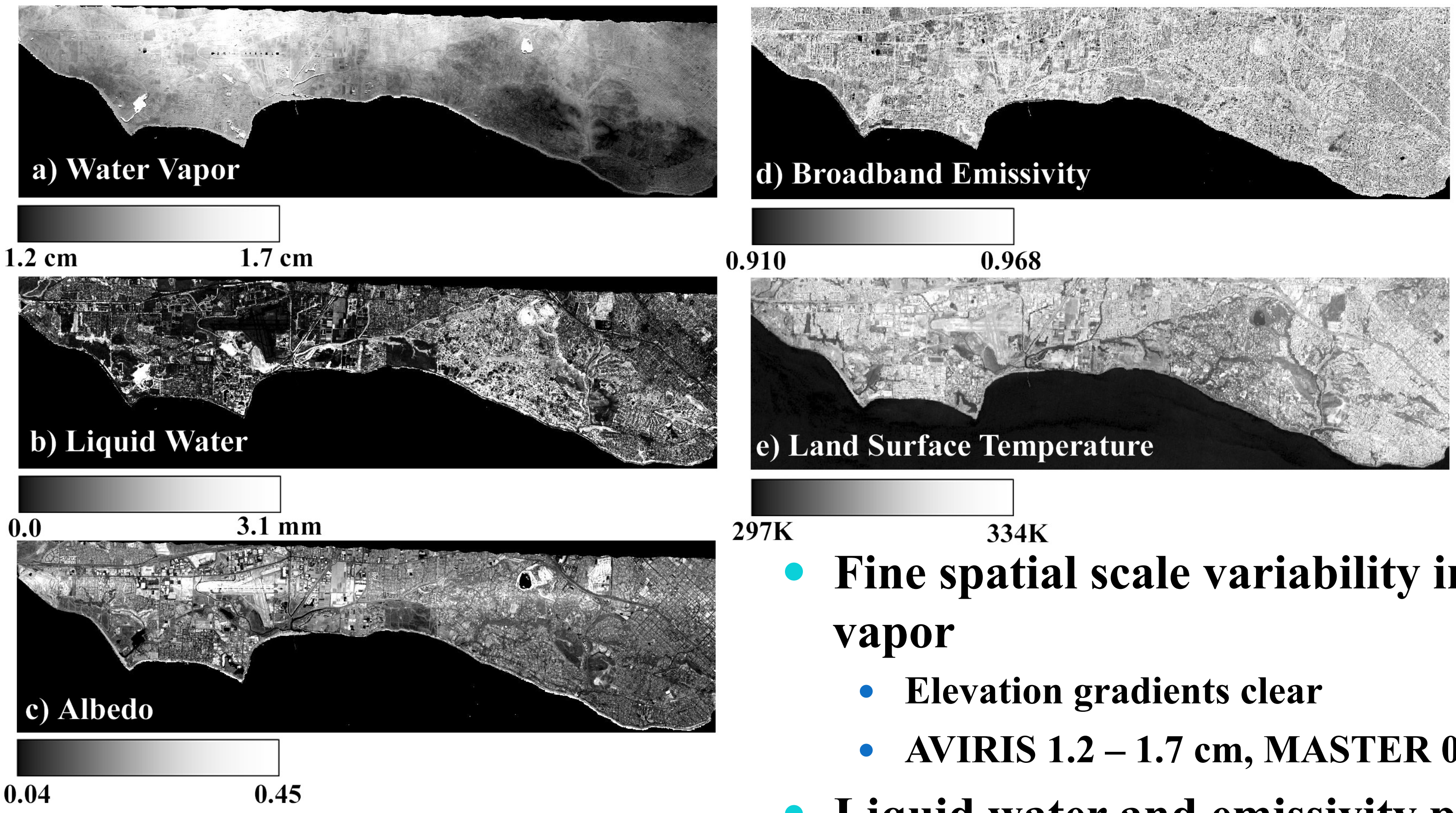
Study Site: Santa Barbara



- Mixed urban-natural systems, ~ 150,000 people
- AVIRIS-MASTER pair, June 19, 2008
  - 7.5 m AVIRIS, 15 m MASTER
  - Spatial degradation, 15 m AVIRIS, 60 m AVIRIS/MASTER

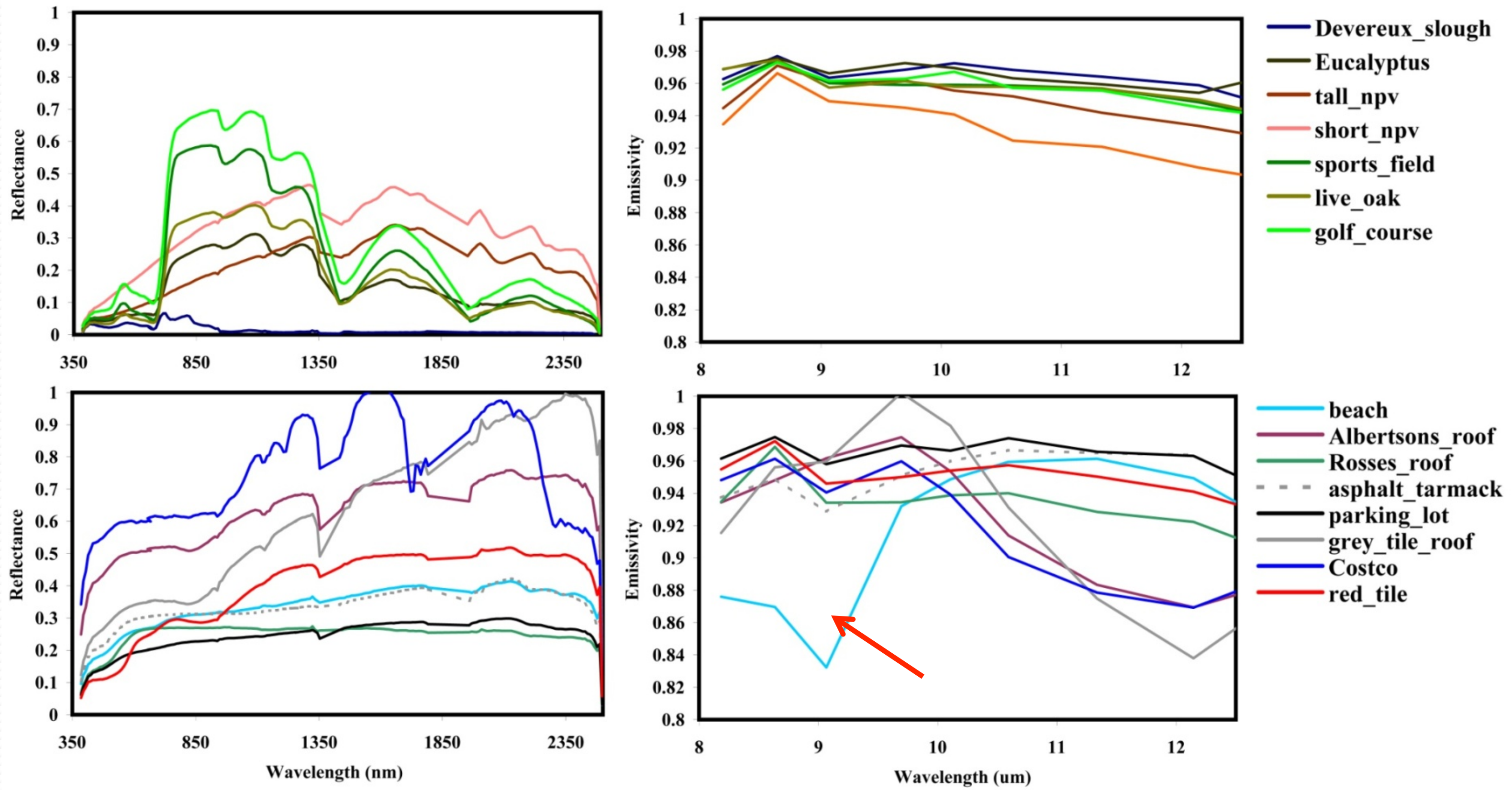
Roberts et al., 2012 RSE

Results
AVIRIS-MASTER Products



- **Fine spatial scale variability in water vapor**
  - **Elevation gradients clear**
  - **AVIRIS 1.2 – 1.7 cm, MASTER 0.78 cm**
- **Liquid water and emissivity positively correlated**
  - **Asphalt also high emissiivty**
- **Albedo and LST poorly correlated**

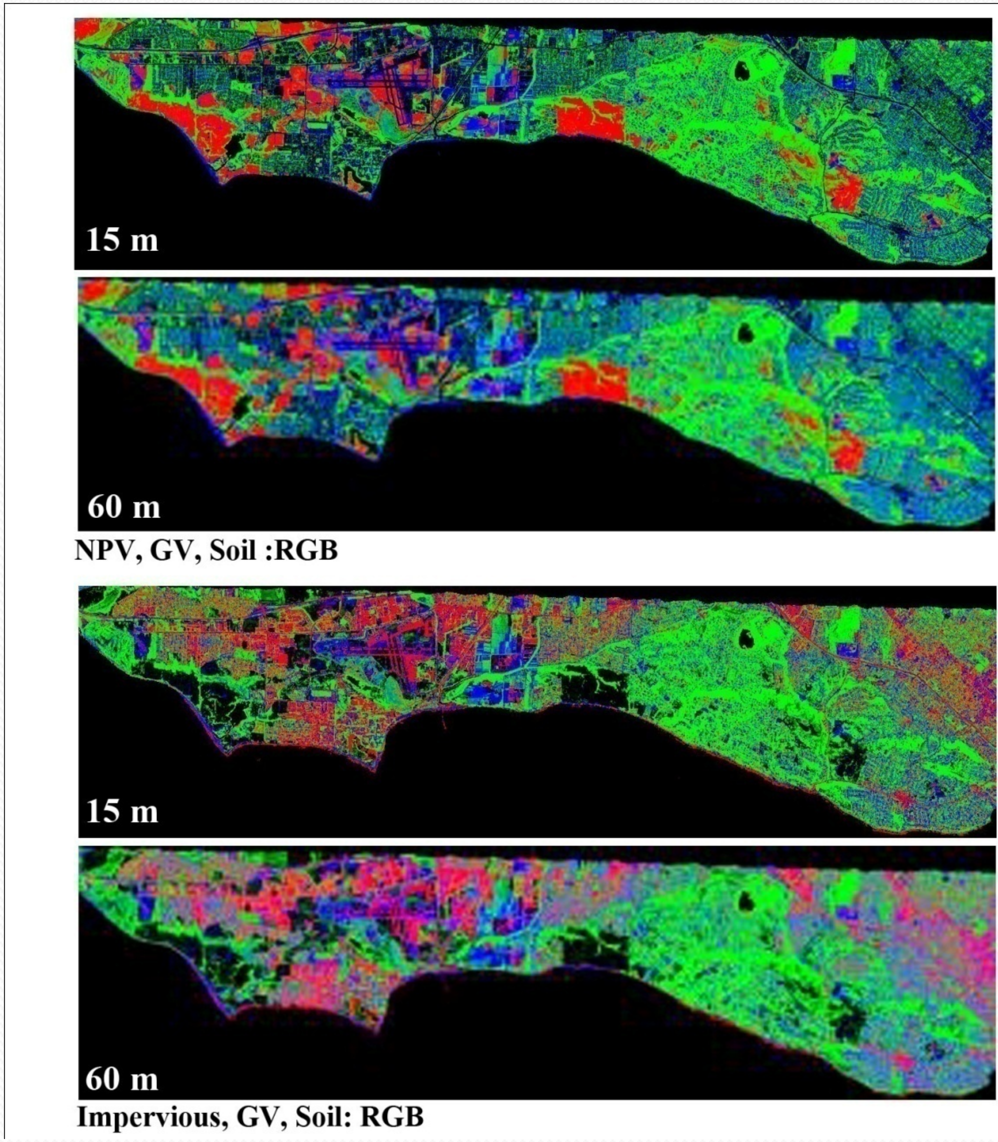
Reflectance and Emissivity Spectra



- **Biotic Materials – Most Distinct in VSWIR (all unique)**
  - **NPV low emissivity in TIR (Differs by stature)**
- **Abiotic Materials – Varies**
  - **AVIRIS: Painted roofs, red tile**
    - **Soils and some road surfaces are not distinct***
  - **MASTER: Quartz beach sands, various roof types**
    - **Asphalt surfaces are near black bodies**

VSWIR-TIR improves discrimination of abiotic materials

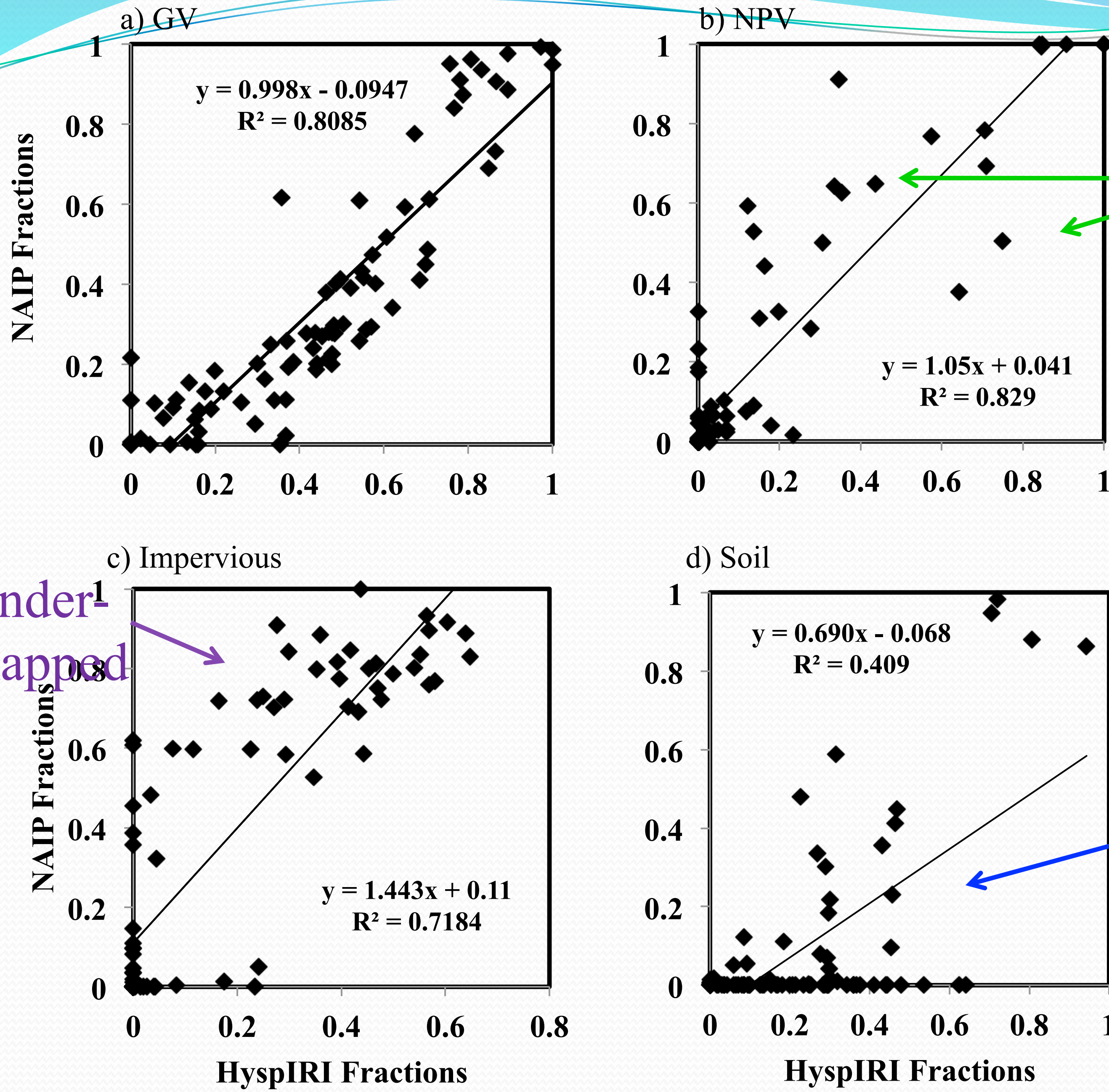
VIS-NPV Fractions: 15 and 60 m



- **GV and NPV fractions scaled well between all spatial resolutions**
  - **7.5, 15 and 60 m**
- **Soil tended to be overmapped at the expense of Impervious at coarser scales**

Two error sources
Asphalt – soil
Red Tile Roof (so variable requires 3 ems)

Fraction Validation: 60 m



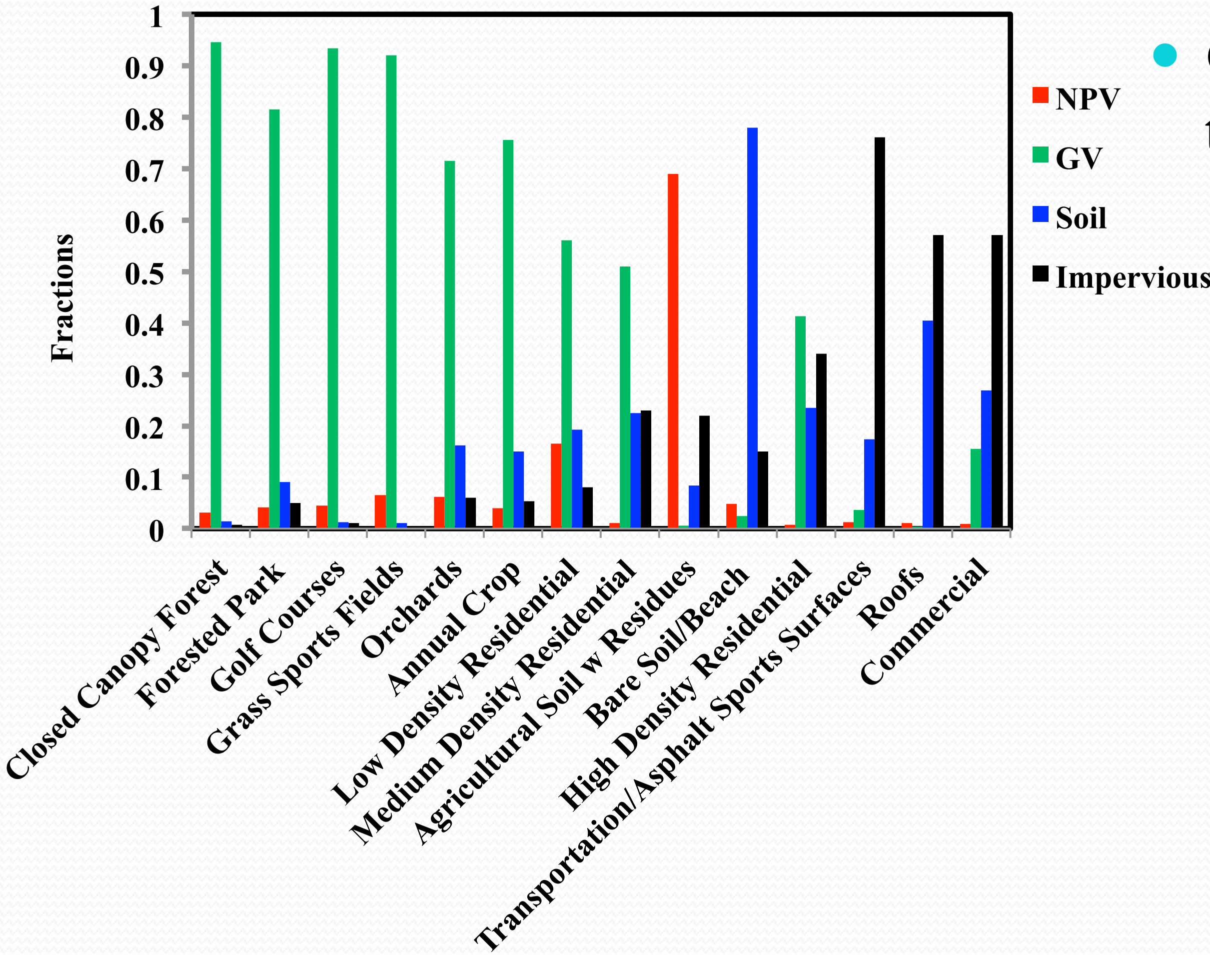
Phenology

GV-NPV Fractions good at HyspIRI scales

Under-mapped

Soil Overmapped (red tile/Asphalt)

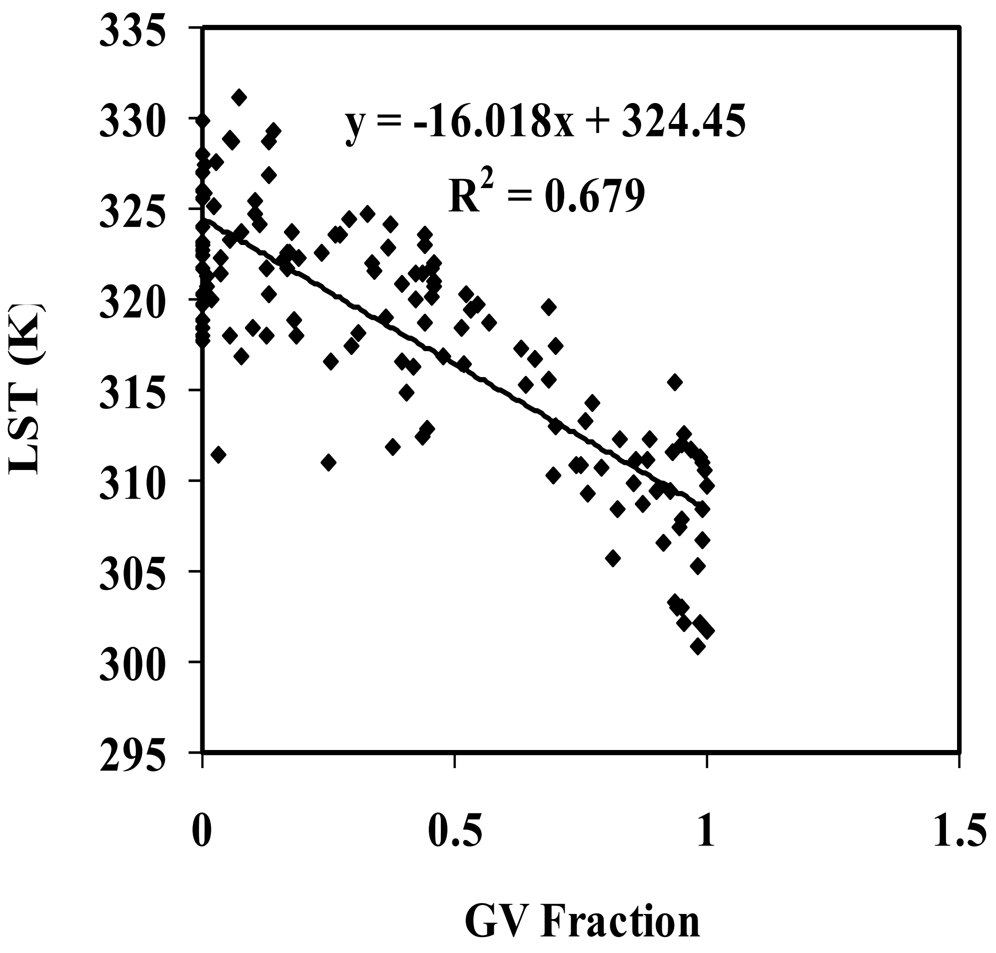
Land-cover Composition



- Cover fractions follow the expected pattern
  - High GV, low Temperature
  - High Impervious, high Temperature
  - Residential
    - Low density, high GV, Low T, low Imp
    - High density, low GV, High T, High Imp

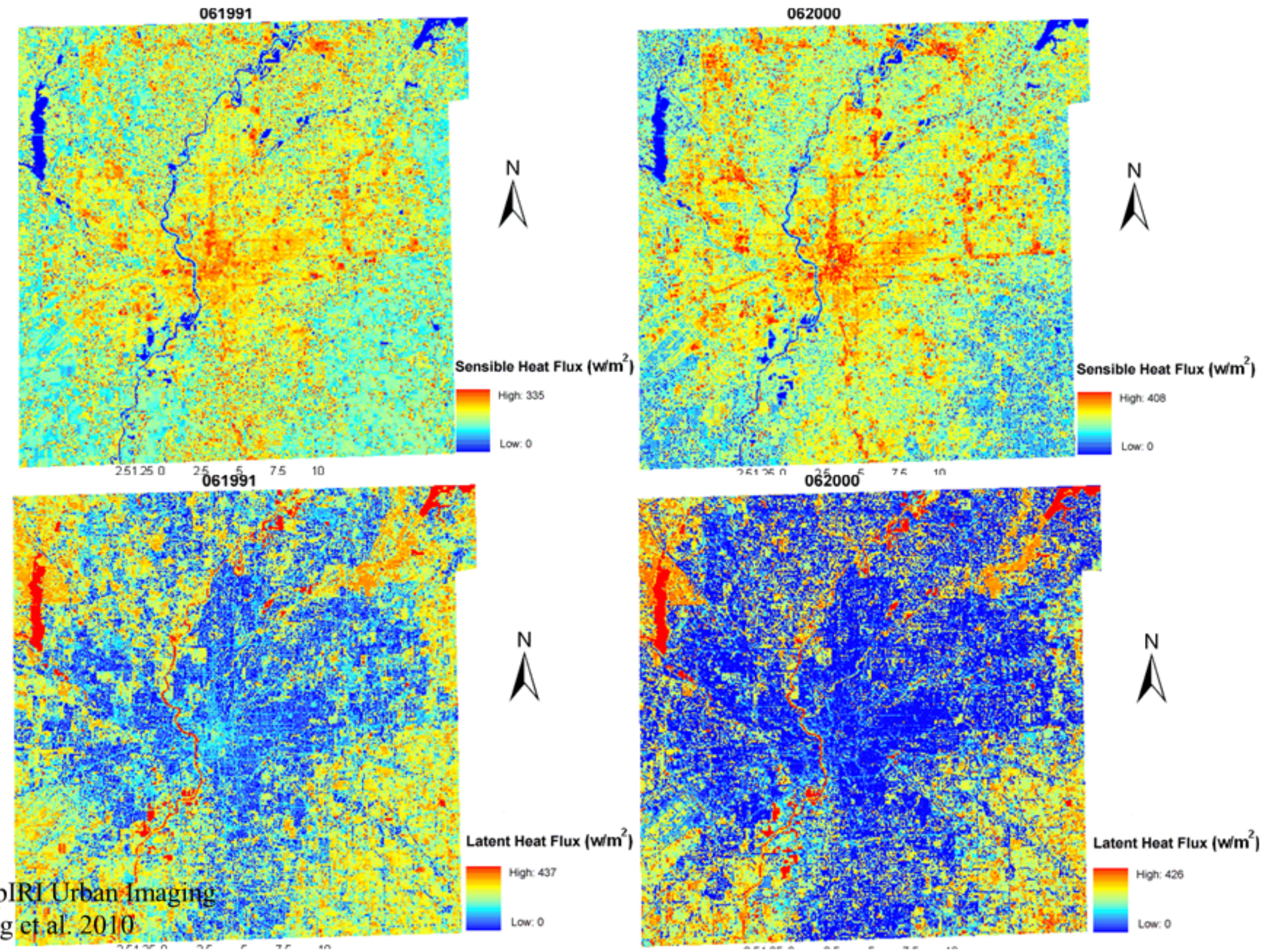
306K  325K

Green Cover and LST



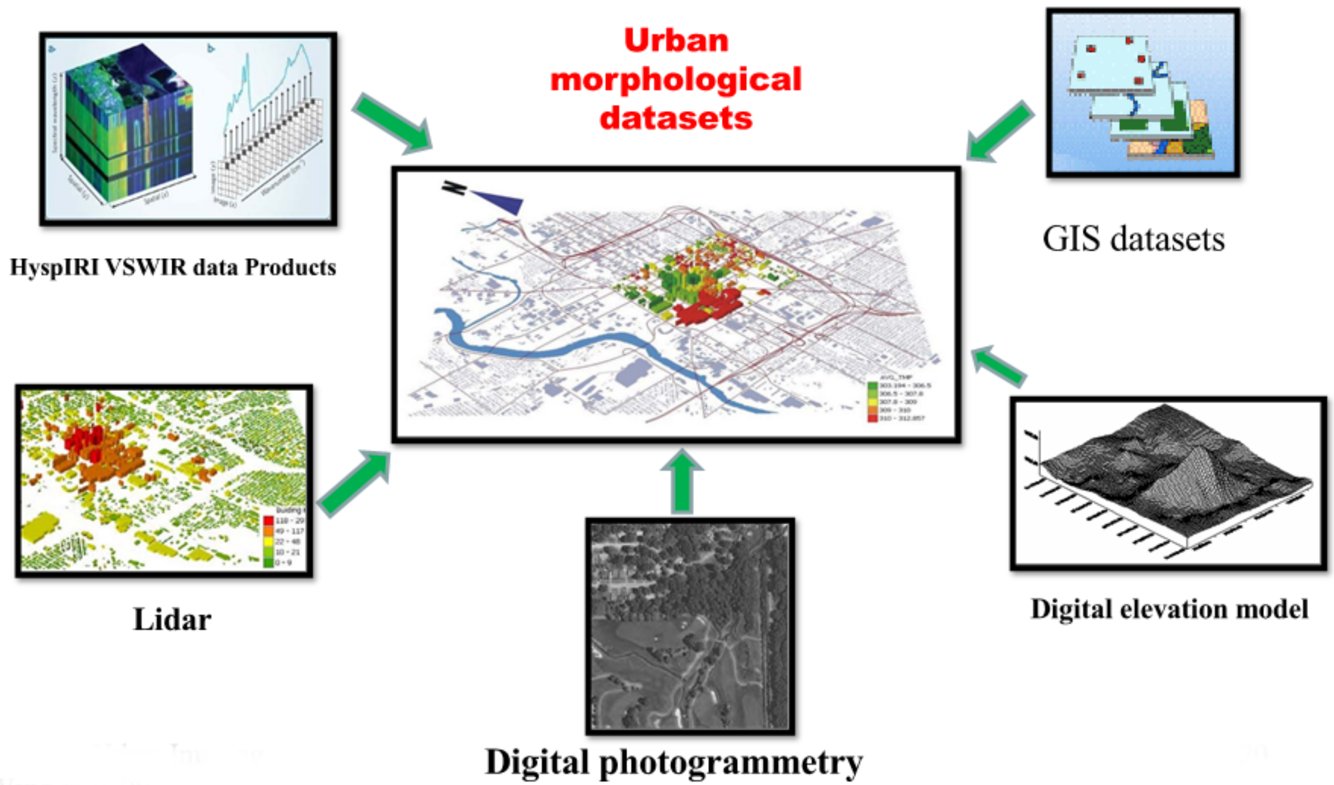
- Standard inverse relationship between GV Cover and LST
- Considerable scatter
  - The scatter is likely to be the most interesting part
  - Moist soils evapotranspiring
  - Closed canopies with variable ET

Changes in Surface Heat Fluxes due to Urbanization



HyspIRI Urban Imaging
Weng et al. 2010

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



Images showing some of the unique characteristics that define individual cities (clockwise from upper left: Boise, ID; Annapolis, MD; St Louis, MO, and Tucson, AZ).