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Impact of Urbanization on the Continental US Surface Climate

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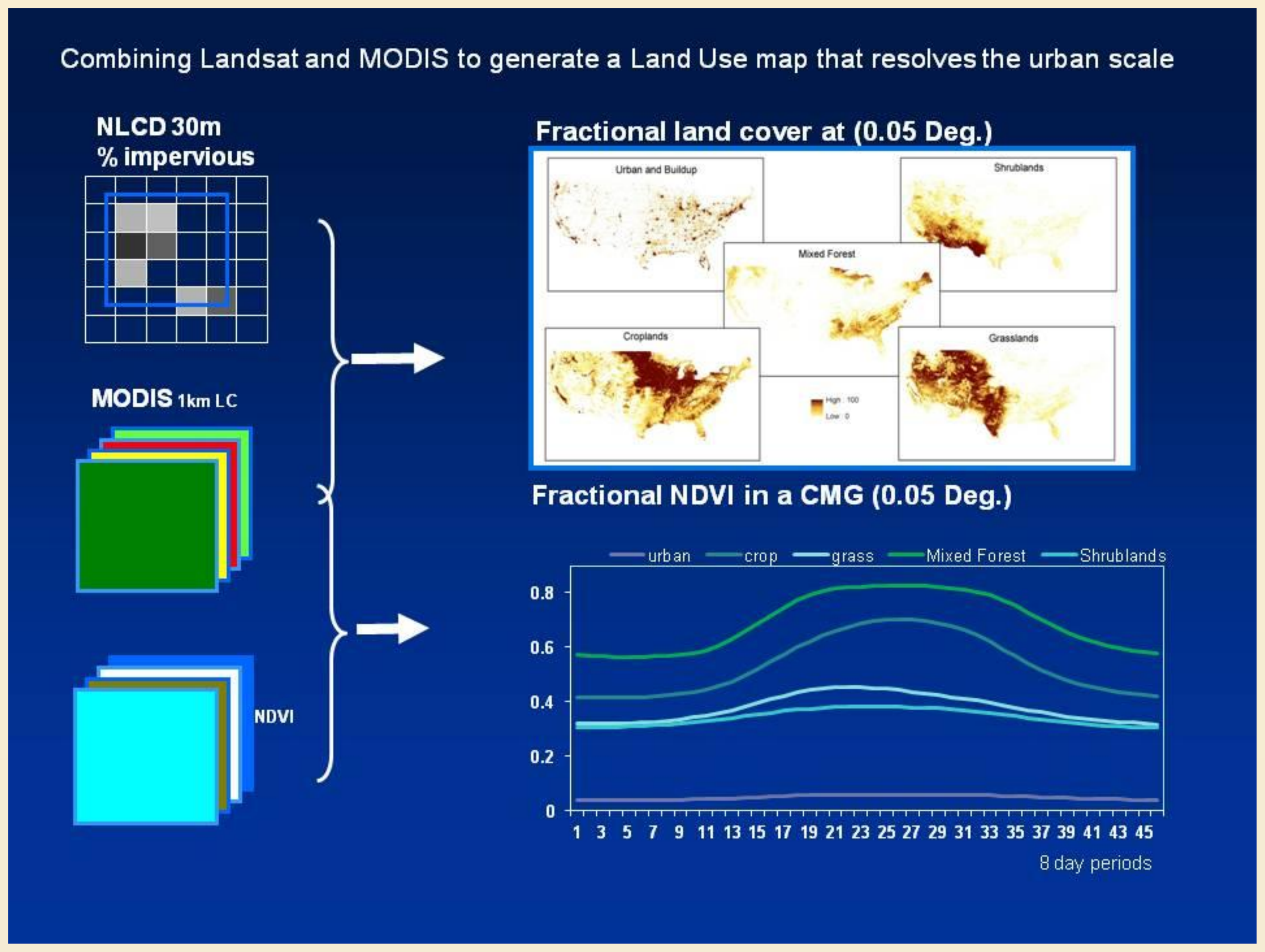
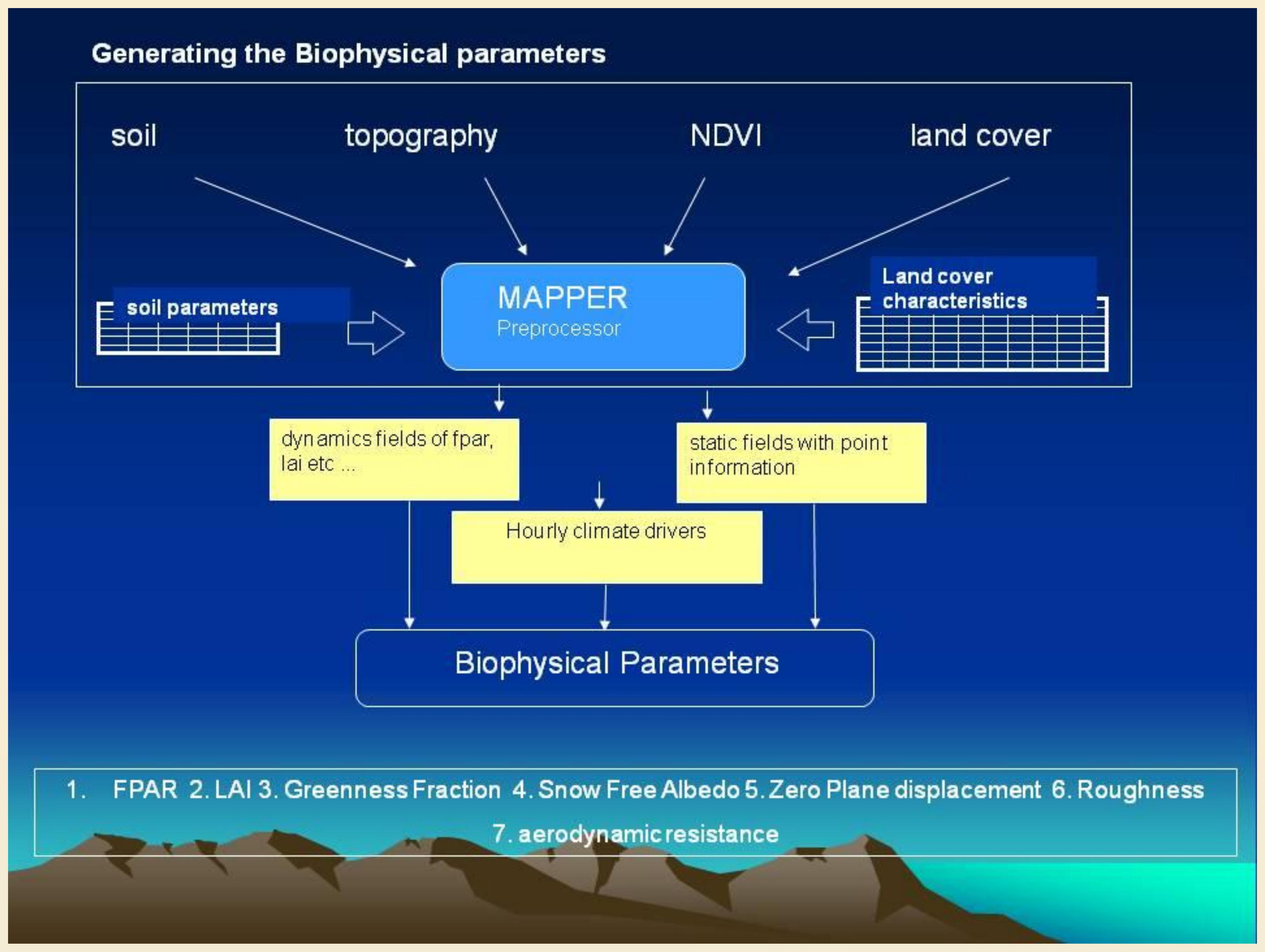
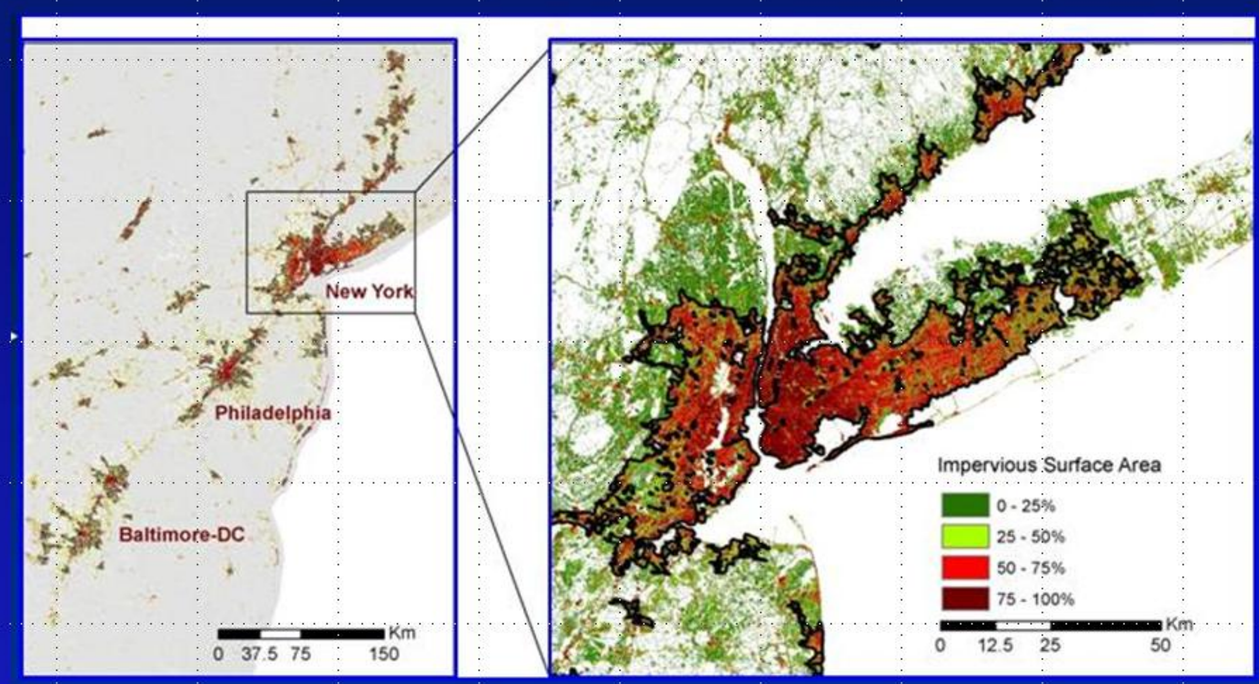
In term of areal extent urbanization appears as a minor land transformation. With respect to biophysical processes however, it represents a significant and long-lasting land disturbance. We combine Landsat- and the Moderate Resolution Imaging Spectroradiometer -based products in a land surface model to assess the impact of urbanization on continental US (CONUS) surface climate [1]. In terms of land surface (skin) temperatures, we found CONUS impervious areas to be 1.9ºC warmer than surroundings during summer and 1.5ºC during winter, and expel 12% of precipitation as surface runoff during summer compared to 3.2 % over vegetation. We also found the carbon lost to urbanization at 1.8% of the total, a striking number considering urbanization occupies only 1.06% of CONUS land. These analyses reveal an uneven impact of urbanization across the continent that should inform upon policy options for improving urban growth including heat mitigation and energy use, carbon sequestration and flood prevention.





No comprehensive study has approached the Northeast urbanized region from the standpoint of an urban aggregation acting on climate



We will run experiments using SiB2 model to simulate the recent past (2001), present (2015), and near future (2020) impact of urbanization on regional mesoscale climate.

Carbon

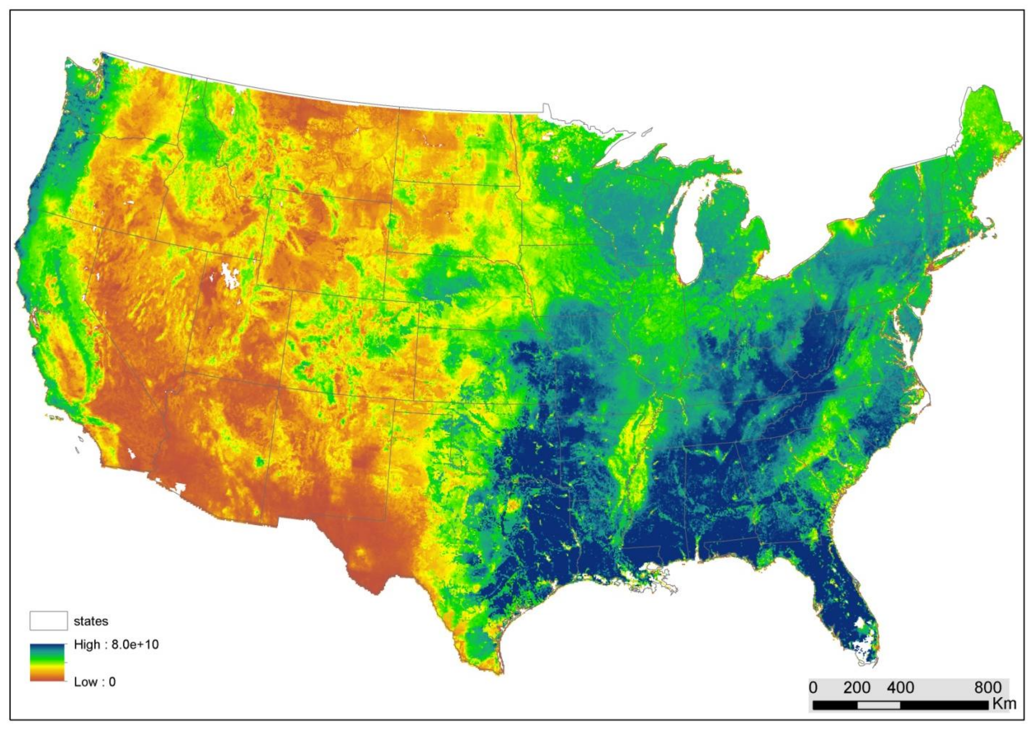


Figure 1: SiB2 GPP in 2001 in gram carbon.

The SiB2 modeled (Gross Primary Production) GPP over CONUS is ***7.10*** Pg which is comparable to the MODIS estimated GPP of ***6.29*** Pg [1 PgC= 10^{15} grams of Carbon], noting that MODIS carbon estimates preclude pixels labeled buildup.

We estimate the carbon lost due to urbanization by postulating that, under same climate, current urban areas had the same carbon uptake rates as surrounding vegetation they replaced. Since LC classes differ in each CMG, we estimate the carbon lost to urbanization by replacing the impervious surface by 1) the least productive vegetation class, 2) by the most productive vegetation and 3) by the weighted average carbon uptake from all vegetation classes existing in the CMG to constrain this reconstructed "PRE-urban" scenario between two realistic extremes. The carbon lost to urbanization is then obtained by subtracting the total actual carbon uptake in the CMG from that of the "PRE-urban" condition.

In the 'maximum impact' scenario, i.e. urbanization and croplands have both replaced the most productive lands; the carbon lost to urbanization represents ***1.8%*** of the total continental uptake, whereas carbon gain from agriculture represents ***5.0%*** of the total. While statistically distinct, these numbers are striking considering ***agriculture*** occupies ***32.1%*** of the total land while ***urban impervious areas*** occupy only ***1.1%*** over the continental US. The carbon loss is ***0.9%*** if both agriculture and urbanization took place over the least productive lands.

Temperature

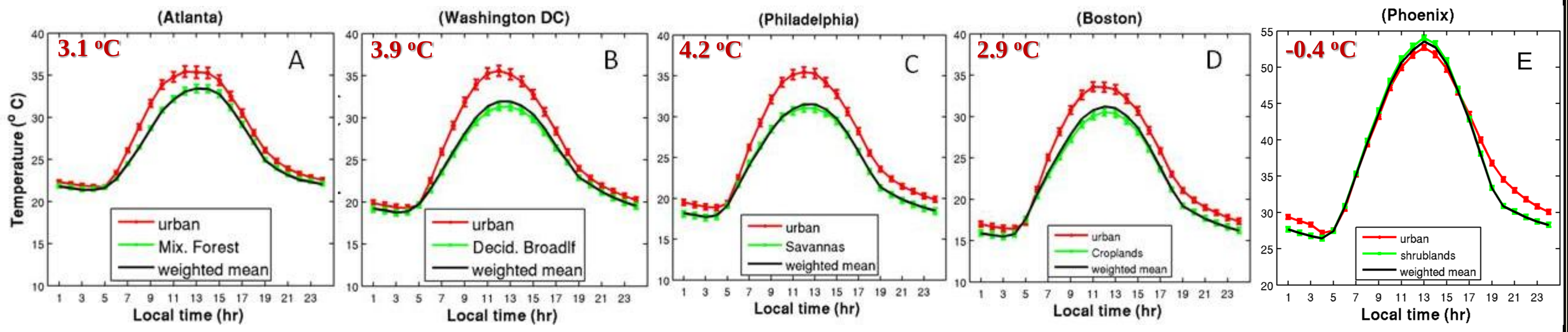


Figure 2: Summer (June, July and August) mean land surface (skin) temperature diurnal cycle for the urban class, the vegetation class with the highest fraction, and the weighted average temperature of all vegetation classes (excluding urban) co-existing within the Climate Modeling Grid for (A) Atlanta, (B) Washington DC, (C) Philadelphia , (D) Boston, and (E) Phoenix. The maximum day time temperature difference between urban and weighted mean for each city is shown on the upper left corner.

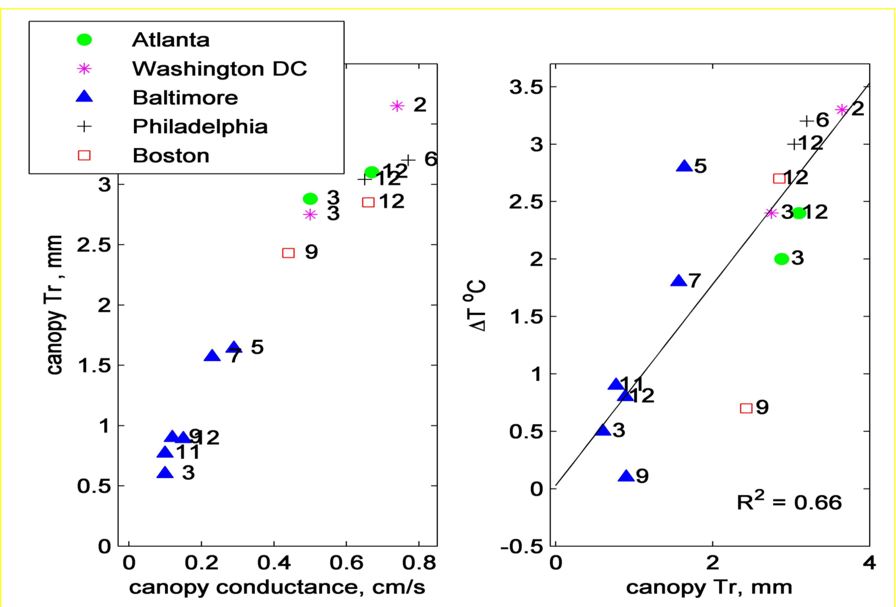


Figure 3: Daytime accumulated Tr and daytime mean canopy conductance (left panel), and daytime mean surface temperature difference (right panel) between urban and vegetation classes within selected cities for JJA. Numbers behind markers are vegetation classes.

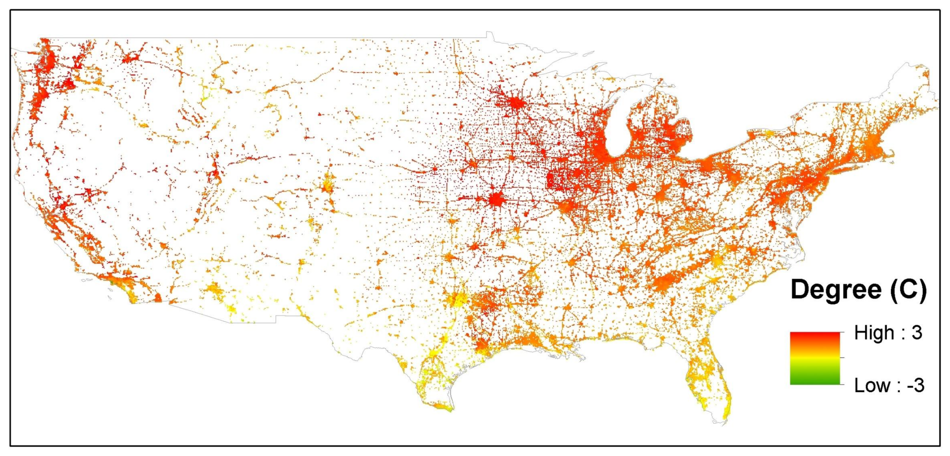


Figure 5: Temperature difference between impervious surface area and the weighted vegetation land cover types co-existing in the CMGs which have ISA equal or more than 1%. The monthly canopy temperature from June, July, August are used for this figure.

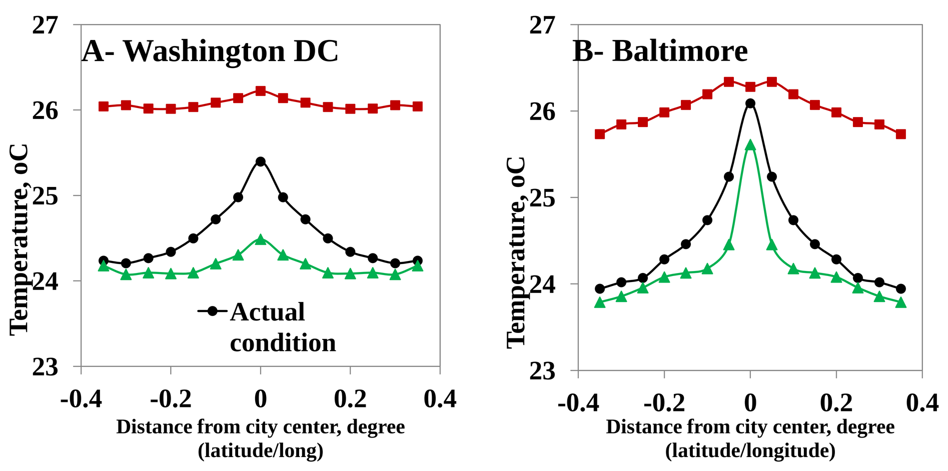


Figure 4: Summer (June-July-August) mean surface temperature profile across Washington DC (A) and Baltimore (B). From the city center, spatial average surface temperature is calculated using rings of CMGs with outward increasing

For most eastern U.S cities, the urban LST is higher than that of vegetated lands for much of the daytime, with absolute differences reaching ***3.1 ºC*** in Atlanta and ***3.4 ºC*** in Washington DC. For Phoenix and similar cities built in arid zones, the model simulated an urban heat sink characterized by urban temperatures slightly cooler than surroundings during daytime.

Aggregated over the CONUS, ISA is warmer than vegetated land by ***1.9 ºC*** during summer and ***1.5ºC*** during winter.

Our results strongly support the concept that ***transpiration-driven cooling*** is a major factor modulating the surface temperature difference between urban and vegetated lands, and that the choice of a mix of trees within an urban composition is an important ecosystem service in the regulation of LST and mitigation of the UHI.

Water

City			DJF		JJA		Annual Mean		Actual runoff
Atlanta	Precipitation		2.71		3.52		2.85		
	Surface runoff	Urban	1.69	**62.4**	1.67	**47.0**	1.58	**55.4**	**28.9**
		MF*	0.12	**4.4**	0.11	**3.1**	0.11	**3.9**	**1.6**
DC	Precipitation		1.85		3.70		2.38		
	Surface runoff	Urban	0.95	**51.4**	1.67	**45.0**	1.17	**49.2**	**25.7**
		BD**	0.04	**2.2**	0.57	**15.4**	0.24	**10.1**	**2.4**

** MF: Mixed Forest* *** BD: Broadleaf Evergreen Forest*

At continental and seasonal scales, urban areas expel 12% of incoming precipitation as surface runoff during summer (June-July-August) compared to only ***3.2 %*** over vegetated lands, with corresponding values of ***14.3%*** and ***1.1%*** during winter (December-January-February). This confirms that the choice of tree species in an urban setting also influences surface water discharge and may be considered to reduce the risk for flash flooding.

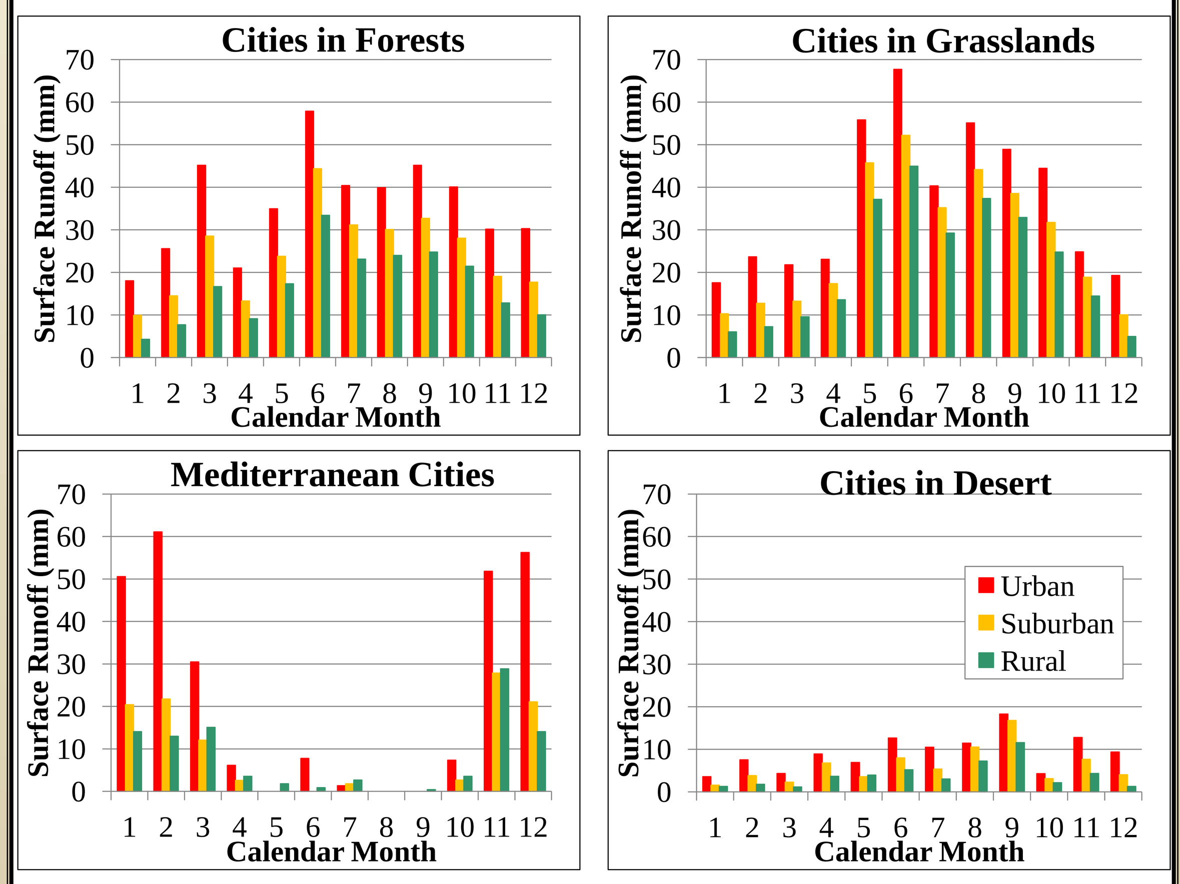


Figure 6: The monthly surface runoff for USA cities built in four major biomes. Urban areas expel more precipitation as surface runoff than surrounding suburban area (0-5km outside the urban area) and rural area (15-20km outside the urban area). Even though forest cities have more precipitation than grassland cites, forest cities have similar or less surface runoff than grassland cities. For desert cities, the surface runoff is less than 20mm/month all year long.

1. Bounoua, L., P. Zhang, K. Thome, et al., 2015. "Mapping Biophysical Parameters for Land Surface Modeling over the Continental US Using MODIS and Landsat," Dataset Papers in Science, vol. 2015, Article ID 564279, 11 pages, 2015. doi:10.1155/2015/564279.