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

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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
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
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
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)
Dramatic increase in urban-residential land use category from 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.
Landsat-derived NLCD-1992

Legend:
- 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

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April 14, 2011
Landsat-derived NLCD-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
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.
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.
Landsat-derived LST July 30, 1990

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June 8, 2011
Landsat-derived LST June 7, 2000

LST (K)

- 314
- 290

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Spatial Mean Landsat-derived LST Per LCLU Class

- 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

LST (K)

July 30, 1990
June 7, 2000
## Weather Data Huntsville International Airport

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Growth of Global Megacities

- 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
Connecting urban environmental processes and climate
Urban Heat Islands and Emissions?

M. Imhoff – Goddard Space Flight Center

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?

M. Imhoff – Goddard Space Flight Center
Consequences of Urbanization on NPP-Carbon in the U.S.

- **Urbanization and NPP**
  - NPP decreased 41.5 M tons C / year.
  - 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%?

  - **Location, Location, Location.**
    - Urbanization is taking place on the most fertile lands

- Reduction of NPP may have biological significance:
  - 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).

- **NPP Lost or Gained (annual)**
  - **Due to Urbanization**
    - Going from a pre-urban to a post urban world

- **Total Reduction**
  - **41.5 Mt C**

- From Ag Lands
  - **25.5 Mt C**

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

Urban 4D
Structures
Vegetation
Temperature

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The Need for HyspIRI Data

- MASTER
  - 3 day/night pairs
  - SUMMER

- LVIS
  - 3 day/night pairs
  - WINTER

- Urban 4D
- Structures
- Vegetation
- Temperature
The Need for HyspIRI Data

Multi-scale Combined Classification

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The Need for HyspIRI Data

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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)

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

Lidar Data

HyspIRI VSWIR/TIR and Lidar composite data set
(X, y, z surface reflectance/thermal interactions of urban ecosystem processes)
HyspIRI Combined “Integrated” Topographic Advanced Product for Urban Ecosystems Analysis

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

Digital Topographic Data (DEM)

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

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