



Combining Satellite Data and Models to Assess the Impacts of Urbanization on the Continental US Surface Climate

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Goals and Objectives

This research aims to advance our understanding of urbanization as a form of land use, the mechanisms by which it affects surface climate and the environment, and the feedbacks of these changes at local, regional and continental scales in an attempt to address the core of the following questions:

1. What is the local, regional and continental impact of existing urbanization on the US current climate?
2. What is the aggregate impact of urbanization on continental US climate since pre-urban era in terms of carbon loss, freshwater gain and surface temperature changes?
3. To what extent can the UAE amplify the urban-climate interactions?
4. What are the observed trends and patterns of urban expansion in the US and how are they likely to continue in the near-future?
5. What is the impact of urban growth on near-future climate in the US?
6. Will urban growth exacerbate the projected climate warming and moistening through the UHI and precipitation effects?
5. What are the socio-economic consequences for populations? And to what extent can these consequences be mitigated?



Tasks and Accomplishments

Task 1: Generating Land Cover Maps and the Biophysical Parameters

- Task 1.1: The Recent-Past Situation (2001)
- Task 1.2: The Present-Day Situation (2010)
- Task 1.3: The Pre-Urban Scenario
- Task 1.4: The Near-Future Scenario (2020)
- Task 1.5: Biophysical Parameters

- Task 2: Offline Continental Scale Simulations
- Task 3: Coupled Regional Scale Simulations
- Task 4: Socio-economic Impact Assessment

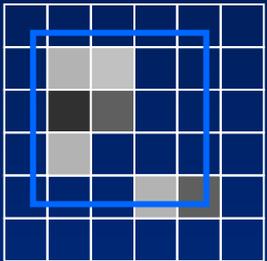
- Multidimensional land cover maps at 5x5km over the continental U.S for the 4 scenarios
- Georeferenced biophysical data representing each existing land cover fraction in the CMG at 8-day
- Full grid and sub-grid contributions to the fluxes and states variables produced at an hourly time step
- Analysis of the impact of urbanization on the biological, hydrological and energy cycles at all scales.
- Assessment of the impact of urbanization on the temperature, carbon and water since pre-urban
- Detailed analysis of the urban heat island effect in major US cities
- Study of the urban archipelagos effects along the northeastern US on climate.
- Socio-economic analysis to assess the impact urban modification of surface climate on human population's behavior, energy consumption and plausible mechanisms for alleviating the urban heat island effect.



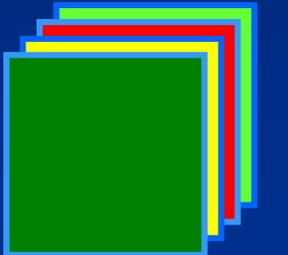
NASA Interdisciplinary Research Science (IDS)
 Science Team meeting, April 23-25, 2014
 Bounoua et al., 2012

T1.1 and T1.5 : Generating Land Use Maps and Biophysics parameters

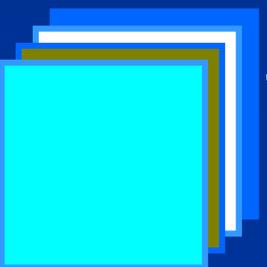
NLCD 30m
 % impervious



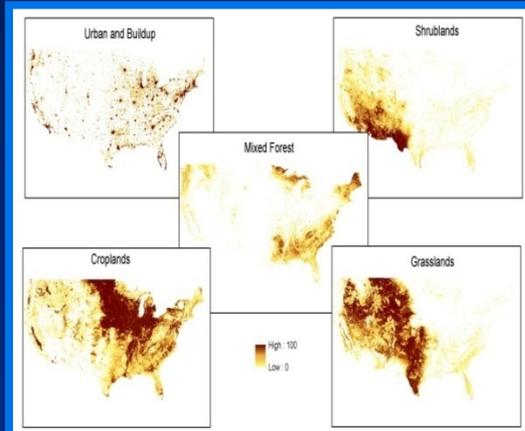
MODIS 500 m LC



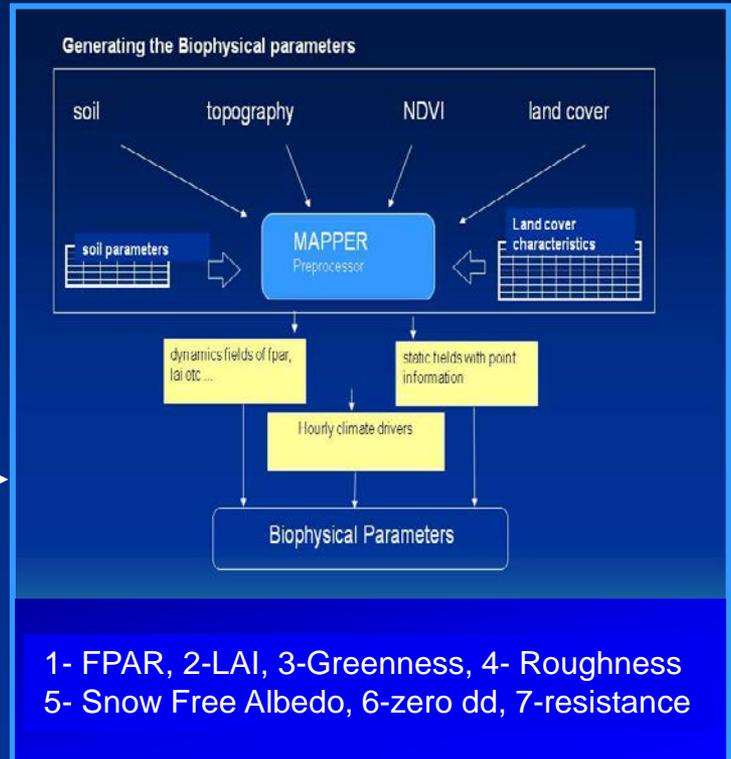
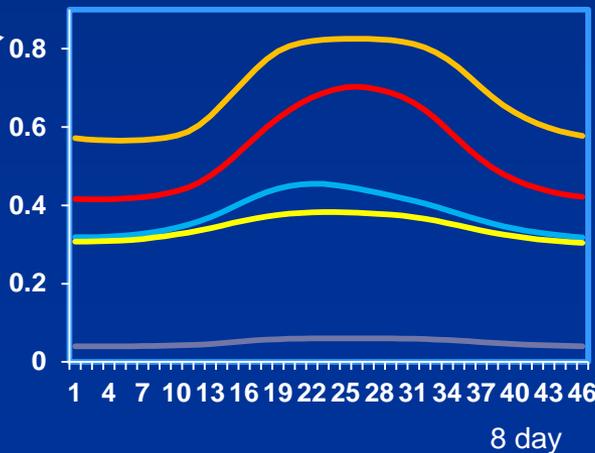
MODIS 500 m VI



Fractional LC and NDVI at (0.05 deg.)



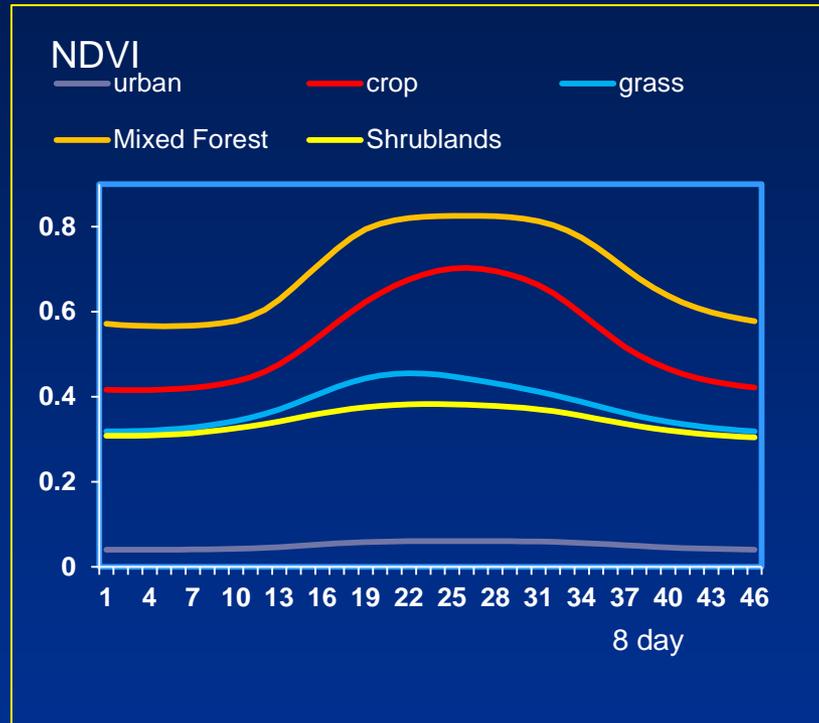
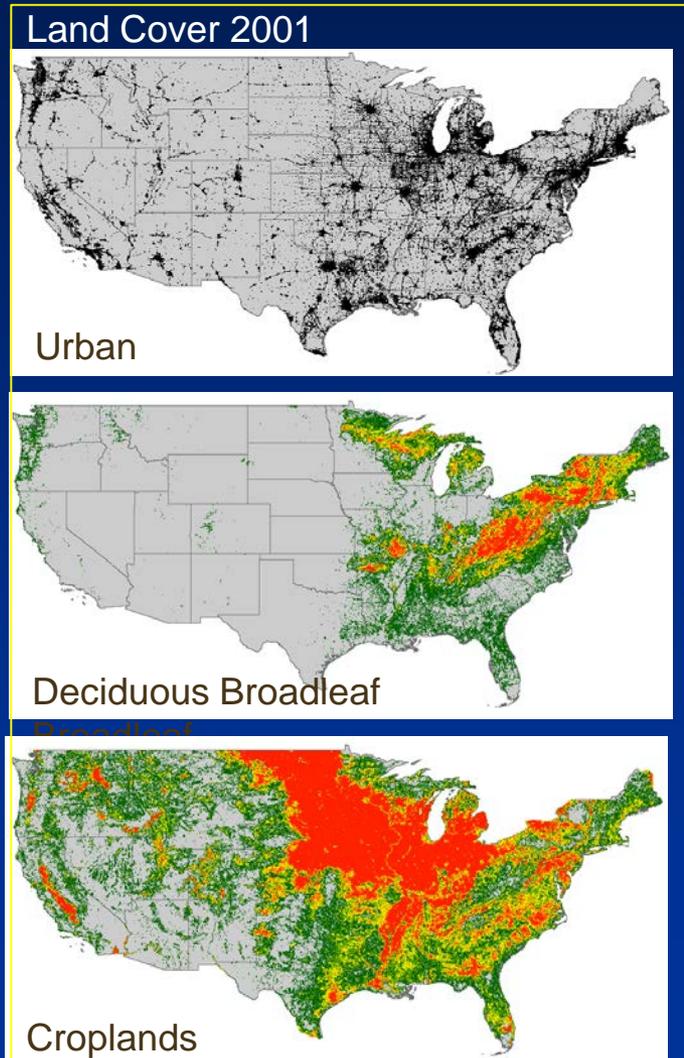
urban (grey)
 grass (light blue)
 Shrublands (yellow)
 crop (red)
 Mixed Forest (orange)



Models



T.1.1 and T1.5: Land Use Maps and Biophysics Parameters

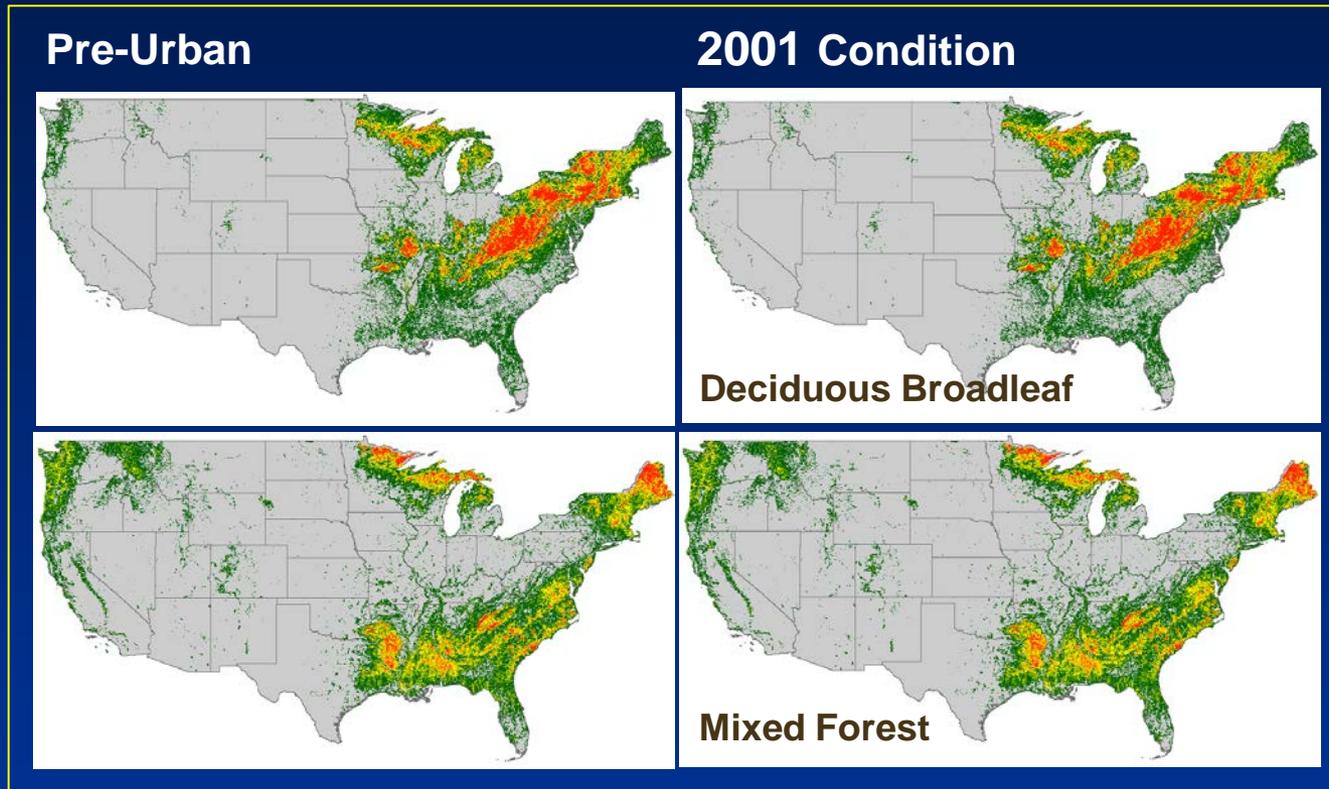


Mapping Biophysical Parameters for Land Surface Modeling over the Continental US Using MODIS and Landsat

L. Bounoua, P. Zhang, A. Safia, J. Masek, M. Imhoff, K. Thome, R. Wolfe, G. Mostovoy, J. Santanello (Dataset Papers in Science)



T1.3 : Pre-Urban Scenario

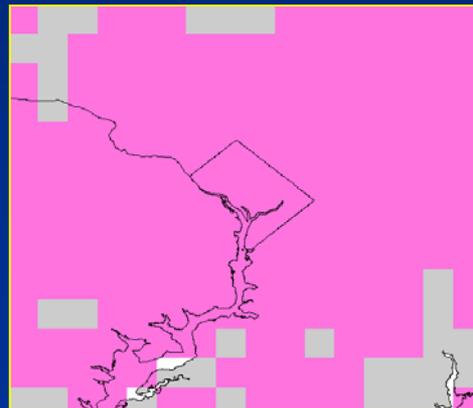
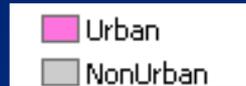
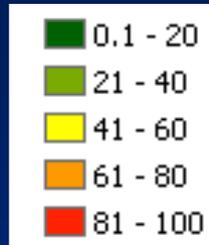
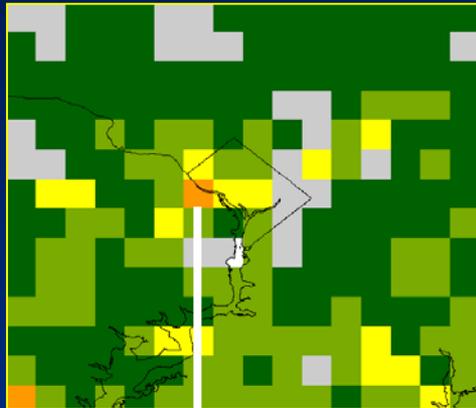


Pre-Urban maps will be used along with NDVI and other vegetation characteristics to estimate the biophysical parameters for the Pre-Urban condition.



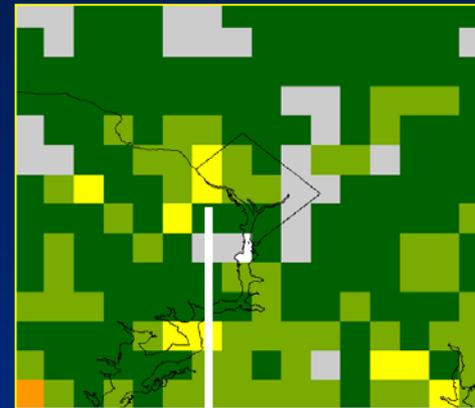
T1.3 : Pre-Urban Scenario

Pre Urban Land Cover



Croplands = 19.44%
Deciduous Broadleaf = 5.56%
Mixed Forest (shown in image)= 61.11%
Savanna = 13.89%
Urban/Buildup = 0 %

2001 Land Cover

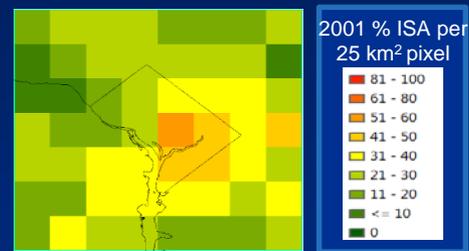
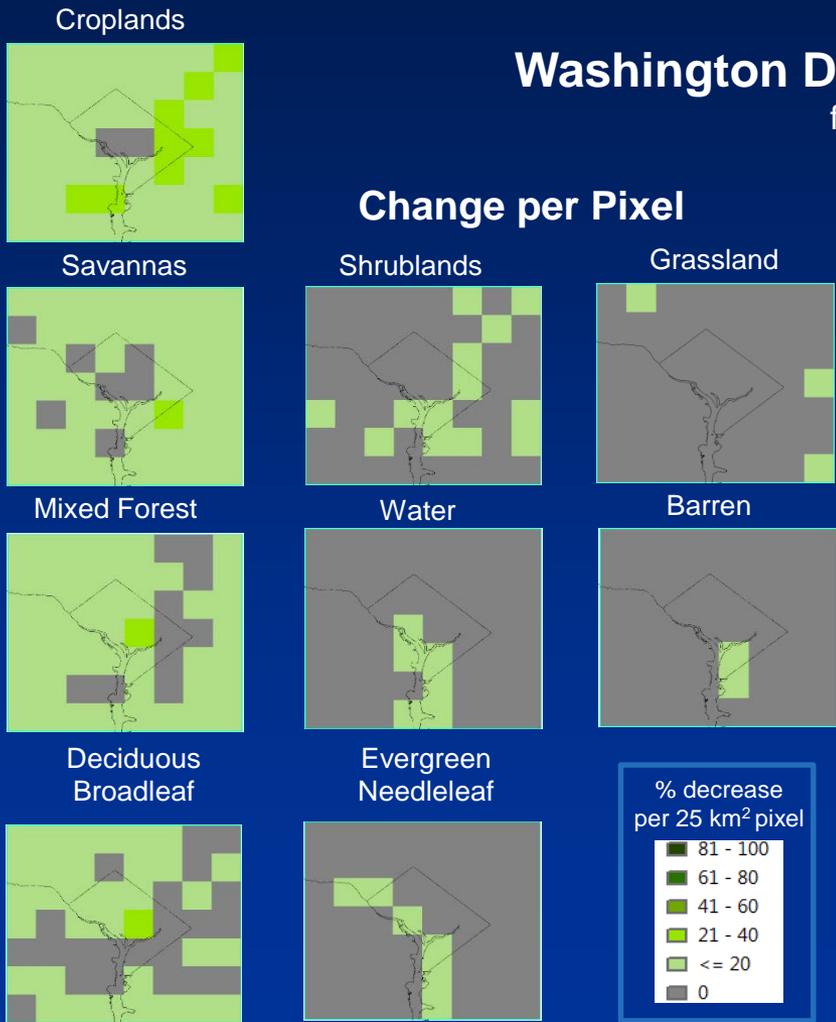


Croplands = 17.17%
Deciduous Broadleaf = 4.9%
Mixed Forest (shown in image)= 53.95%
Savanna = 12.26%
Urban/Buildup = 11.72%



T1.3 : Pre-Urban Scenario

Washington D.C.: % Decrease in Land Cover from Pre-Urban to 2001



Change in Entire D.C. Region (7 x 8 pixels)

Land Cover Type	Pre-Urban	2001	% Difference
Croplands	53.03%	40.34%	-12.69%
Savannas	14.84%	10.31%	-4.52%
Mixed Forest	18.10%	13.88%	-4.21%
Deciduous Broadleaf	8.87%	7.01%	-1.87%
Shrublands	1.80%	1.18%	-0.63%
Water	1.63%	1.14%	-0.50%
Evergreen Needleleaf	0.82%	0.64%	-0.18%
Grassland	0.52%	0.35%	-0.18%
Barren	0.38%	0.24%	-0.15%
Urban/BuildUp	0.00%	24.92%	24.92%
	100.00%	100.00%	

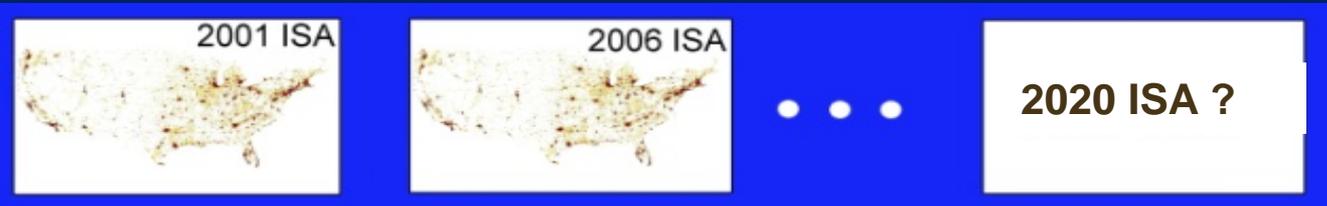


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Bounoua et al. 2012

Present and Future Scenarios

Impervious Surface



Population data



Present day (2010) and the Near future (2020) scenarios will be started in 2014



Other Tasks

Task 2: Offline Continental Scale Simulations

Task 3: Coupled Regional Scale Simulations

Task 4: Socio-economic Impact Assessment

M. Shepherd – **U. of Georgia**
*Modeling the Urban Archipelagos
Effect (UAE)*

J. A. Silva – **UMCP**
*Exploring Linkages between
Climate variables and Energy use*

D. Quattrochi – **NASA-MSFC**
*Analyzing The Urban Energy
Balance*

C. Rosenzweig - **NASA-GISS**
*Comparing and validating Model
Outputs*

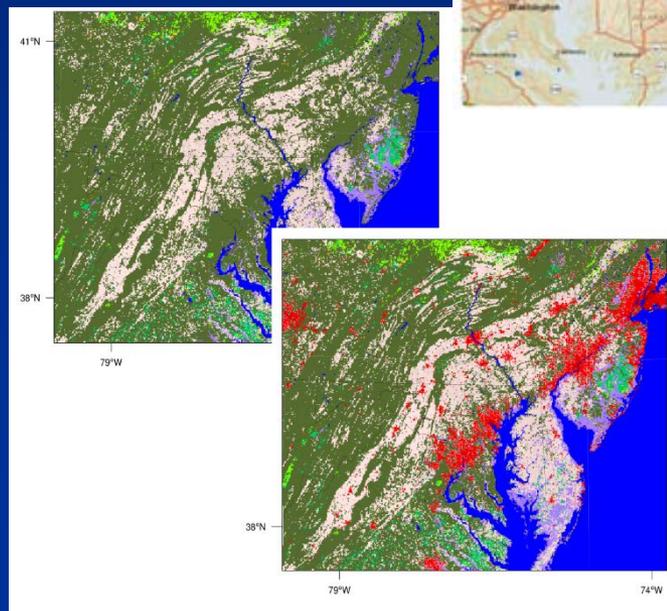


Urban Climate Archipelagos (UCA)

- The expansion and agglomeration of cities may have unique impacts on the climate
- The literature is fairly conclusive on urban modifications to dynamical flow, temperature, and precipitation
 - However, the mid-Atlantic region has been inadequately studied within these contexts
- Based on current and predicted trends, urban areas will increasingly influence weather phenomena
- Objective: Use WRF-UCM simulations to explore the collective impacts of cities arranged in an 'urban-chain' along the northeastern US

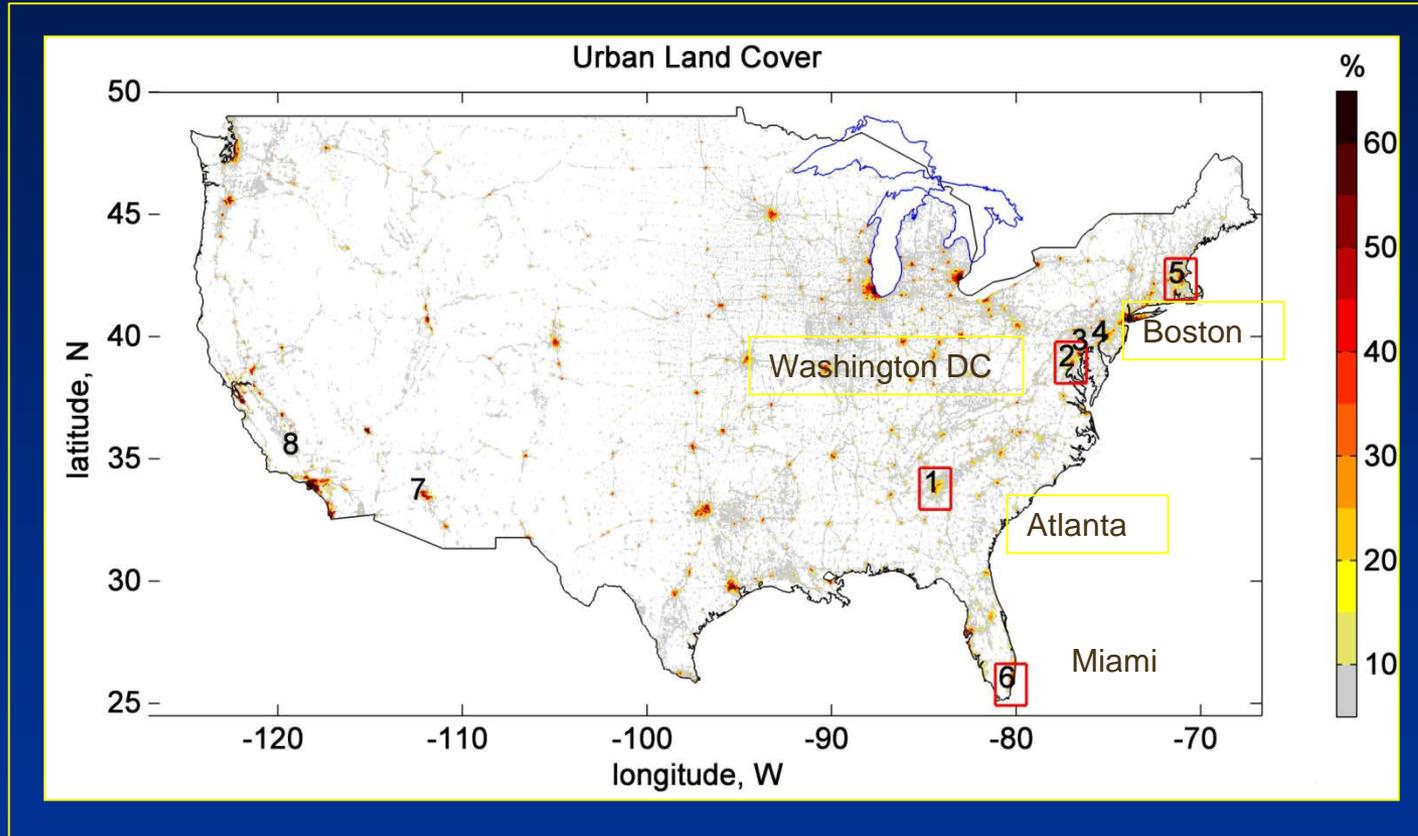
Compare URBAN vs. NOURBAN simulations for a convective weather event (1 June 2006)

- Determine how the UCA modifies the storm characteristics in the study region
 - Precipitation
 - Surface and upper level winds
 - Temperature
 - Sensible and latent heat flux
- Better understand the mechanisms through which urbanization interacts with the atmosphere

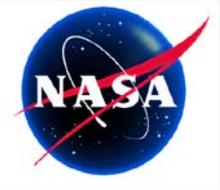




Preliminary Results



Geographical distribution of urban LC type (ISA %) over CONUS. Numbers indicate cities selected for analysis. Red boxes indicate 1.5°x1.5° latitude/longitude areas used for urban heat island analysis.

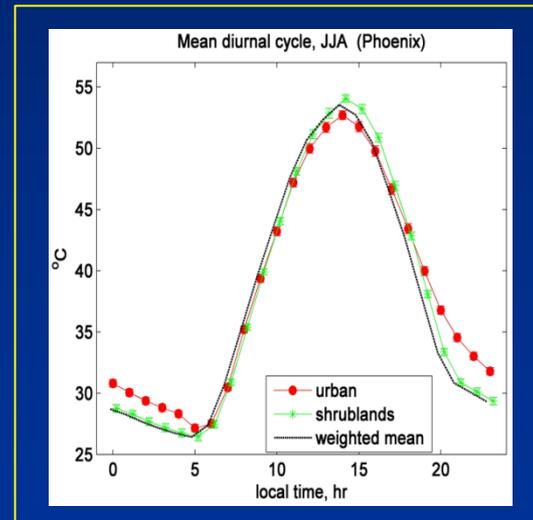
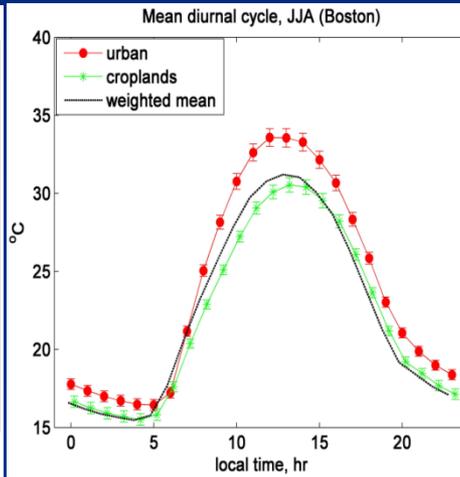
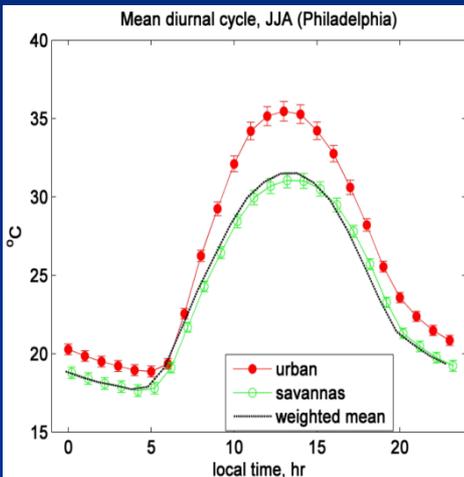
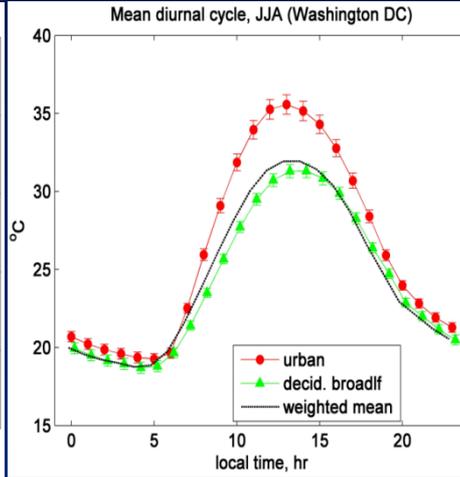
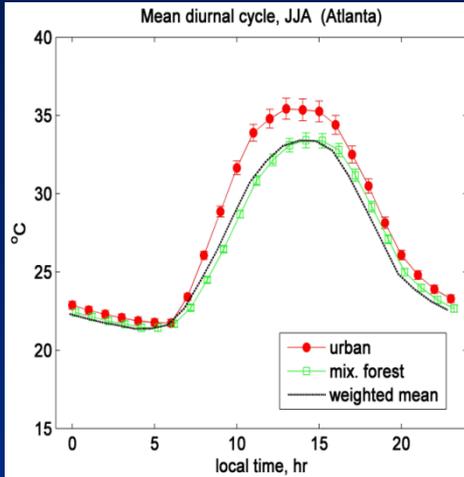


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Preliminary Results

Difference between urban and dominant vegetation

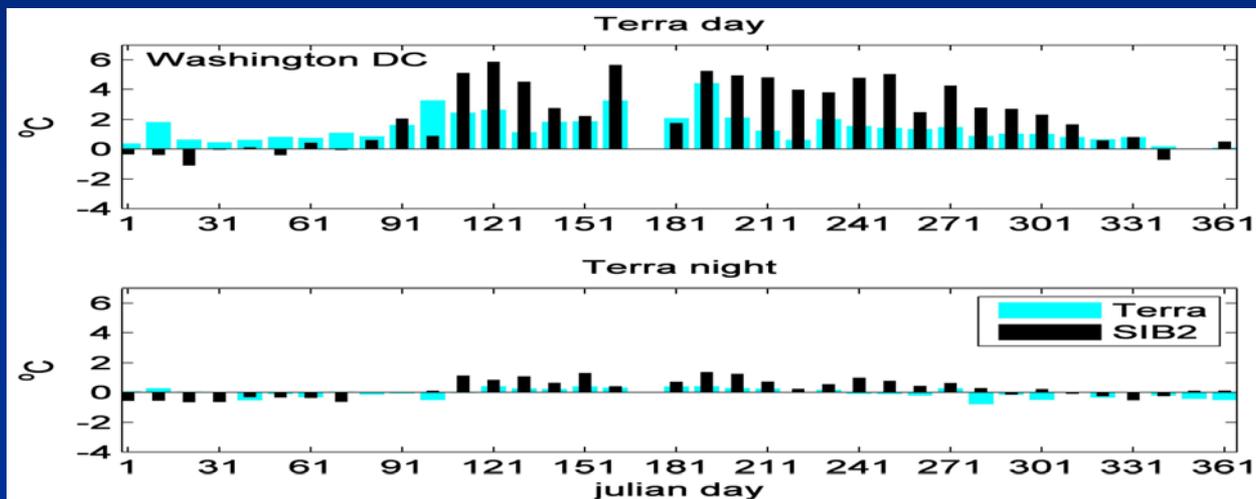
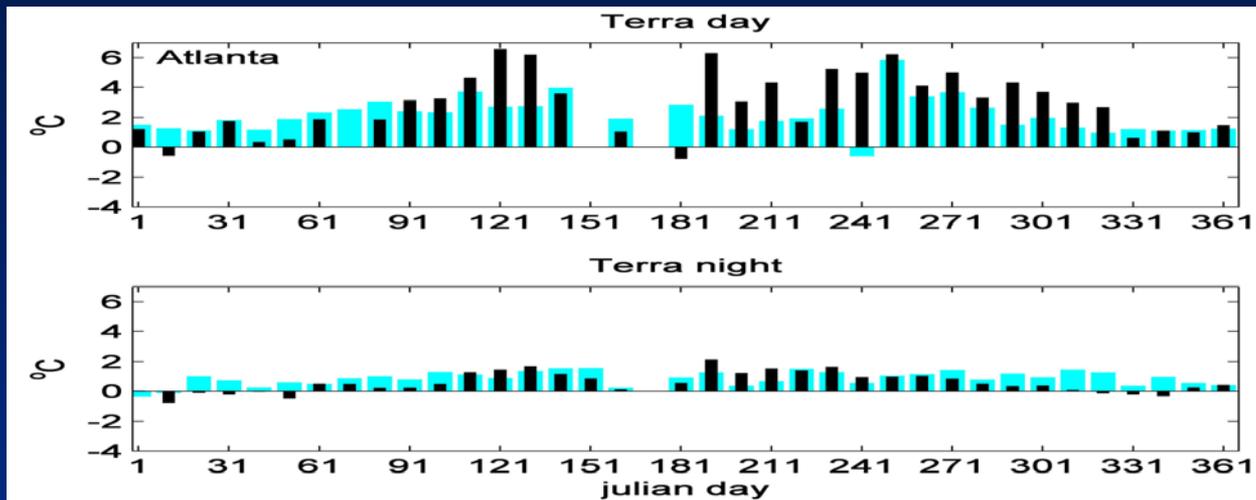
	Atla	W. DC	Phila.	Bost.
Daytime mean	2.0	3.3	3.2	2.7
Nighttime mean	0.6	0.7	1.5	1.1
Absolute	3.1	4.5	4.5	3.6



Day-	Night	Abs.
- 0.7	2.0	3.7



Preliminary Results



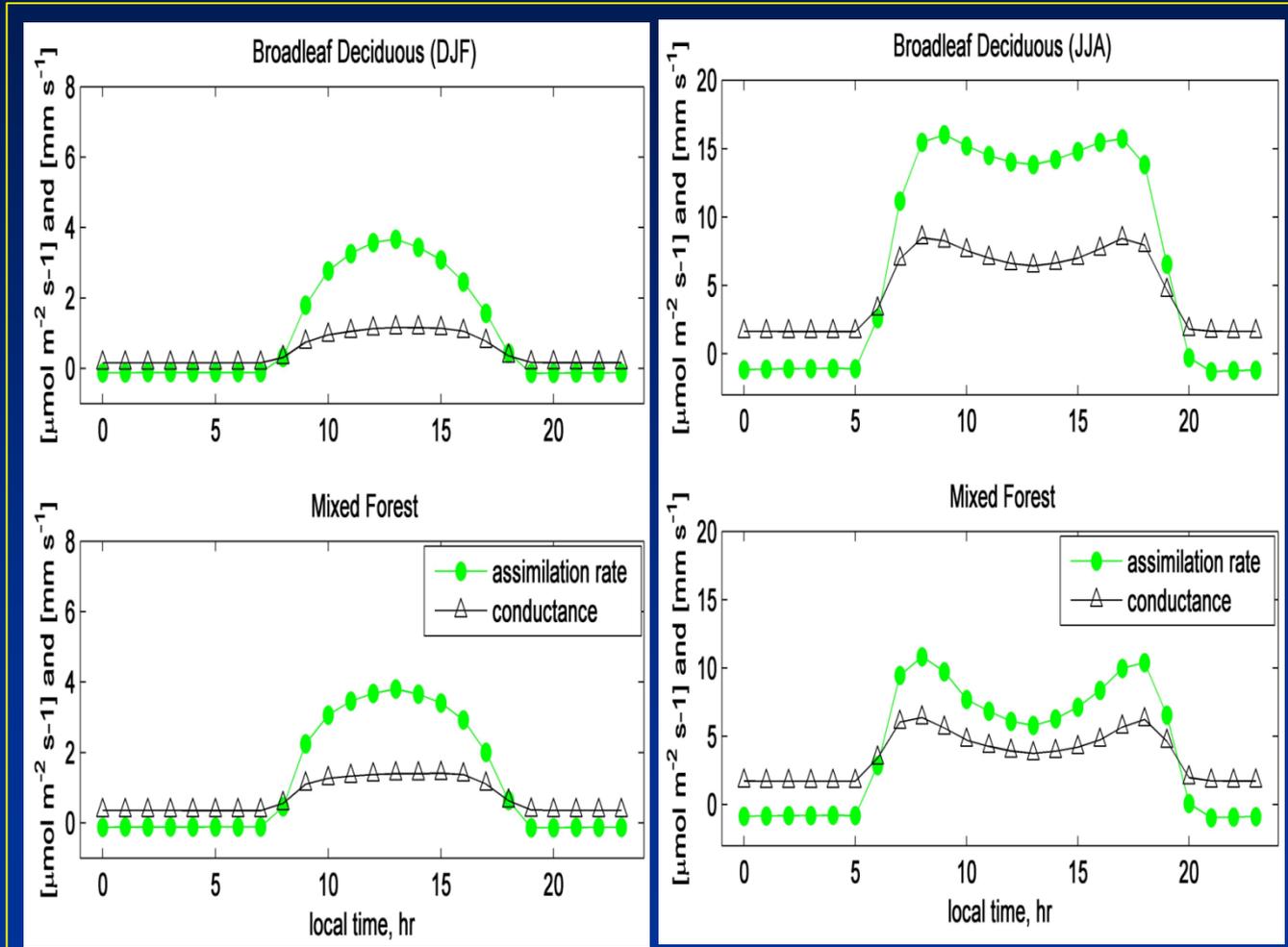
SIB2-simulated surface temperature versus MODIS /Terra LST 10-day composite difference between urban and forested land for Atlanta (a) and Washington DC (b).



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Preliminary Results

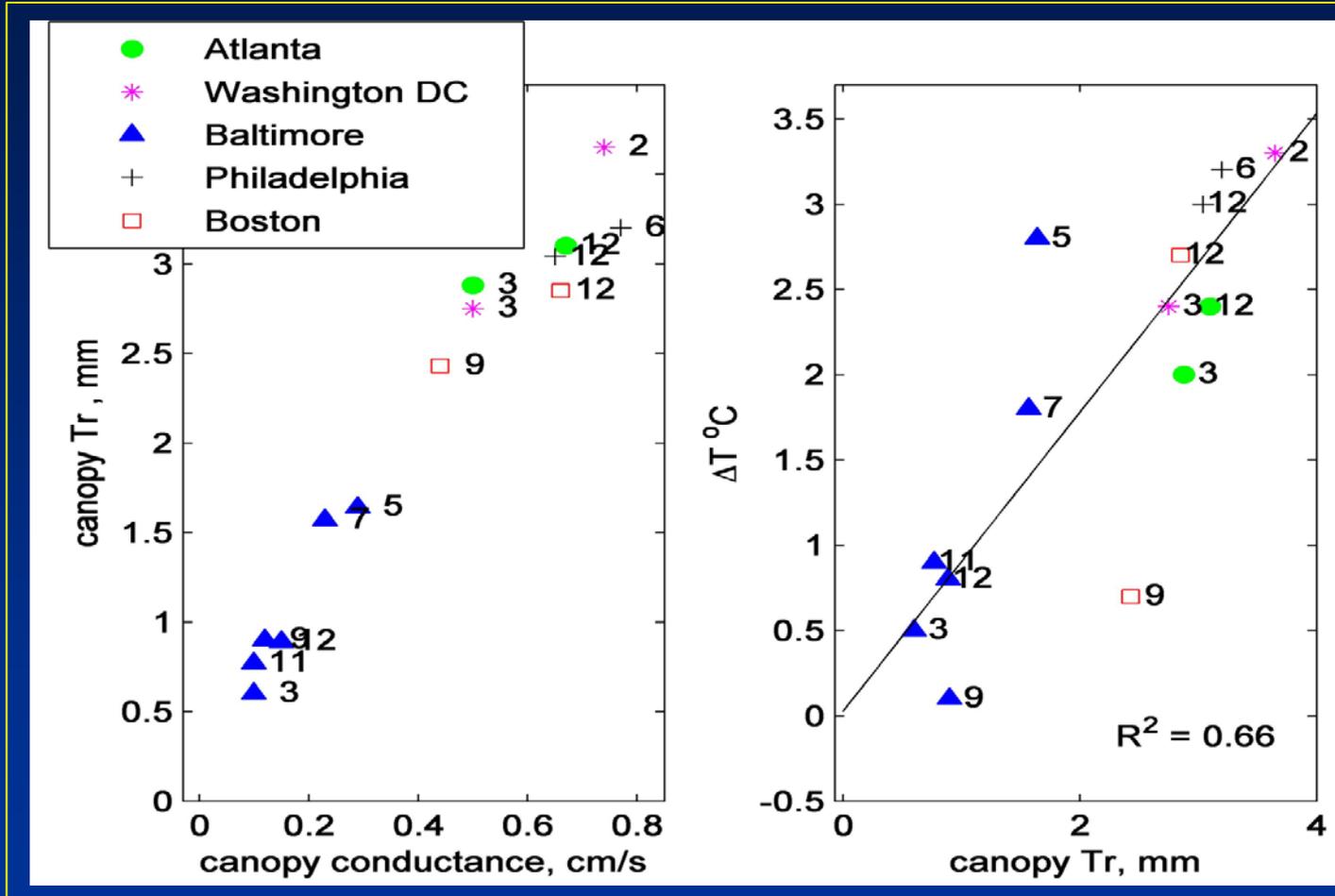
Washington DC Canopy Assimilation and conductance



Vegetation physiological activity plays an important role in modulation of surface temperature.



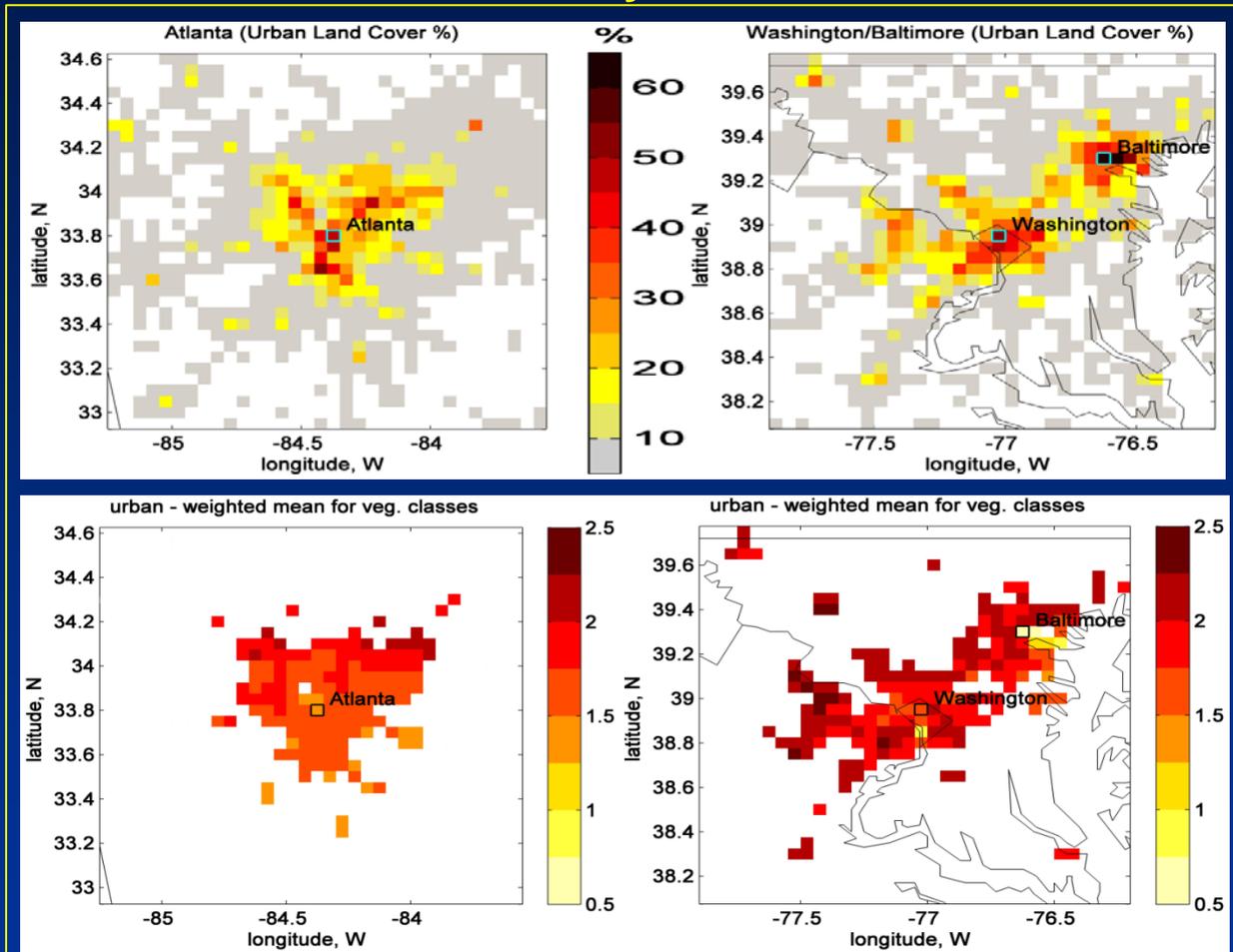
Preliminary Results



a) daytime accumulated Tr) and daytime mean canopy conductance, and (b) daytime mean surface temperature difference between urban and vegetation classes within selected cities for JJA. Numbers behind markers are vegetation classes.



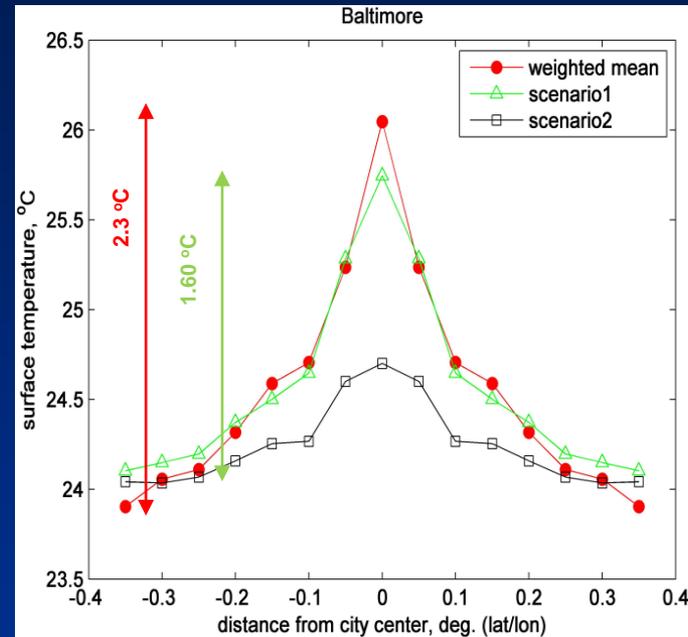
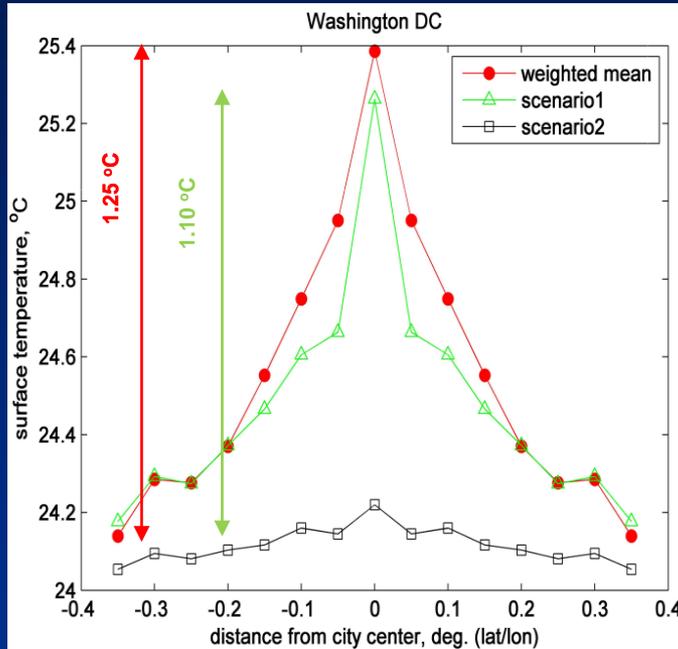
Preliminary Results



1. Geographical distribution of urban LC class (% within CMG , upper row) and surface temperature difference ($^{\circ}\text{C}$), averaged for JJA (lower row) for Atlanta (left frames) and Washington/Baltimore (right frames) regions. The difference was taken between urban class and weighted mean temperature for vegetated classes observed within each CMG . Only CMG with ISA $\geq 10\%$ are shown in lower frames



Preliminary Results



- Monthly mean surface temperature profile around city center for Washington DC and Baltimore.
- “Scenario1” represents a situation where all vegetation is replaced by broadleaf deciduous trees without changing urban temperatures and ISA fractions.
- “Scenario2” represents a situation where all vegetation and urban classes were replaced by broadleaf deciduous forest.



Preliminary Results

Water Cycle.

		DJF	MAM	JJA	SON	Annual	
	Precipitation	2.71	3.98	3.52	1.17	2.85	
Atlanta	Surface Runoff	Urban	62.4	62.8	48	37.6	55.4
		Mixed forest	4.4	3	3.1	6.8	3.9
Washington DC	Precipitation	1.85	3.04	3.9	0.96	2.38	
	Surface Runoff	Urban	51.4	56.3	45	36.5	49.2
		Broadleaf Dec.	2.2	8.6	15.4	9.4	10.1

Seasonally averaged precipitation (mm/day) and surface runoff (%) for Atlanta and Washington DC.



Preliminary Results

Carbon Cycle

We estimate the carbon loss due to urbanization by postulating that current urban areas had the same carbon assimilation rates as the surrounding land cover they replaced. Since the surrounding land in each CMG may have several cover types, we estimate the carbon lost to urbanization by replacing the urban areas by :

- 1) the vegetation class that has the lowest carbon uptake,
- 2) by that having the highest carbon uptake and
- 3) by the weighted average carbon uptake from all vegetation existing in the CMG.

To put these results into context, we compare them to the total gain made by agriculture since Pre-Agriculture.

	Minimum	Average	Maximum
Carbon loss to urbanization (%)	-0.90	-1.35	-1.80
Carbon gain from agriculture (%)	23.5	12.50	5.01

In the worst case scenario, (urbanization and croplands have both replaced the most productive lands, we estimate carbon lost to urbanization to be 1.8% whereas agriculture has increased carbon uptake by 5.01% over the CONUS.

While statistically distinct, these numbers are striking considering that agriculture represents about 32.10% (2.75 PgC) of the total land whereas urbanization represent only 1.06% (0.003 PgC).



Thank you