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A wedge strategy for mitigation of urban warming in future climate scenarios

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Outline

- ◆Background
- ◆Objective
- ◆Methods
- ◆Results and discussion
- ◆Conclusion

Background

More than 50% of the world’s population currently lives in cities, and that number is projected to increase to 70% by year 2050.

Heat island effect will directly endanger the health of urban residents.

Heat stress associated with climate change is projected to a large reduction in workplace productivity.

参考文献（作者、时间）	减缓措施	模拟工具	模拟区域	模拟时间	最内层嵌套分辨率	实验案例设计	研究结果 城市峰值温度降低幅度（°C）
Hashem Akbari (2012)	高反射率屋顶	UVic ESCM	全球±20°/±45°	2010-2300	~	△cool roofs =0.1(±20°) △cool roofs =0.1(±45°)	模拟结果表明（表面反照率增加0.01）长期全球降温效应为3×10^{-15} K。
Dev Millstein (2011)	高反射率屋顶	WRF (3.2.1) - SLUCM	美国	12summer periods (1998-2009)	(Domain1) 25Km	Cool urban (0.25×0.25+0.15×0.35)=+0.115	城市地区下午的夏季温度降低了0.11-0.53°C
Surabi Menon (2010)	高反射率屋顶	AGCM	全球/美国	1984-1995 (June to August)	2°×2.5° 0.5°×0.5°	△urban albedo=0.03	全球陆表面温度降低约0.08°C 美国陆表面温度降低约0.09°C
K.W. Oleson (2010)	高反射率屋顶	CAM (3.5)	全球	1941-1999	1.9°×2.5°	Cool roof = 0.9	城市区域日最大降温0.6°C，最小降温0.3°C
Mark Z. Jacobson (2011)	高反射率屋顶	(GATOR-GCMOM)	全球	2006-2025	4°×5° 0.01°×0.01°	cool roofs =0.65	城市区域年平均温度降低0.02°C
F. Salamanca (2016)	高反射率屋顶	WRF-BEP+BEM	美国菲尼克斯	2009.7 10-19号	(Domain1) 4Km	Cool roof fraction= 25% 50% 75% 100%	高反射率屋顶能减少13 - 14%能源需求

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Hongyun Ma (2014)	高反射率屋顶	WRF (3.0) - SLUCM	中国北京	2002.7 13-15号	(Domain2) 1Km	Cool roof=0.8	高反射率屋顶在7月14号中午最大降温为1.4 °C
Mingna Wang (2013)	高反射率屋顶	WRF (3.3) - SLUCM	中国北京-天津-河北大都市区	2010.7 2-6号	(Domain2) 4Km	Control roof=0.12 Cool roof=0.8	城市日平均温度降低了0.51°C，可抵消80%城市20年（1990-2010）扩张引起的增温效应。
Meichun Cao (2015)	高反射率屋顶	WRF (3.6) - SLUCM	中国广州	heat-wave events 31 episodes (2001-2010)	(Domain3) 4Km	Control roof=0.12 Cool roof =0.55	6次最强热浪城市中午平均降温1.2°C 25次（2004-2008）夏季热浪中城市中午平均降温0.8°C

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Ting sun (2016)	绿色屋顶	WRF - PUCM	中国北京	2010.7 03-07号	(Domain3) 1Km	Green roof fraction= 10% 20% 50% 80% 100%	Green roof 10%: 0.22; 20%: 0.4; 50%: 1.1; 80%: 1.8; 100%: 2.5
Xian-Xiang Li (2015)	绿色屋顶	WRF (3.2.1) - SLUCM	新加坡	28 episodes (2007-2008)	(Domain5) 0.3Km	Green roof=100%	平均降低城市热岛强度1oC，特别在新加坡西部地区下午两点最高平均降低2oC。
Kathryn R. Smith (2010)	绿色屋顶	WRF - SLUCM	美国芝加哥	15-16 July 2006	(Domain1) 1Km	Green roof =100%	城市环境的温度降低3oC
Dan Li (2014)	高反射率/绿色屋顶	WRF - PUCM	美国华盛顿大都市区	2008.7 07-10号	(Domain3) 1Km	Green roof fraction=10% 20% 30% 50% 70% 100% Albedo roof=0.70 Cool roof fraction=10% 20% 30% 50% 70% 100%	10% / 20% / 30% / 50% / 70% / 100% Green roof: 0.4 / 0.8 / 1.2 / 1.85 / 2.5 / 3.5 Cool roof: 0.3 / 0.6 / 1.0 / 1.7 / 2.4 / 3.3
A Sharma (2016)	高反射率/绿色屋顶	WRF（3.4.1） - SLUCM	美国芝加哥大都市区	2013.8 16-18号	(Domain3) 1Km	Green roof fraction= 25% 50% 75% 100% Cool roof=0.85	Green roof: 25%: 0.84; 50%: 1.68; 75%: 2.56; 100%: 3.41 Cool roof: 0.85: 3.22
Matei Georgescu (2014)	高反射率/绿色屋顶、高反射率绿色屋顶	WRF（3.2.1） - SLUCM	美国	2001-2008	(Domain1) 20Km	Control ① A2 cool roofs ② A2 green roofs ③ A2 green-	加利福尼亚 / 亚利桑那州 / 德克萨斯州 / 佛罗里达 / 大西洋中部 / 芝加哥,底特律 ①: 1.45 / 0.47 / 1.24 / 0.41 / 1.80 / 1.37 ②: 0.24 / 0.15 / 0.46 / 0.21 / 1.19 / 0.85

Objective

- Investigate the urban heat island intensity under current and future climate scenarios for three climate regions in the US and southern Canada.

- quantify the effectiveness of several mitigation strategies (street vegetation, green roof, cool roof and bright pavement)

- estimate aggregated temperature reduction potential of these strategies using a UHI mitigation wedge approach.

Method

Objective: Compute climatological mean temperatures and the UHI intensity

Climate scenarios: Current climate,RCP4.5,RCP8.5

Data: 33 years (1972-2004) of data in the current climate and the last 30 years (2071-2100) of data in the two future scenarios

Region： 57 cities(US and southern Canada) (temperate climate, continental climate and dry climate)

Method

Model simulations	Albedo		Mitigation strategy method			
	CTR	WHT	Cool roofs	Street vegetation	Green roofs	Reflective pavement
Current (1972–2004) RCP 4.5 (2005–2100) RCP 8.5 (2005–2100)	default (0.18 – 0.37)	0.88	online simulations, offline attribution	two-endmember interpolation	offline attribution	offline attribution

Table 1. The simulations run and the methods used to assess the temperature mitigation strategies. The online simulation method calculated the mitigation potential of cool roofs as the difference between the WHT and CTR simulations (WHT – CTR). The offline attribution and two-endmember interpolation methods used diagnostic data from the CTR simulations.

Method

Model:Community Earth System Model (CESM)
Community Land Model (CLM)

Cool roof: the average prescribed roof areal fraction in CLM 4.0 is 48.8 %

Street vegetation: $\delta T = -V \times \triangle T_C$

anthropogenic heat contribution

Urban canyon effect

Offline UHI diagnostics

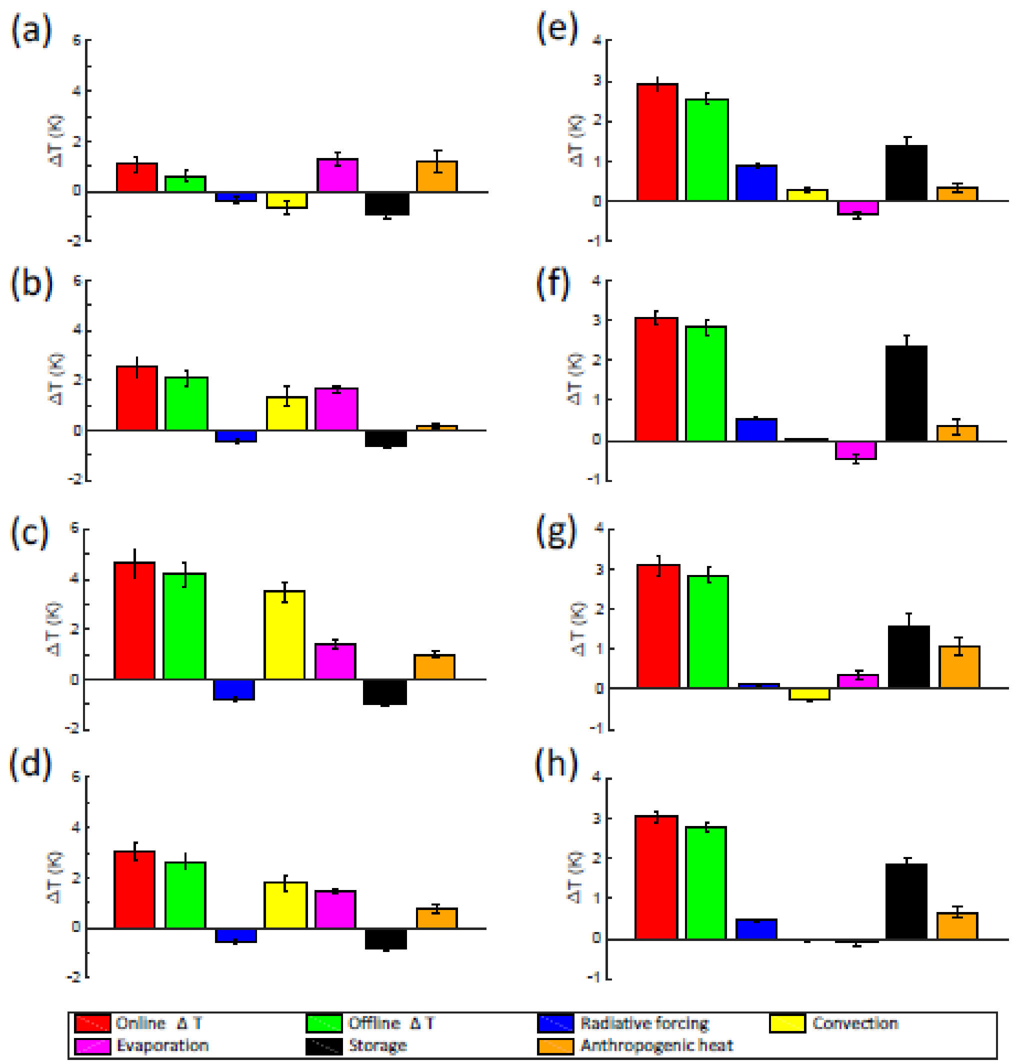

Fig 1. Attribution of summer mean UHI intensity during 2071–2100 under the RCP 4.5 scenario for the control (CTR) run. (a, b, c, d) daytime; (e, f, g, h) nighttime. (a, e) dry climate; (b, f) continental climate; (c, g) temperate climate; (d, h) all selected cities. The radiative forcing term results mostly from albedo differences between urban and rural land in the daytime and from small differences in surface emissivity at night. Error bars are 1 standard error.

Future UHI under RCP scenarios

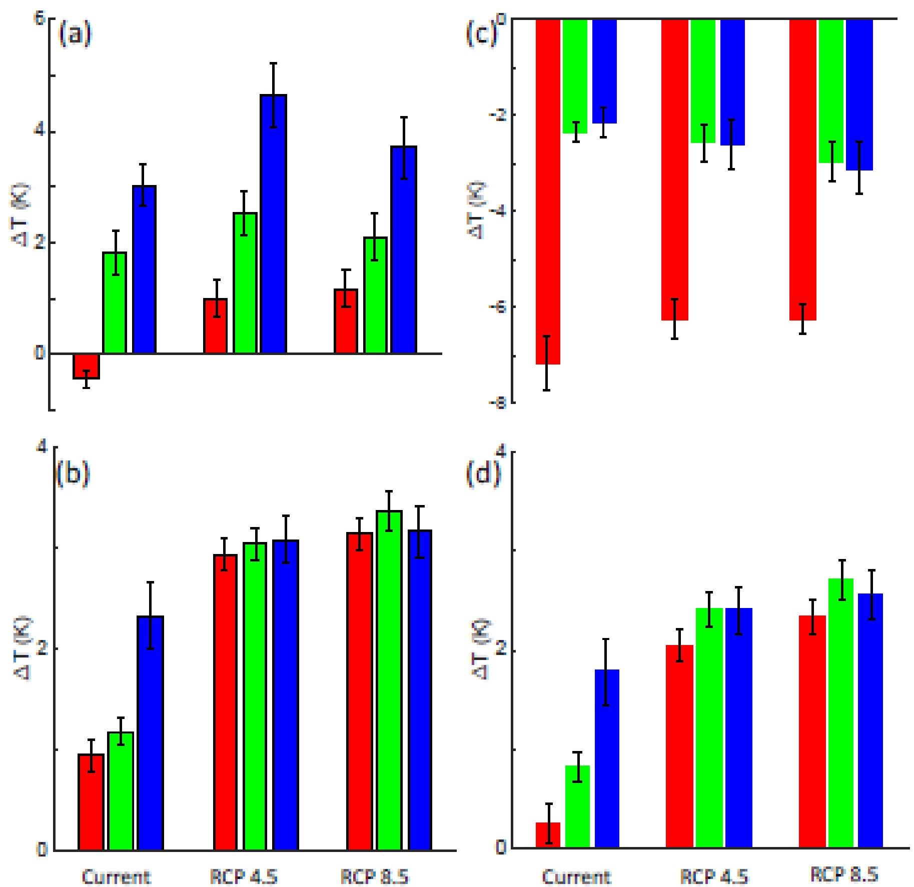

Fig 3. Urban heat island intensity from the control (CTR; a, b) and white roof (WHT; c, d) simulations. (a, c) daytime; (b, d) nighttime. Red, green, and blues bars denote dry, continental, and temperate climate zones, respectively. Error bars are 1 standard error.

Cool roof

Temperature reduction: 6.5 ± 0.3K(RCP4.5)

Reason:the higher albedo(0.88) previous studies (0.3–0.9).

define △T using radiative surface temperature rather than screen-height air temperature.

analysis and results are restricted to midday hours (13:00 local time) and summer months.

Street vegetation

Vegetation:25%-45%

Assumption: adapt to local soil moisture

Result:

1.3 ± 0.2K (temperate, RCP4.5)

0.3 ± 0.1K (dry, RCP4.5)

1.1 ± 0.1K (temperate, RCP8.5)

0.3 ± 0.1K (temperate, RCP8.5)

Problem:

anthropogenic heat contribution

street vegetation composition

Green roof

Assumption: plant water-conserving native grass on the roofs

the albedo of green roofs (0.20) is lower than the average
default roof value (0.29)

Result:1.6± 0.2K (RCP4.5, RCP8.5)

a major factor in determining the mitigation potential

White oasis effect

Oasis effect :surface cooling by evaporation
typically results in a stable inversion air layer

White oasis effect
:implementation of cool roofs may decrease the dispersion capacity of urban air

Mitigation wedges

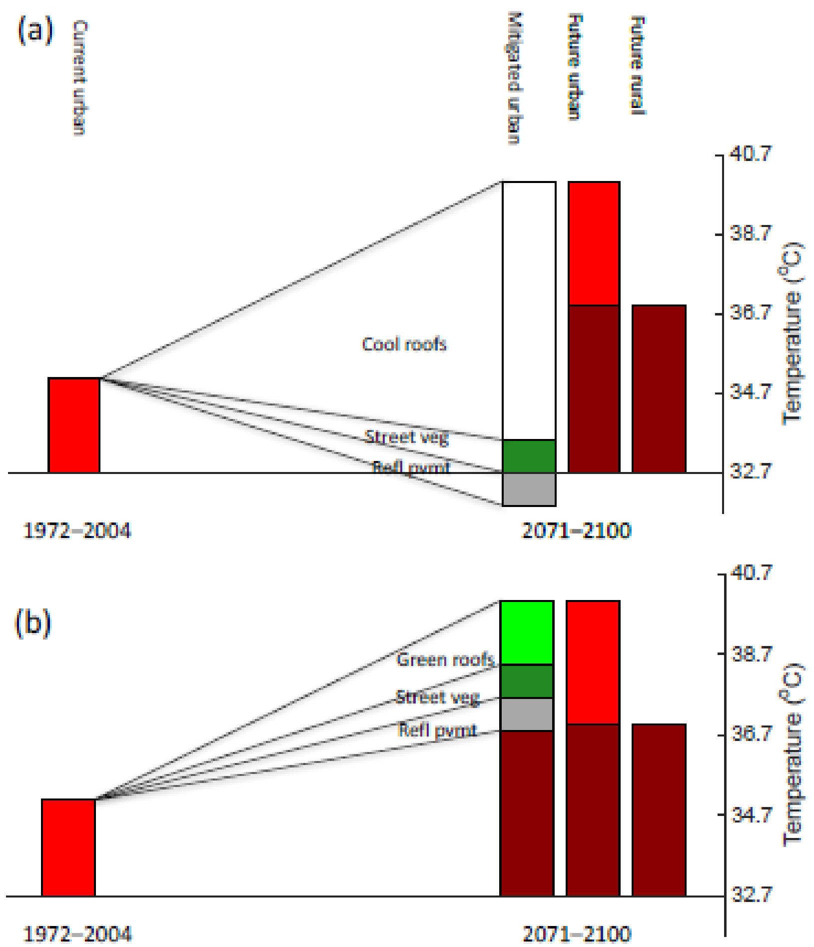

Fig 5. A UHI strategy consisting of three mitigation wedges under the RCP4.5 scenario. (a) cool roof, street vegetation, and reflective pavement; (b) green roof, street vegetation, and reflective pavement. The horizontal line marks the mean midday rural surface temperature of all 57 cities in the current climate conditions, and other temperatures are mean values relative to this rural background.

Mitigation wedges

Cool roof,Green roof

Wedge strategy: 50% cool roof,50% green roof, 100% street vegetation, and 100% reflective pavement

Aggregated potential:5.7K

Mitigation wedges

solar photovoltaics

Futuristic electricity conversion efficiency:25%

Albedo:0.33

Wedge strategy: 100% solar PV roof, 100% street vegetation, and 100% reflective pavement

Aggregated potential:2.8K

Conclusion

- Our modeling analyses favor cool roofs as the preferred method for urban heat mitigation in comparison to green roofs, street vegetation, and reflective pavement.

- Favor cool roofs as the preferred method for urban heat mitigation.

- UHI mitigation wedge strategy consisting of 50%cool roof, 50%green roof,street vegetation, and reflective pavement has the potential to reduce the urban daytime surface temperature by 5.7K in the summer from the unmitigated urban scenario.

Thanks for your listening!