CLIMATE ADAPTATION
RESEARCH SYMPOSIUM

MEASURING & REDUCING SOCIETAL IMPACTS

Designing Cooler Cities

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The session will begin shortly.

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Aldo Brandi

Arizona State University

Edith de Guzman

LA Urban Cooling Collaborative and UCLA

V. Kelly Turner

UCLA

Aldo Brandi

Ph.D. Candidate, Arizona State University

@aldobrandi5

Influence of Projected Climate Change, Urban Development and Heat Adaptation Strategies on End of Twenty-First Century Urban Boundary Layers Across the Conterminous US

Influence of Projected Climate Change, Urban Development and Heat Adaptation Strategies on End of 21st Century Urban Boundary Layers Across the Conterminous US

Aldo Brandi[*], *Ashley Broadbent*[*], *Scott E. Krayenhoff*[**], *Matei Georgescu*[*]

abrandi@asu.edu

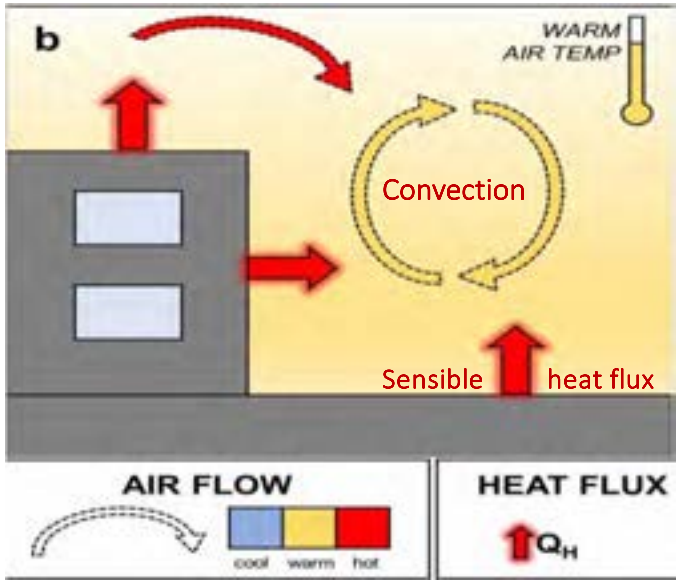
[*] Arizona State University – School of Geographical Sciences and Urban Planning
[**] University of Guelph – School of Environmental Sciences

ASU School of Geographical Sciences and Urban Planning, Arizona State University

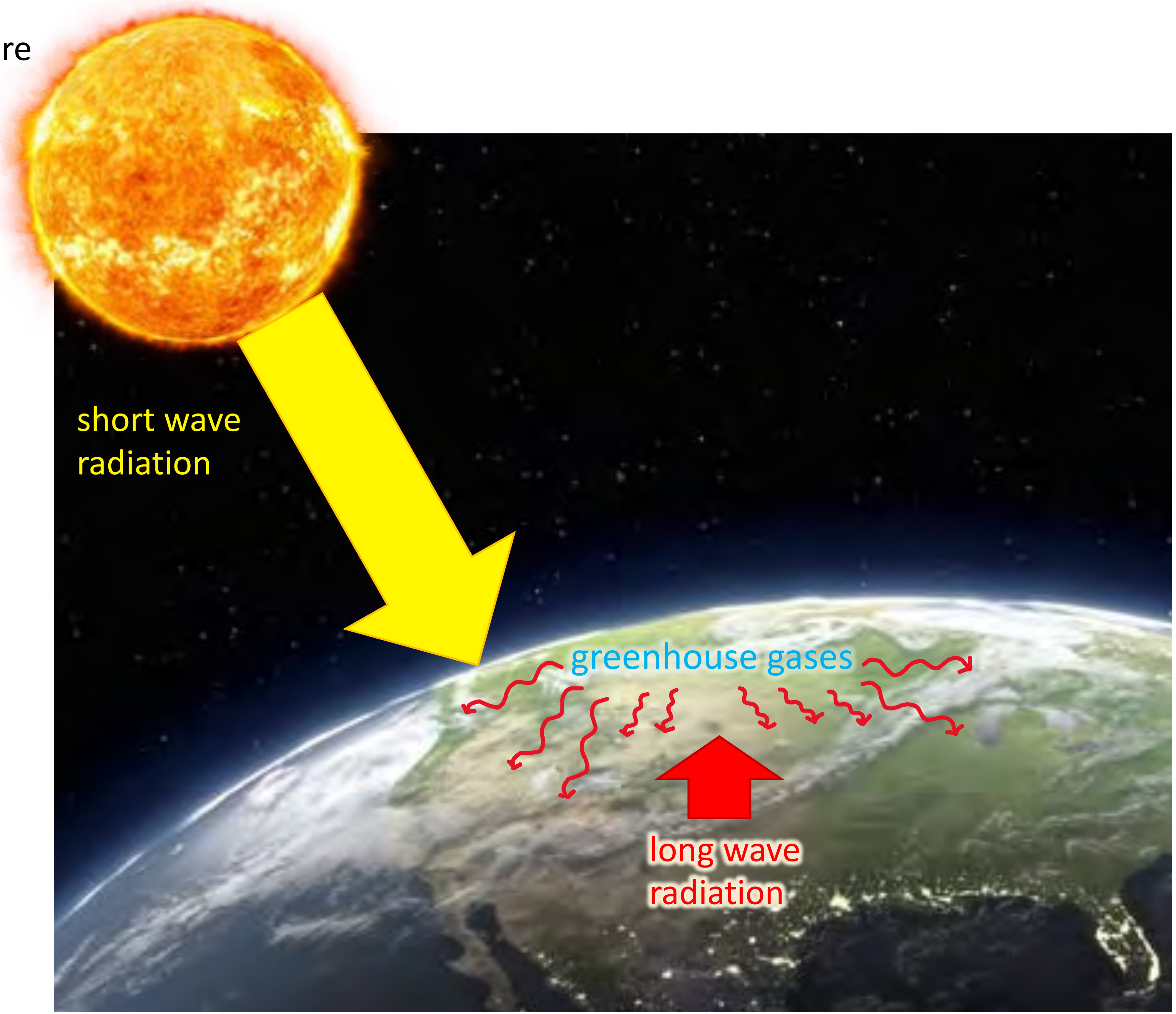
ASU Urban Climate Research Center, Arizona State University

Introduction Heat in the Atmosphere

- The **atmosphere** is **mostly transparent to short wave** solar radiation
- The **Earth surface emits long wave** radiation as a function of its temperature
- **Greenhouse gases** (**GHG;** H_2O, CO_2, CH_4) **absorb and re-emit long wave** radiation in the atmosphere

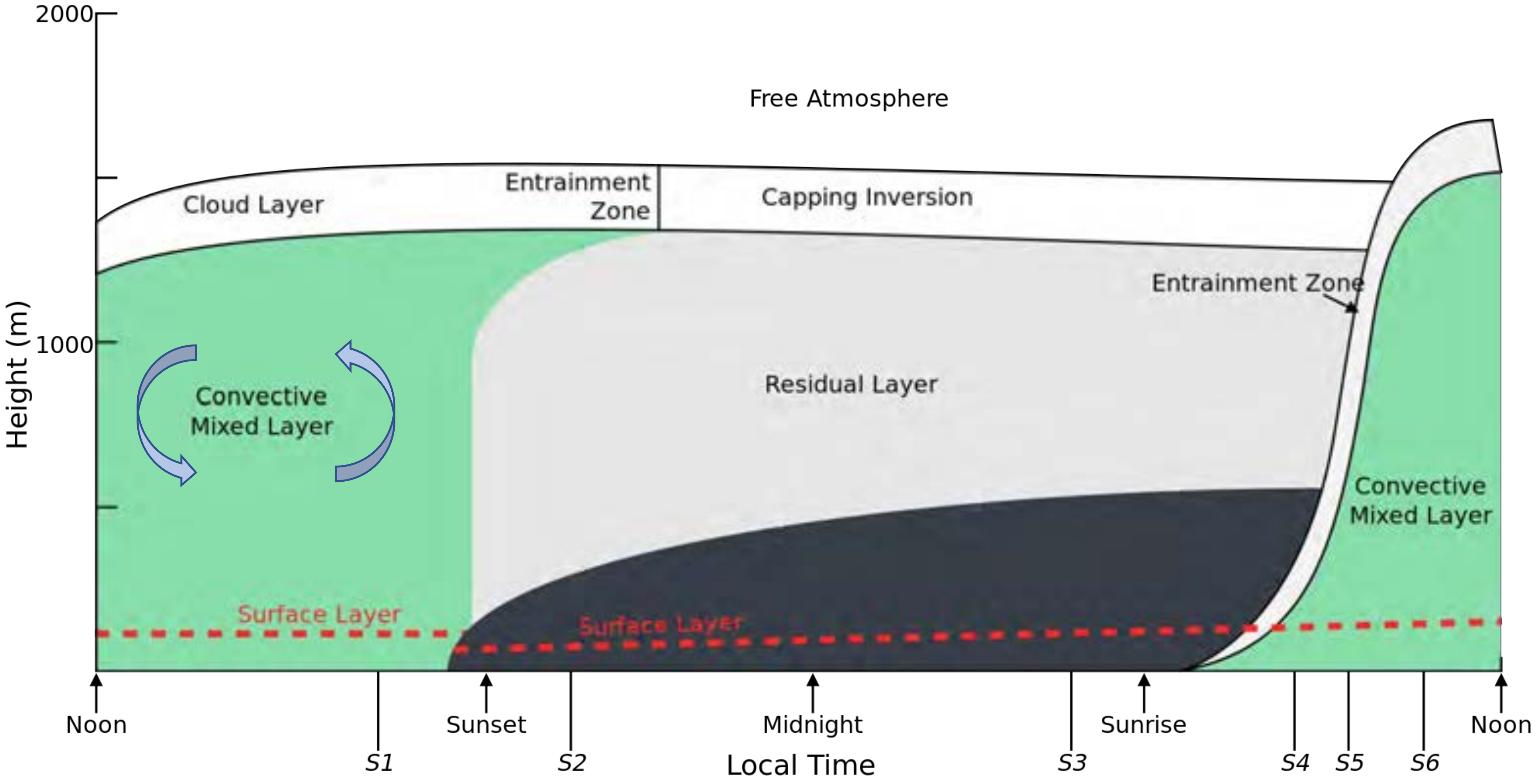


Modified from Krayenhoff et al., 2021



Introduction The Planetary Boundary Layer

"... is that part of the troposphere that is directly influenced by the presence of the earth's surface" (Stull, 1988)



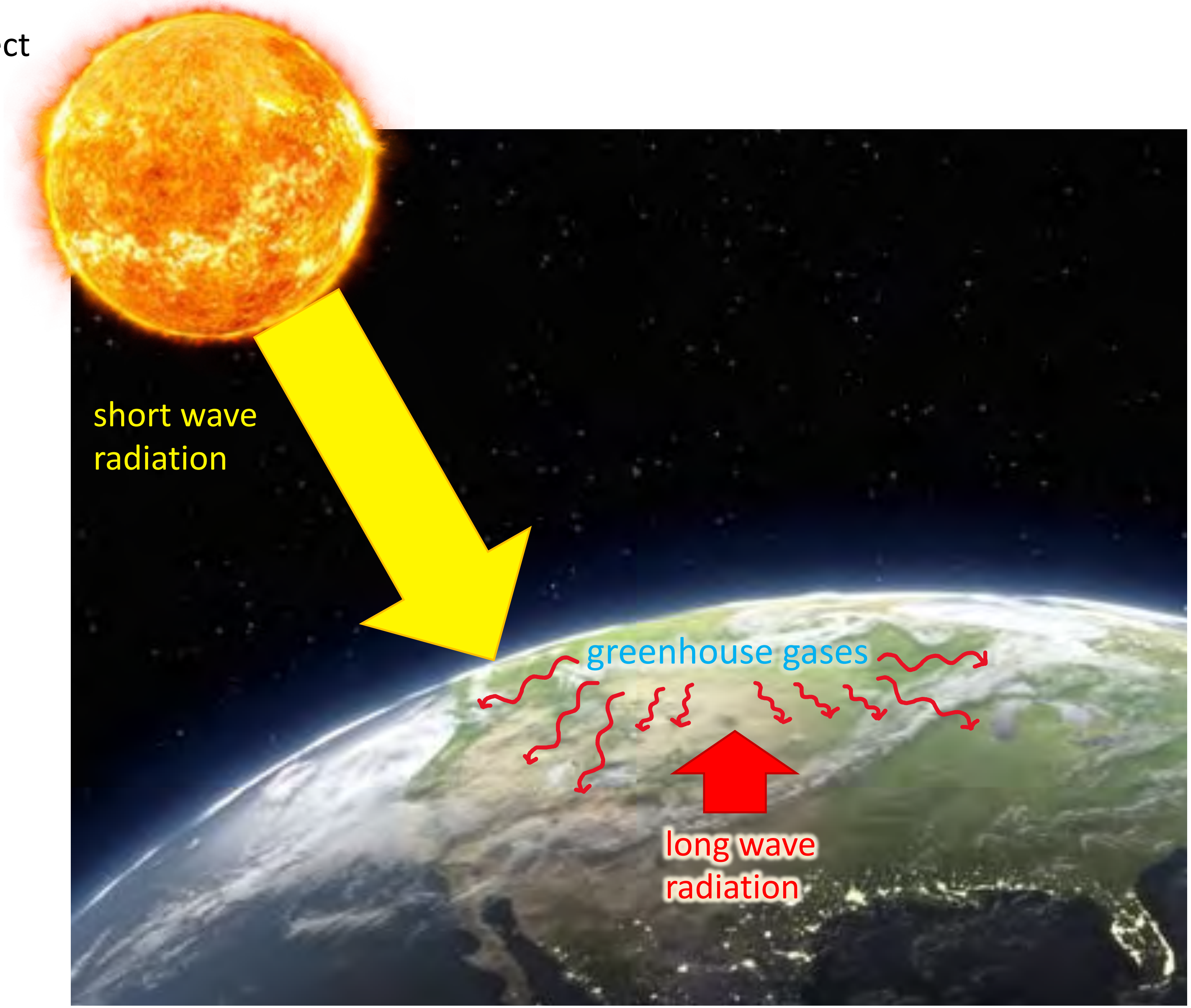
From "An Introduction to Boundary Layer Meteorology" - Stull, 1988

Introduction The Greenhouse Effect

Increase in GHG concentration

Global Warming

Climate Change



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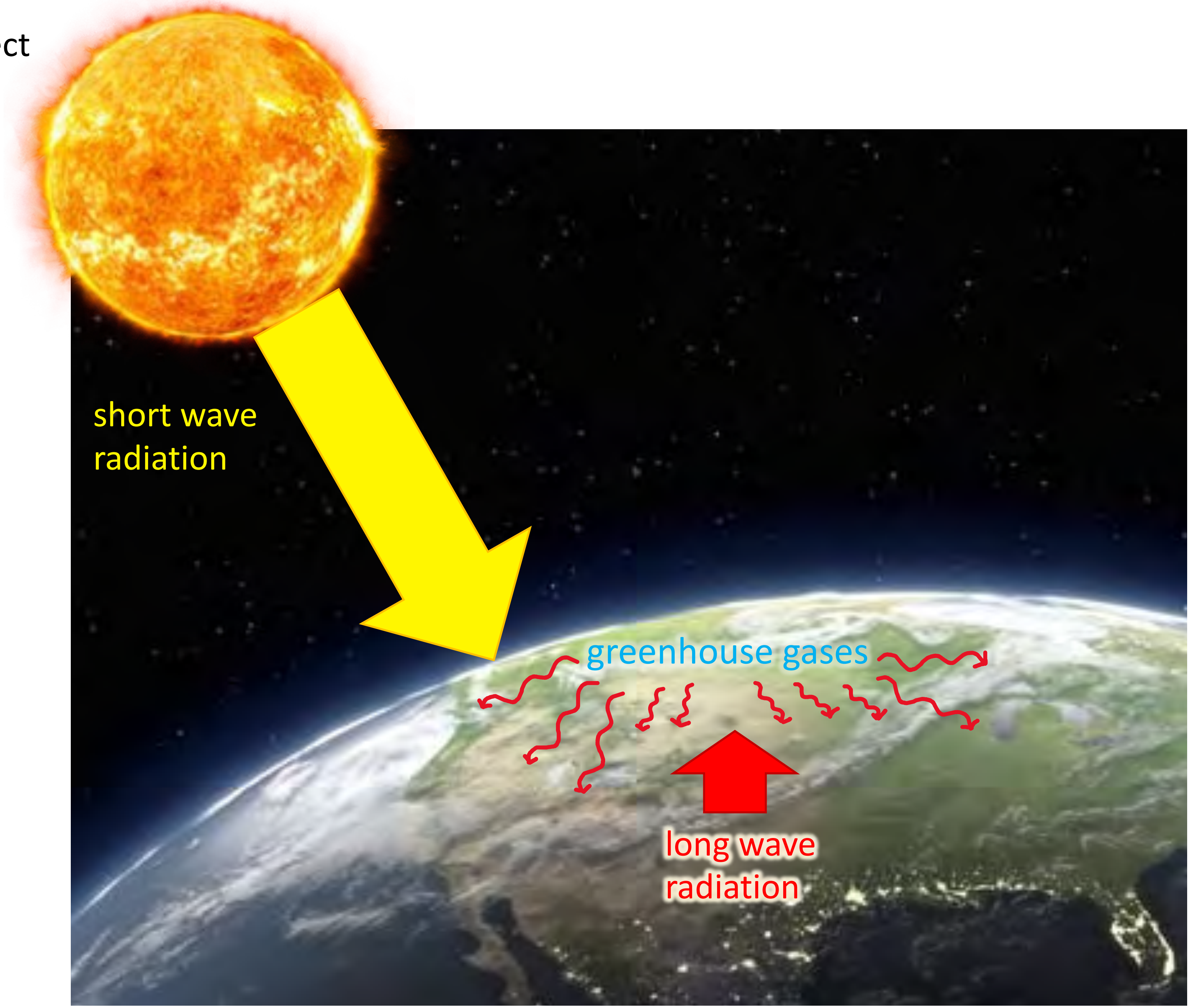
From https://twitter.com/DrShepherd2013, 2021



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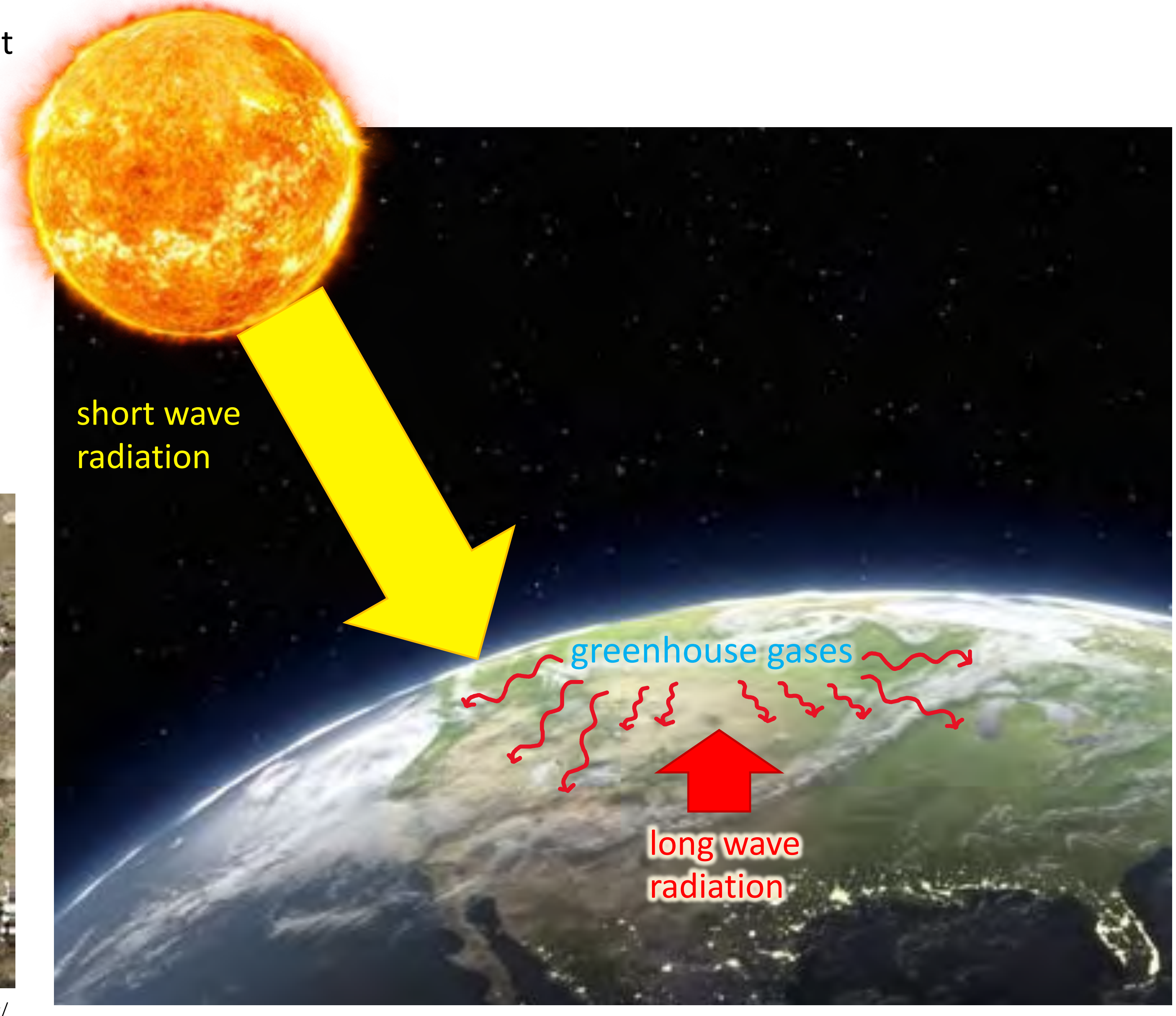
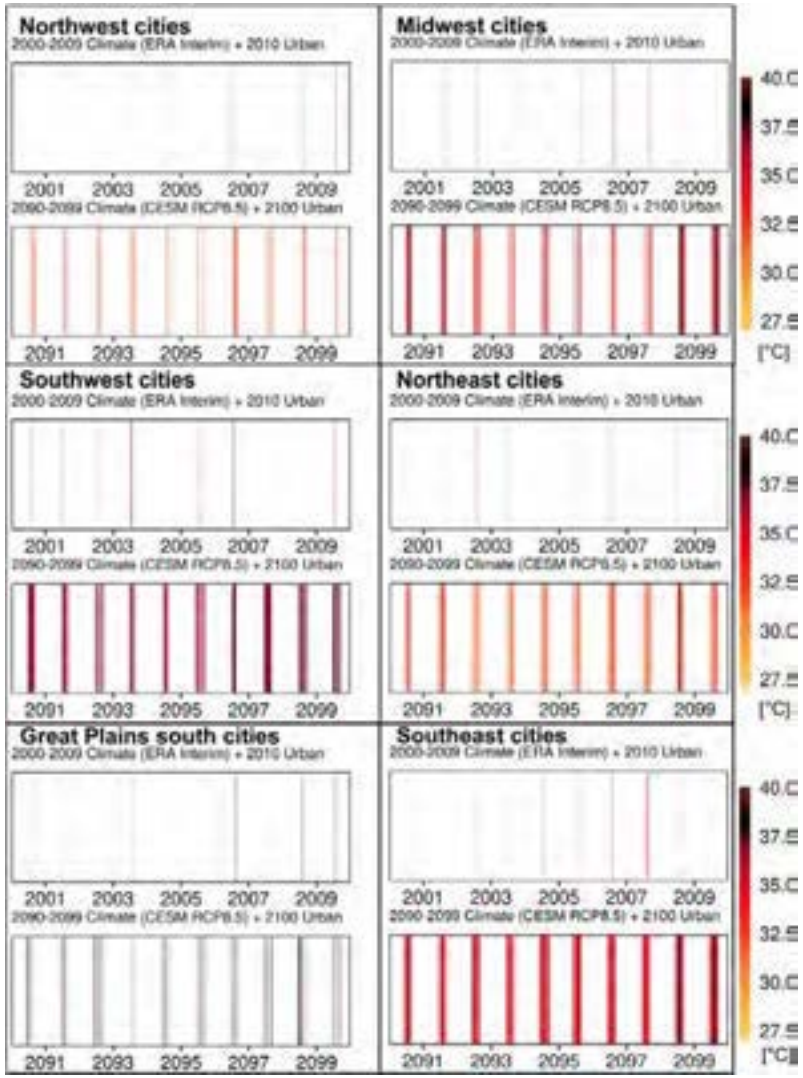
From https://www.nasa.gov/

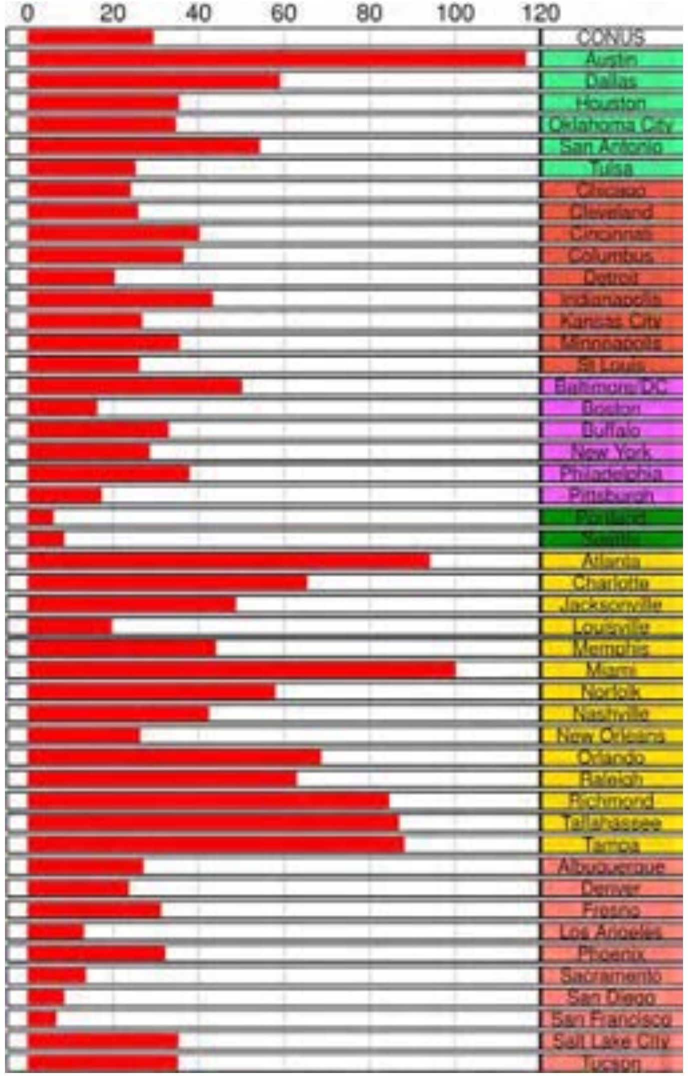


Introduction Climate Change Impacts

Heat Waves

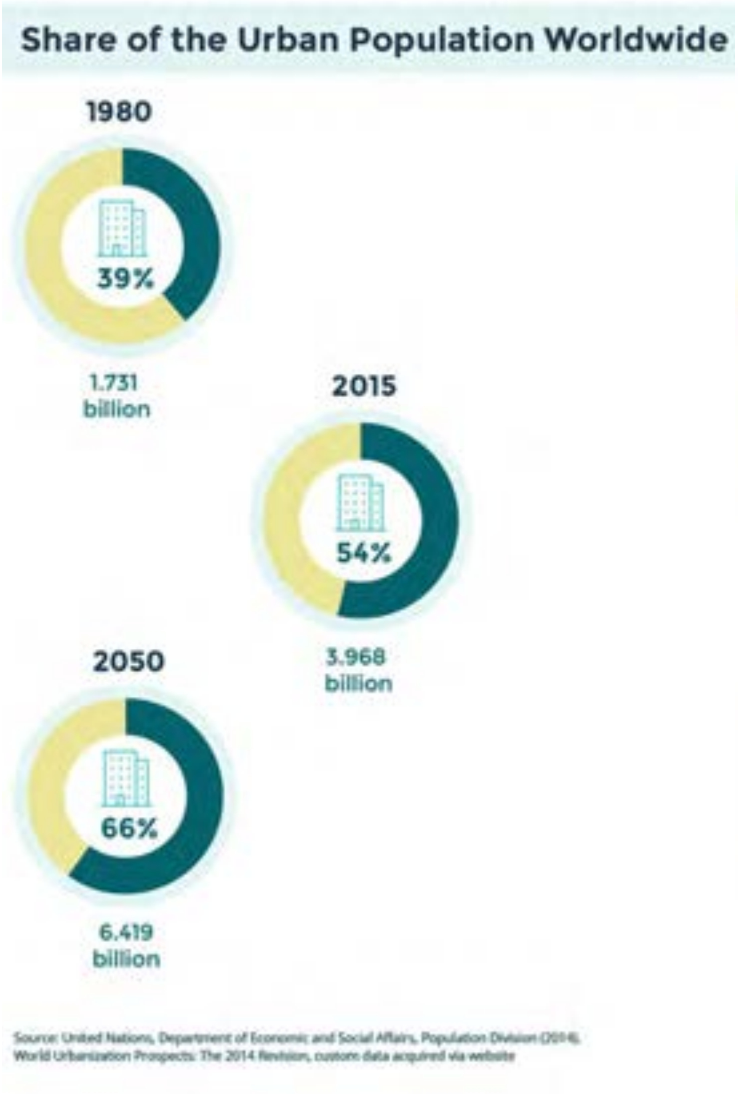
- ⇧ Intensity
- ⇧ Frequency
- ⇧ Length

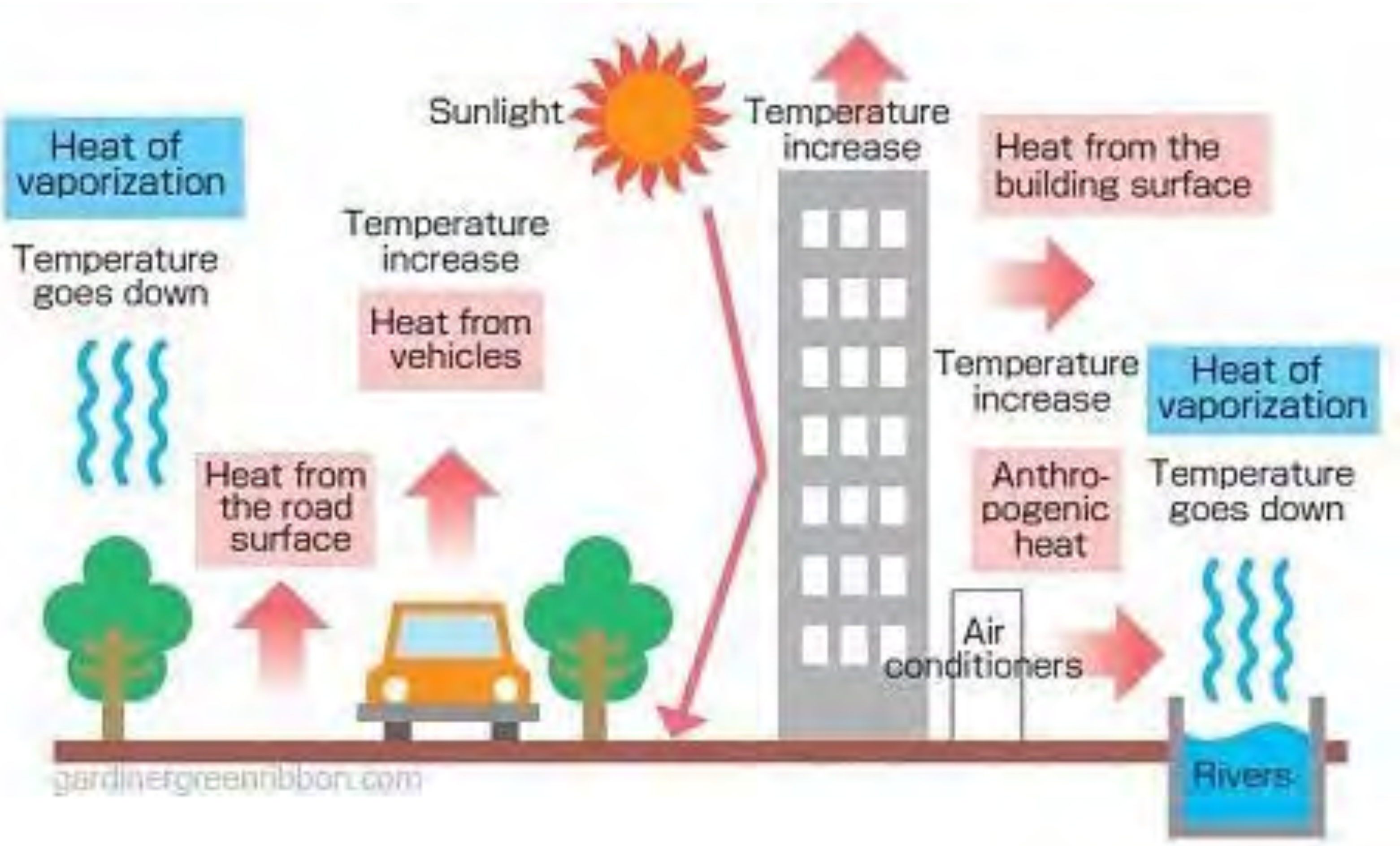




From Broadbent et al. 2020

Introduction Urban Environments





Introduction A matter of scale

Climate Change

Global

Mitigation

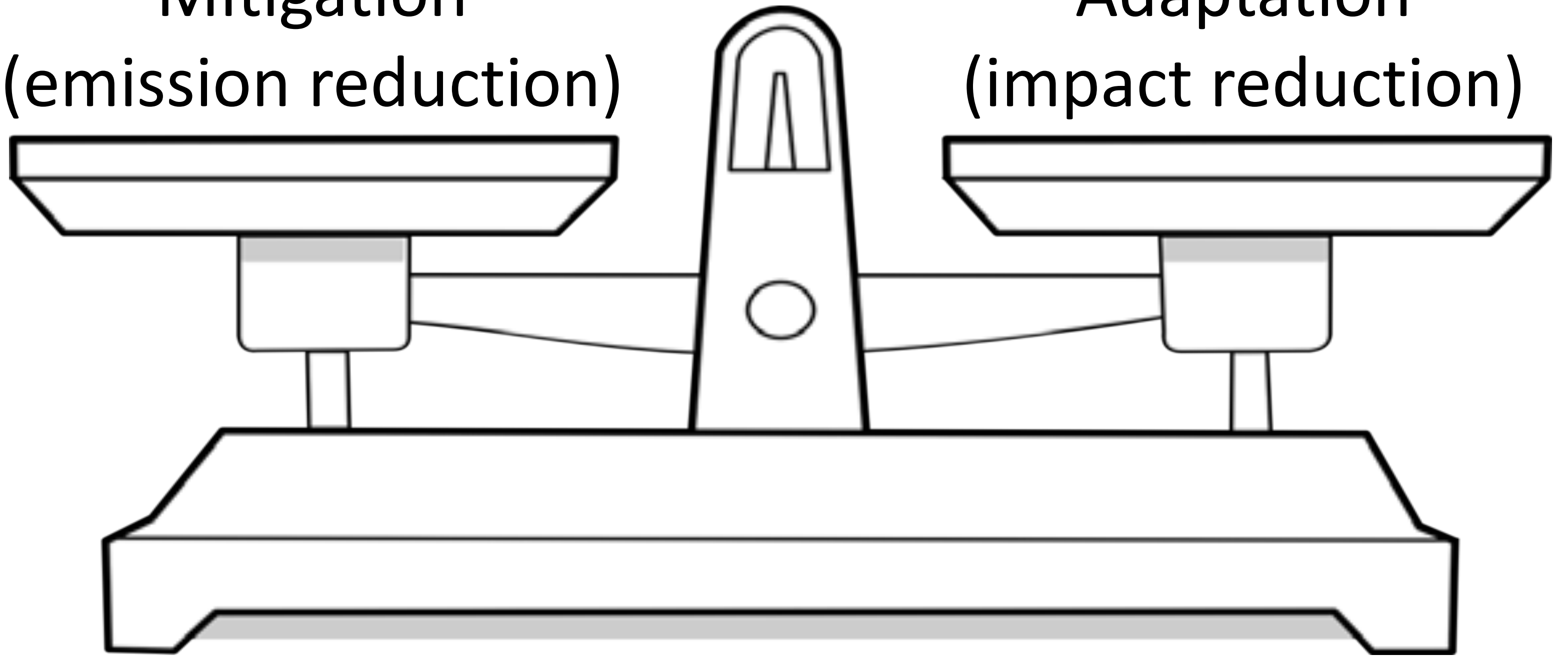
(emission reduction)

Urban Heat

Local

Adaptation

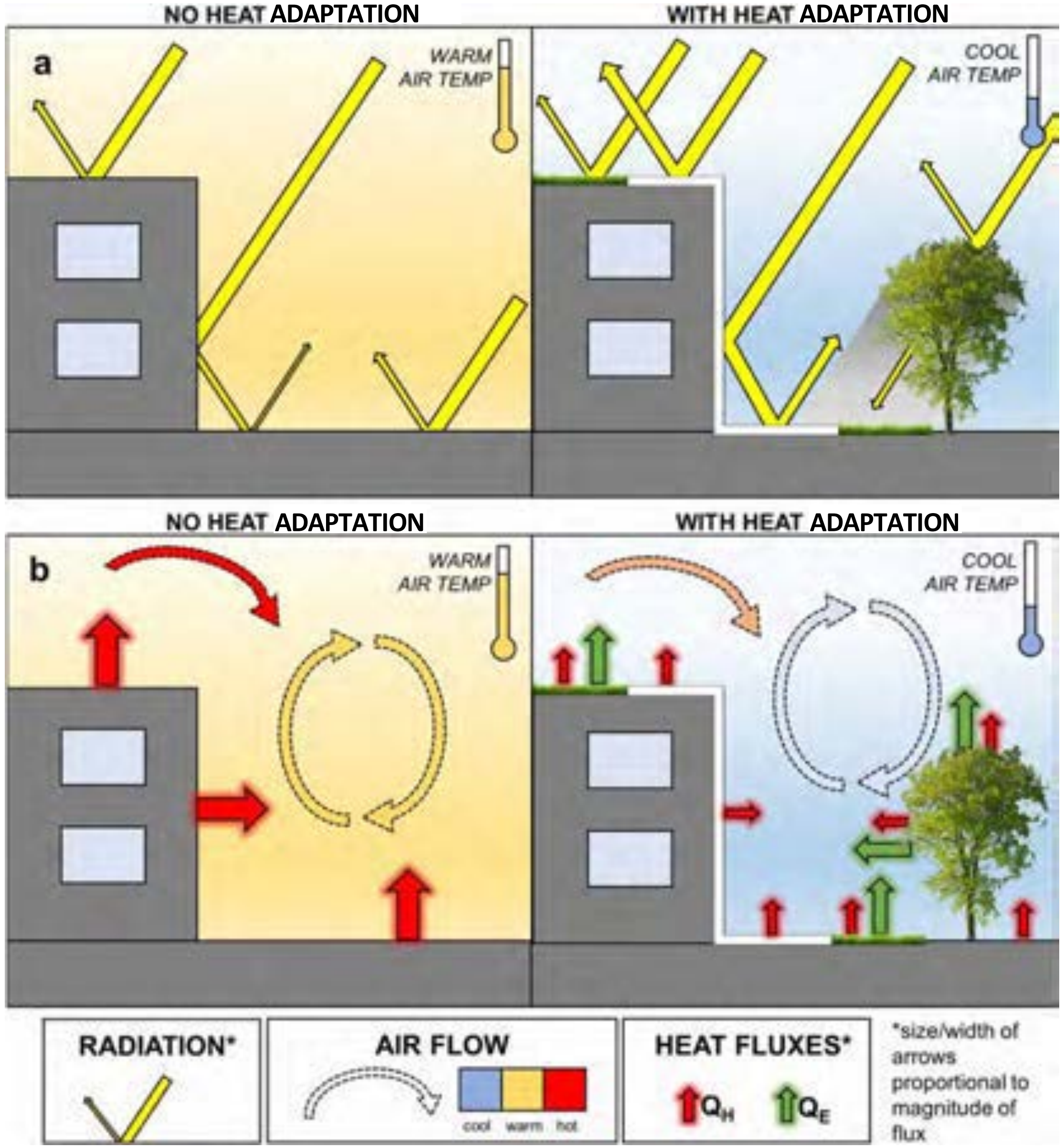
(impact reduction)



Introduction Heat Adaptation

Main goals:

- ➢ Reducing heat absorbed by surfaces by shading or reflection
- ➢ Using evapotranspiration processes of plants to absorb part of surface heat and "store" it into water vapor

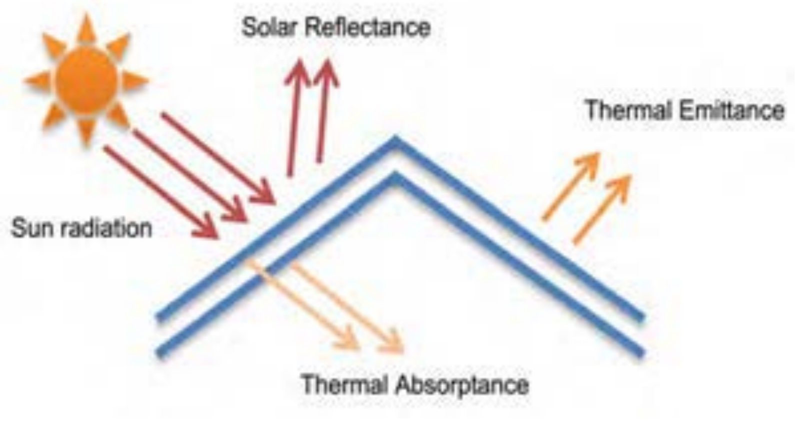


Modified from Krayenhoff et al., 2021

Introduction Heat Adaptation

Cool Roofs

Increase Reflectivity



From Al-Obaidi et al., 2014

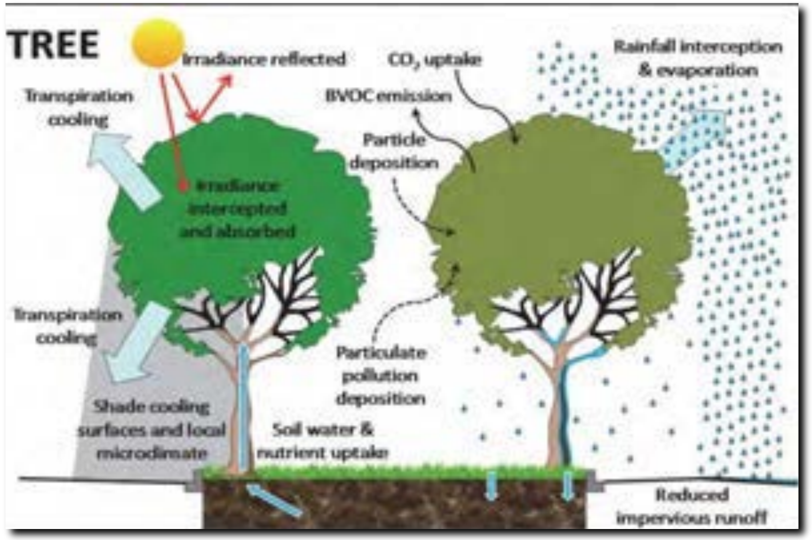
Green Roofs

Increase Evapotranspiration

From Liu and Chui, 2019

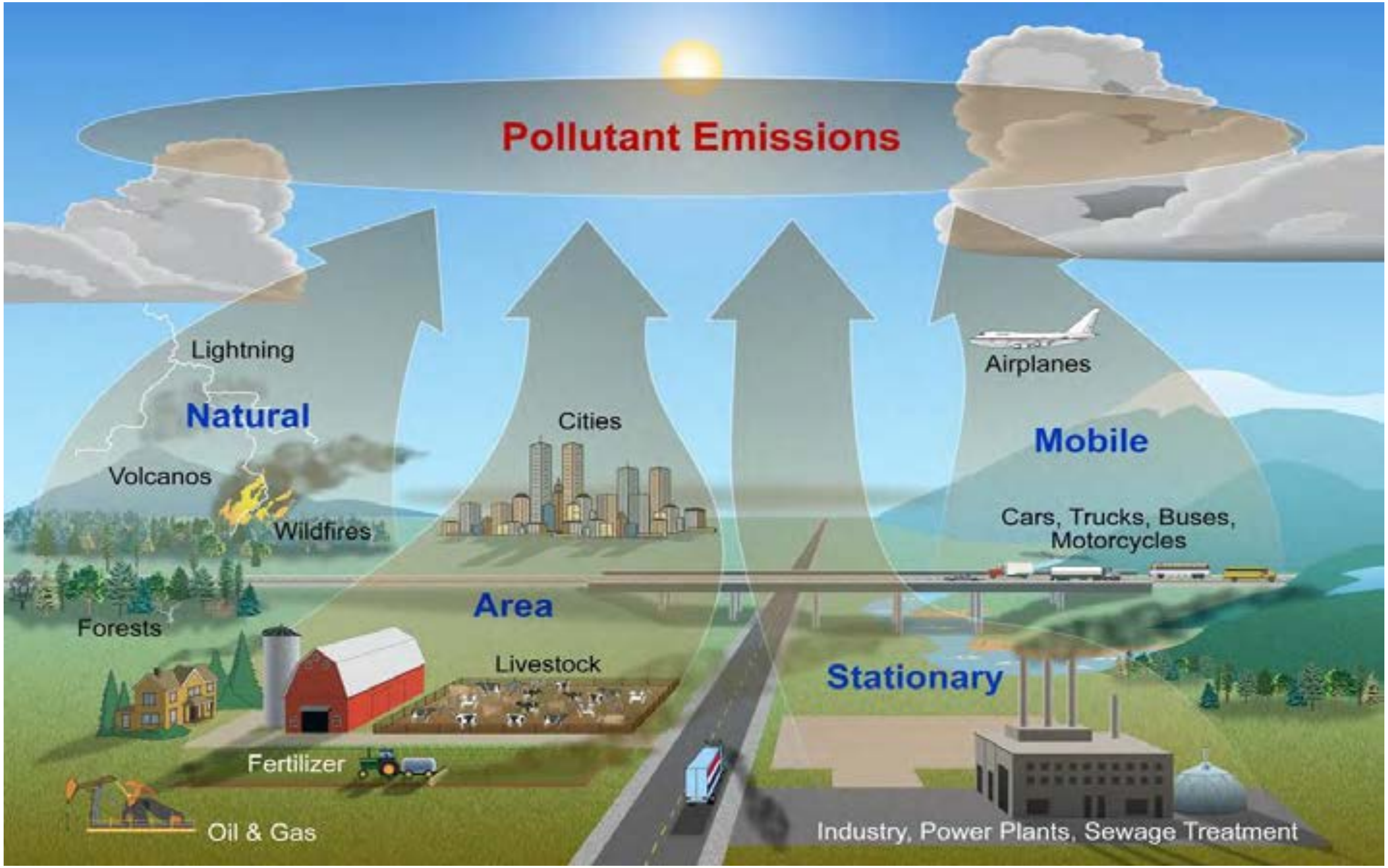
Street Trees

Shading + Evapotranspiration



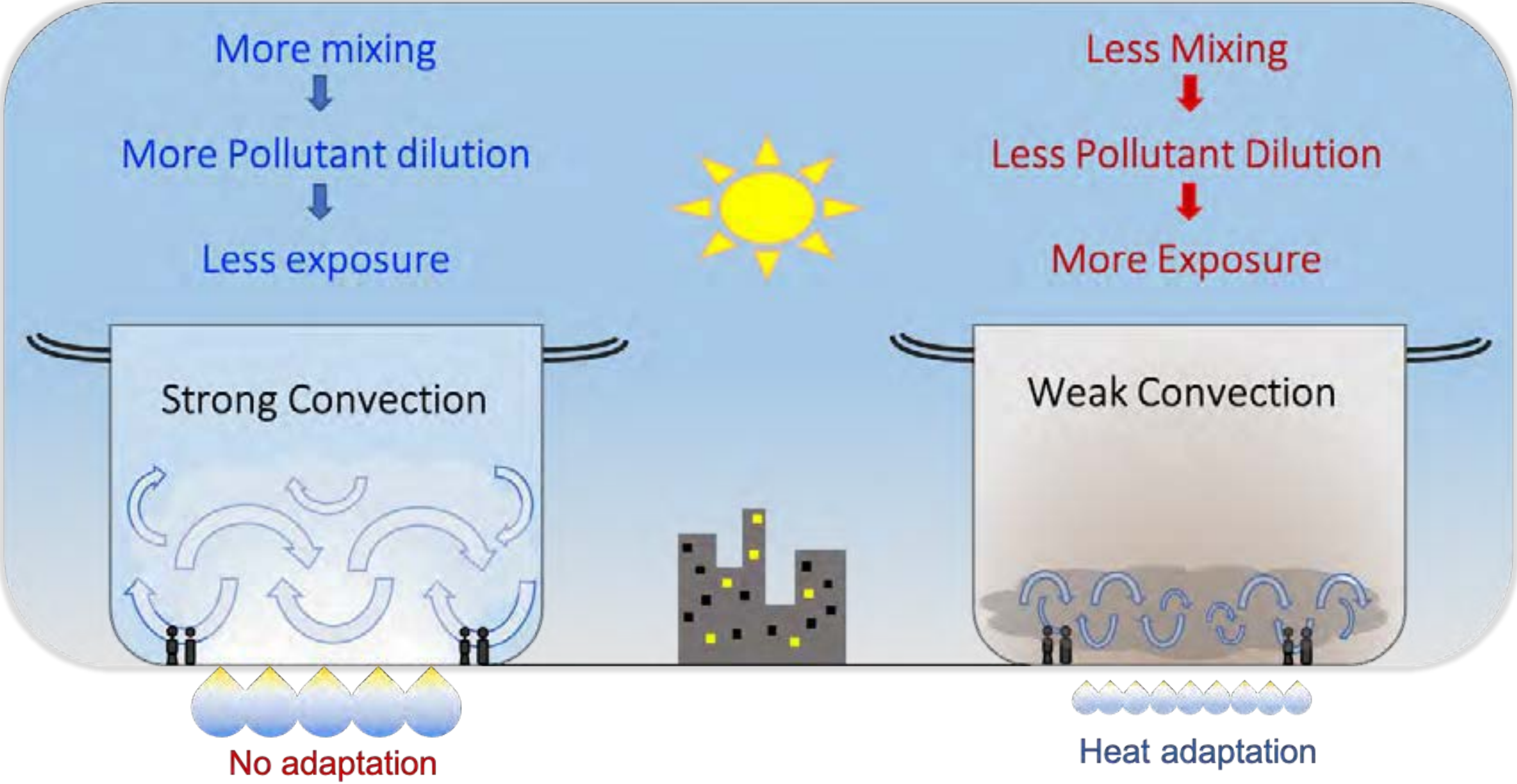
From Livesley et al,. 2016

Introduction Air quality



From https://www.nps.gov/subjects/air/sources.htm

Introduction Why this is important



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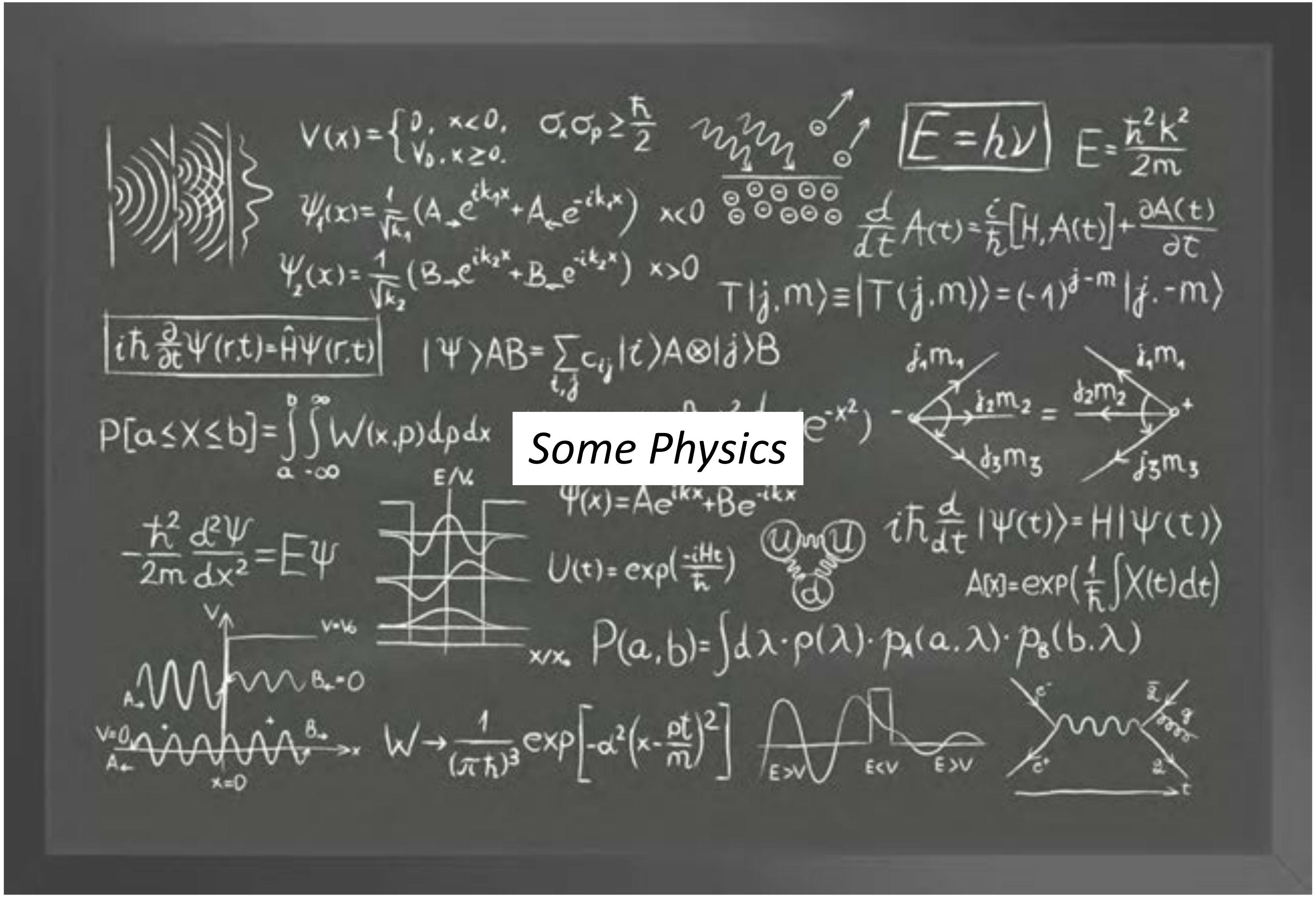


Some Physics

The Urban Boundary Layer (UBL)

Thermal anomalies

\+ <u>Anthropogenic heat</u>

human metabolism, transportation, manufacturing, heating/cooling systems

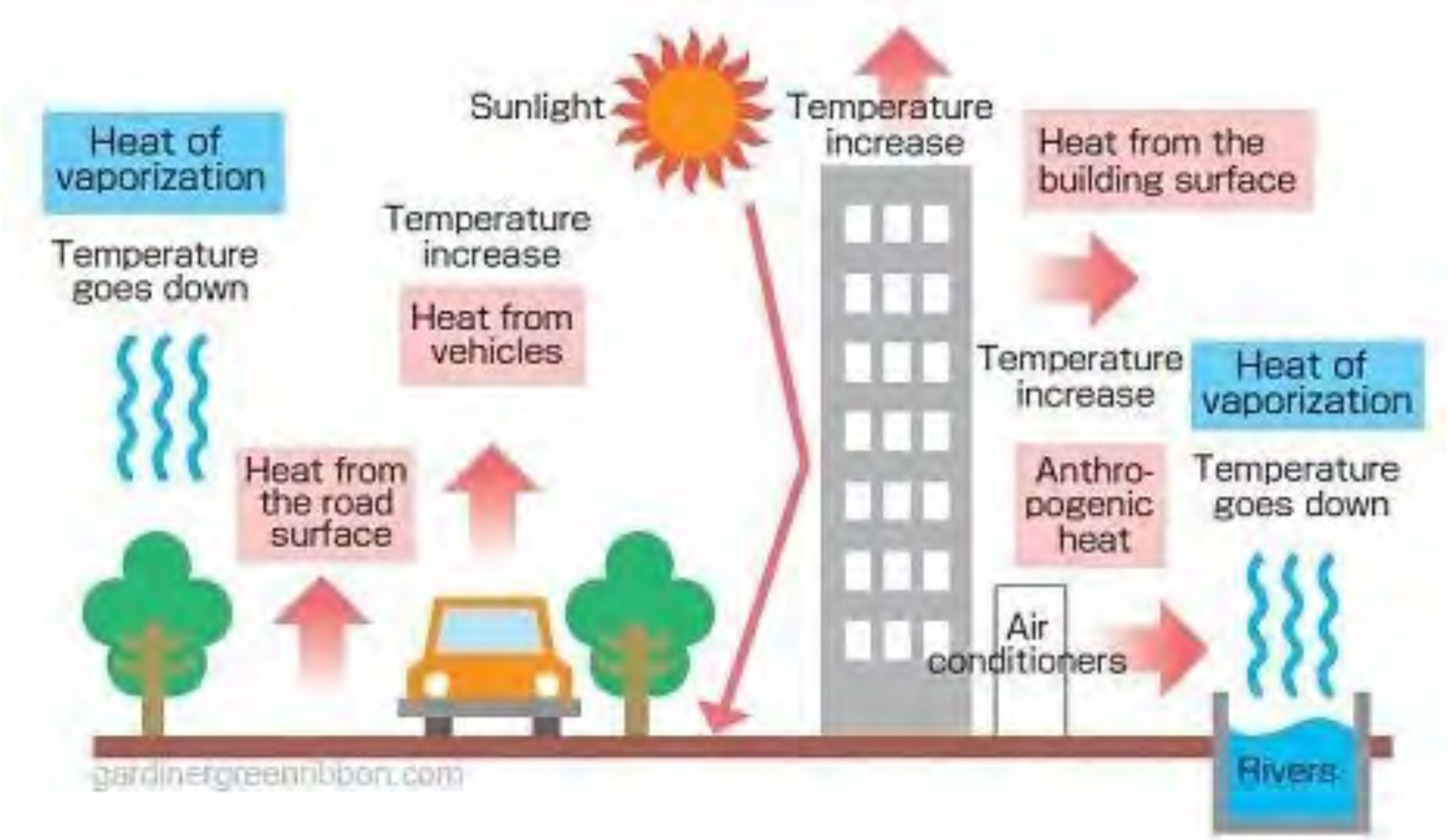
\+ <u>Paved impervious surfaces</u>

- ⬆ heat storage >> ⬆ sensible heat (Q_H)
- ⬇ soil moisture >> ⬇ latent heat (Q_E)
- ⬇ sky view factor >> ⬆ canyon trapping and venting

Aerodynamic anomalies

\+ <u>Building 3D morphology</u>

- ⬆ roughness length (z_0)
- ⬆ zero-plane displacement (z_d)



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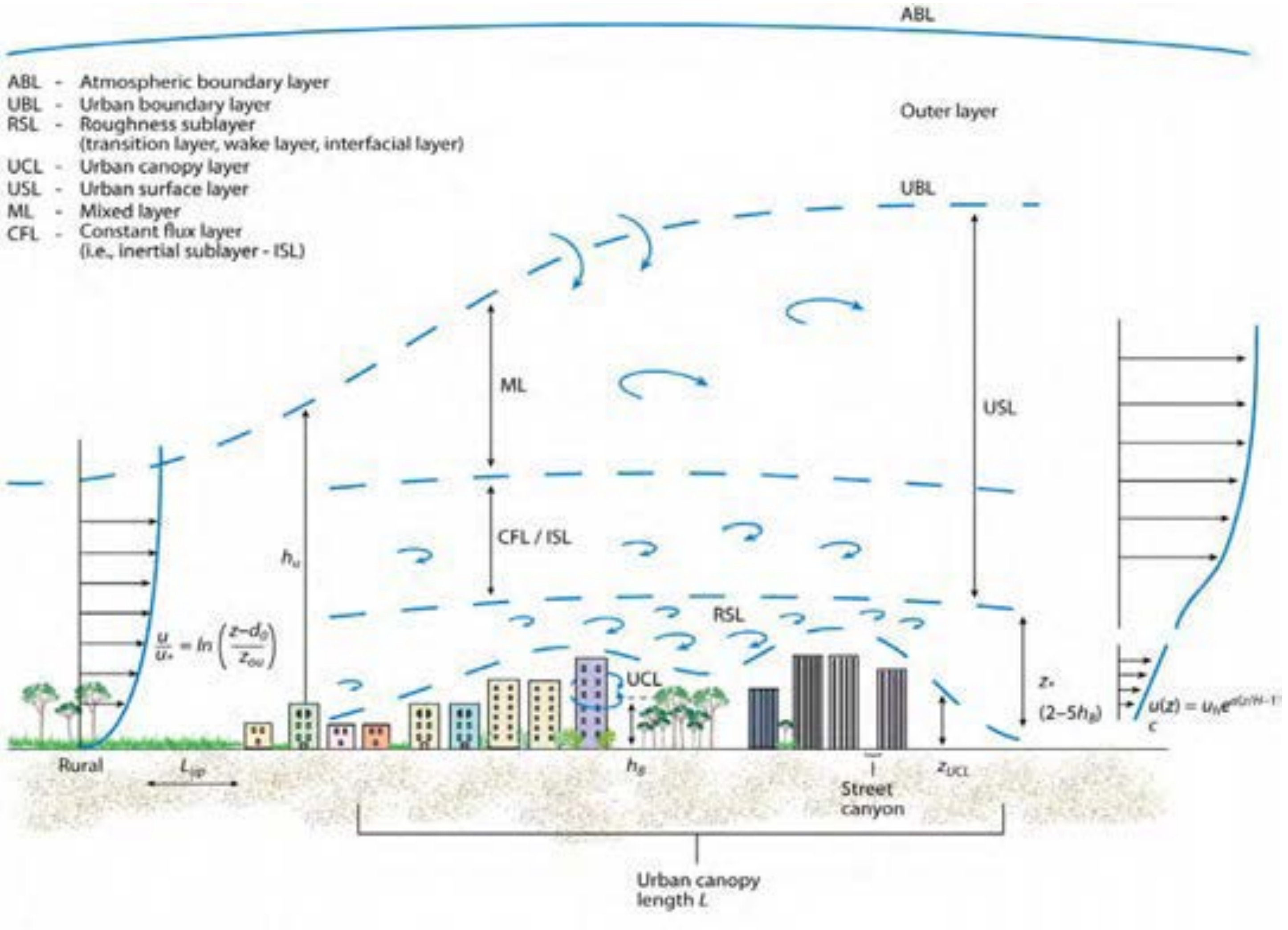
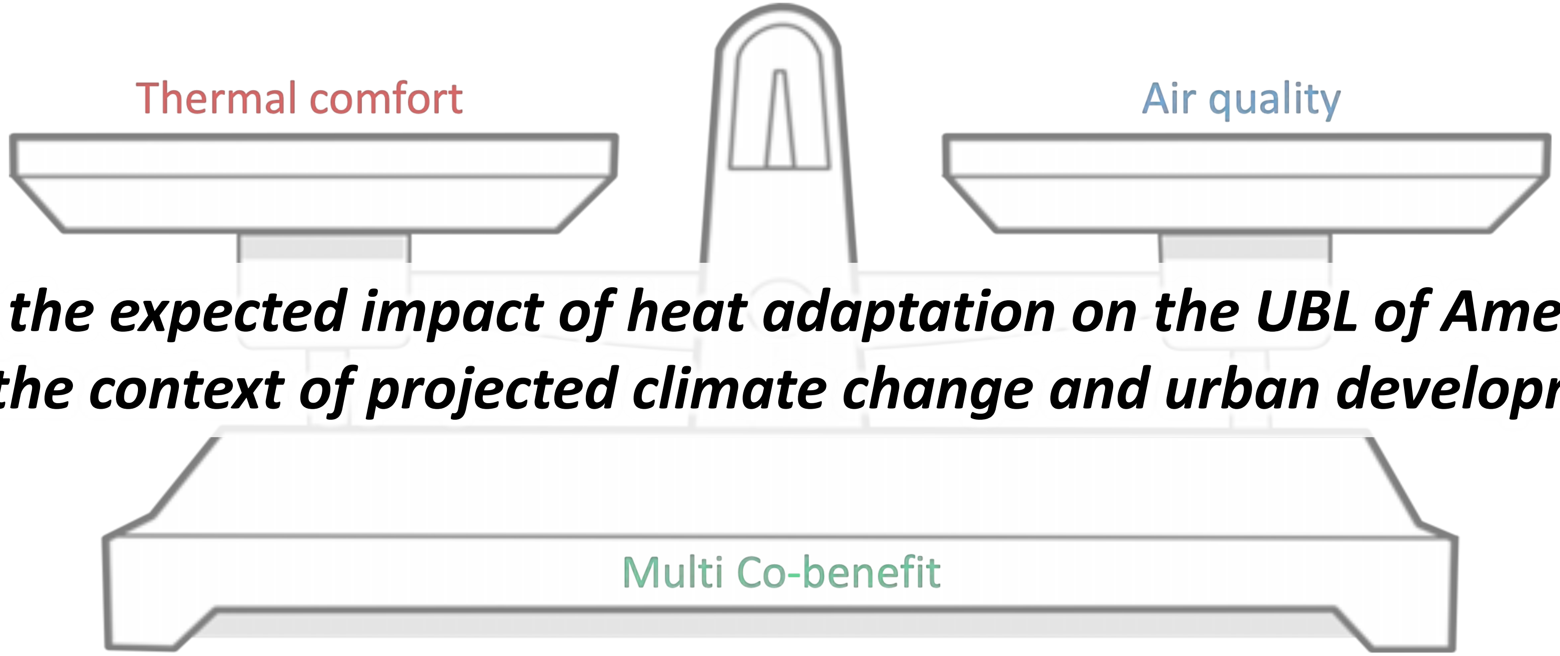


Fernando HJS. 2010.
Annu. Rev. Fluid Mech. 42:365–89

Our research question



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Published: 02 April 2021

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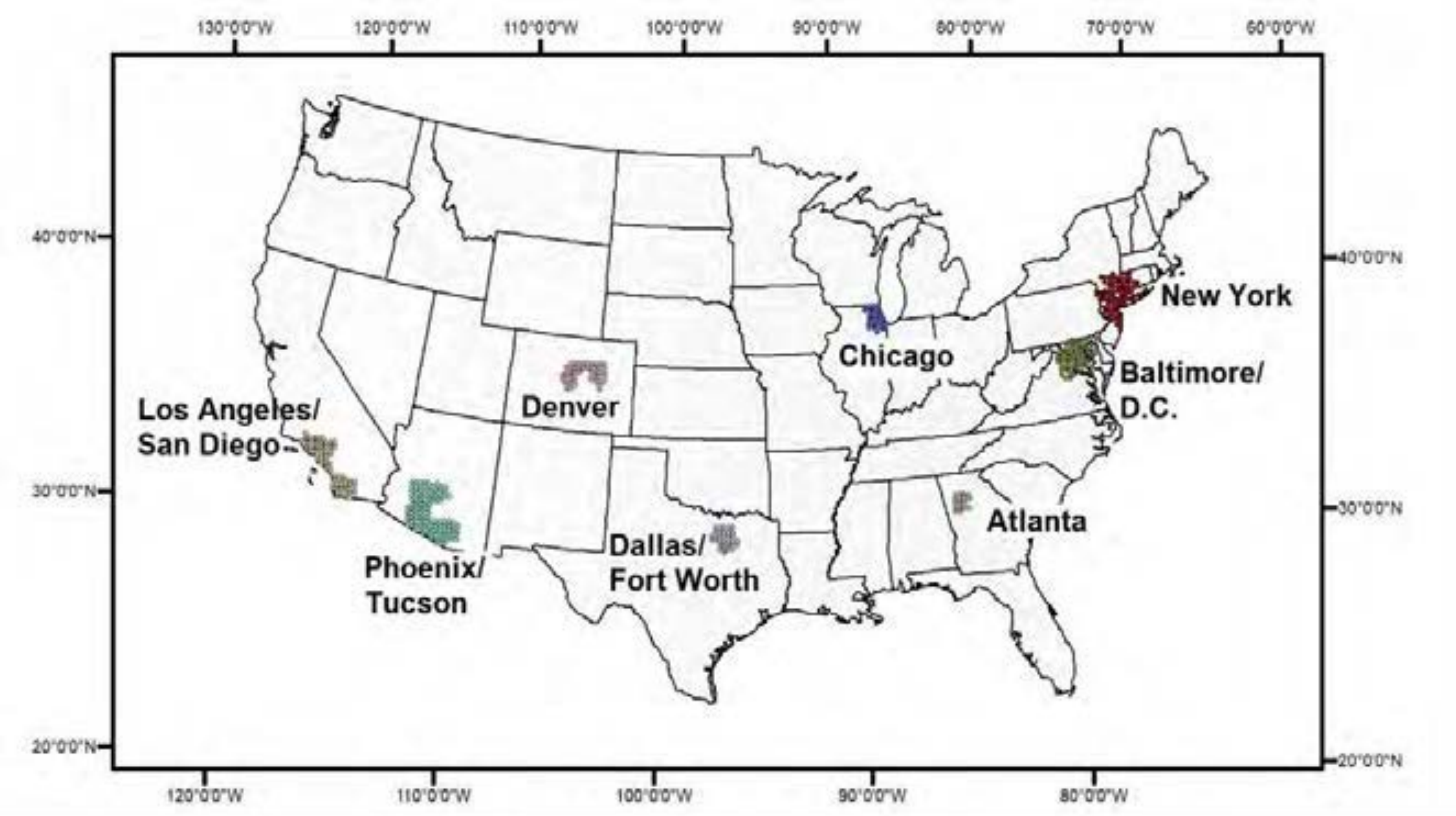
Climate Dynamics (2021) | Cite this article

Analysis domain and case study cities



From Brandi et al. 2021

Data & Methods

WRF-ARW V3.6
w/ Single Layer Urban Canopy Model

Spatial extent and resolution
North America, 20-km grid spacing, 29 vertical levels

Temporal extent and resolution
Contemporary (Climate and Urban Extent) = 2000 - 2009
Future (Climate and Urban extent) = 2090 - 2099
3-hourly outputs

Climate Forcing
Contemporary = ECMWF 'Era Interim' Reanalysis
Future = CESM CMIP5 – RCP 8.5

Land Cover
EPA ICLUS 1.3.2 A2 SRES Scenarios (2010 and 2100)
3 Urban Classes - ICLUS 31, 32, 33

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Full Adaptation Scenario
A combination of individual adaptation strategies

Cool Roofs
.88 albedo, uniformly applied on all roofs in the Contiguous US

Green Roofs
Evaporating surfaces with unlimited water availability, uniformly applied on all roofs in the Contiguous US

Street Trees
2.0 m^2 m^{-2} Canyon Mean Leaf Area, distributed evenly between heights 2.5 and 7.5 m in streets of all urban classes

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More detailed information can be found in:
Krayenhoff E. S., Moustaoui M., Broadbent A. M., Gupta V. and Georgescu M. (2018). *Diurnal interaction between urban expansion, climate change and adaptation in US cities.* Nat. Clim. Change **8** 1097

Data available at:
https://dataverse.asu.edu/dataverse/USRegClimateChgAssess
Georgescu, Matei; Brandi, Aldo; Broadbent, Ashley; Krayenhoff, Scott (2021) "2090-2099 Projected Climates and Urban Development Scenarios - Conterminous U.S. (CONUS) Simulation Data", https://doi.org/10.48349/ASU/3TYXZI, ASU Library Research Data Repository, V1

Results (JJA - 14:00 MST)

Urban Development
(ICLUS 2100 – 2010)

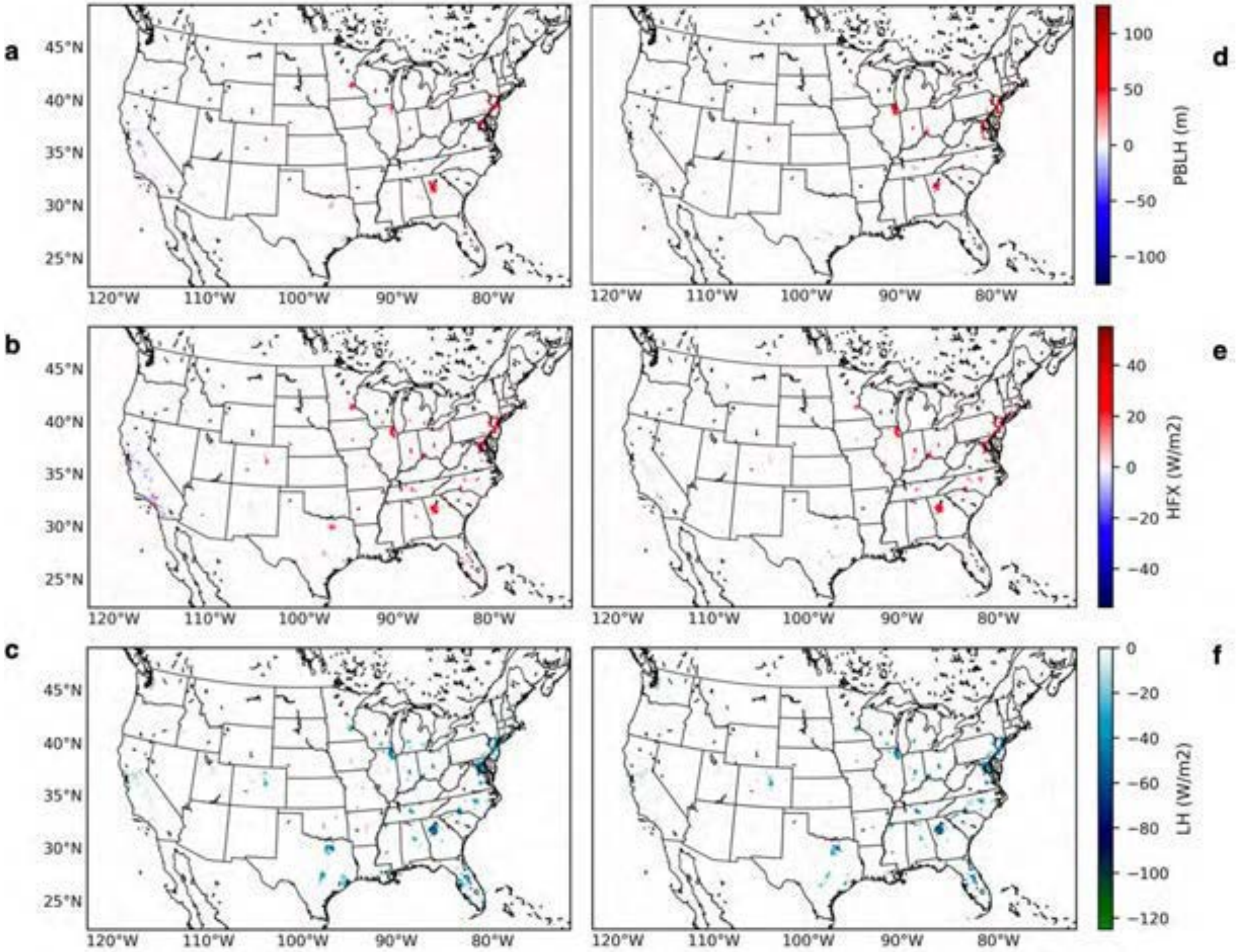
- ⬆ UBL Depth (PBLH)
- ⬆ Sensible Heat Flux (HFX)
- ⬇ Latent Heat Flux (LH)
- ⬆ Ground Heat Flux

Greater changes in Eastern CONUS

Climate Change exacerbates Urban Development impacts

Transition from arid to urban landscapes (California)

2000-2009 ECMWF **Climate Change** CESM 2090-2099



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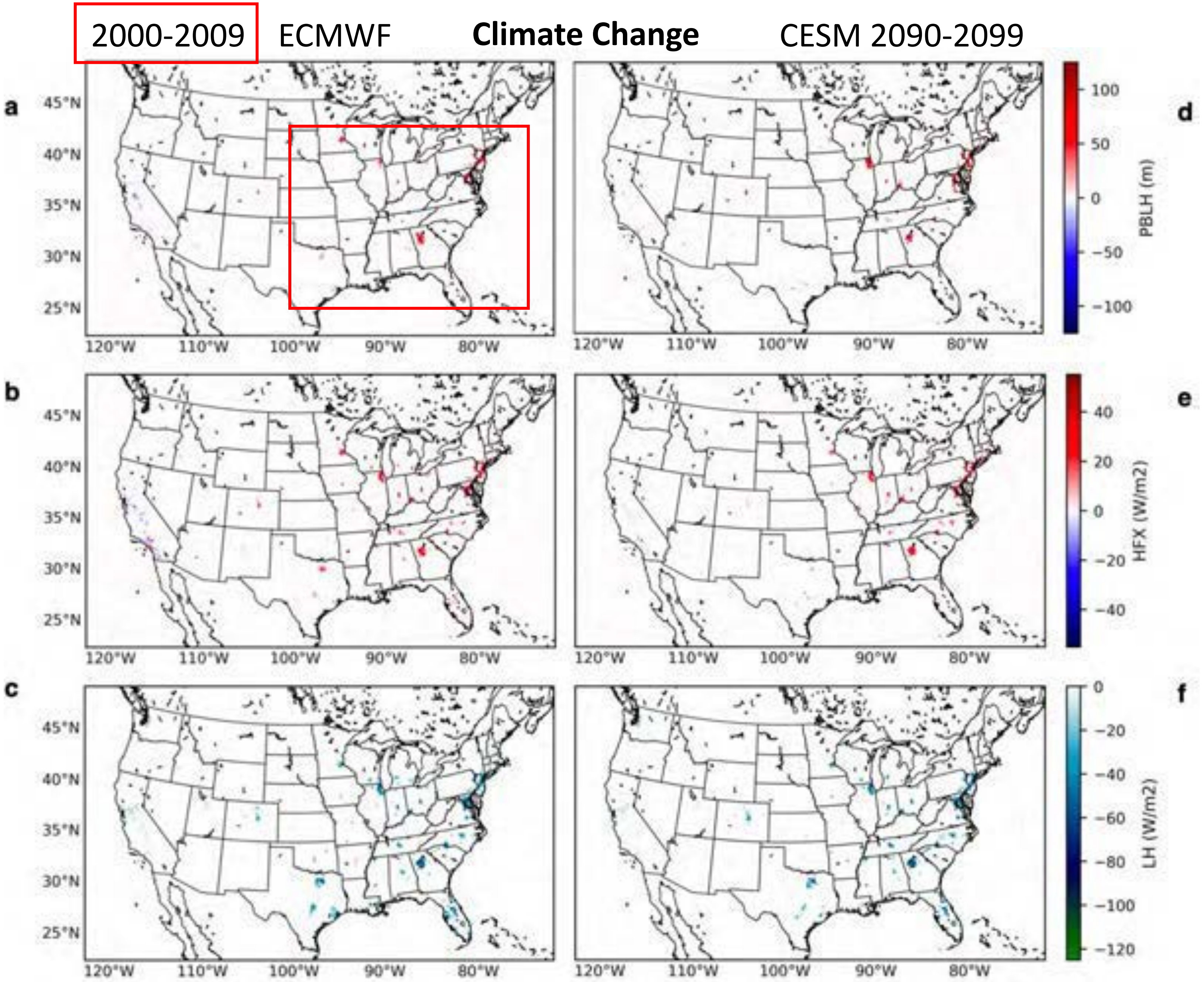

From Brandi et al. 2021

Results (JJA - 14:00 MST)

Urban Development
(ICLUS 2100 – 2010)

- UBL Depth (PBLH) (up)
- Sensible Heat Flux (HFX) (up)
- Latent Heat Flux (LH) (down)
- Ground Heat Flux (up)

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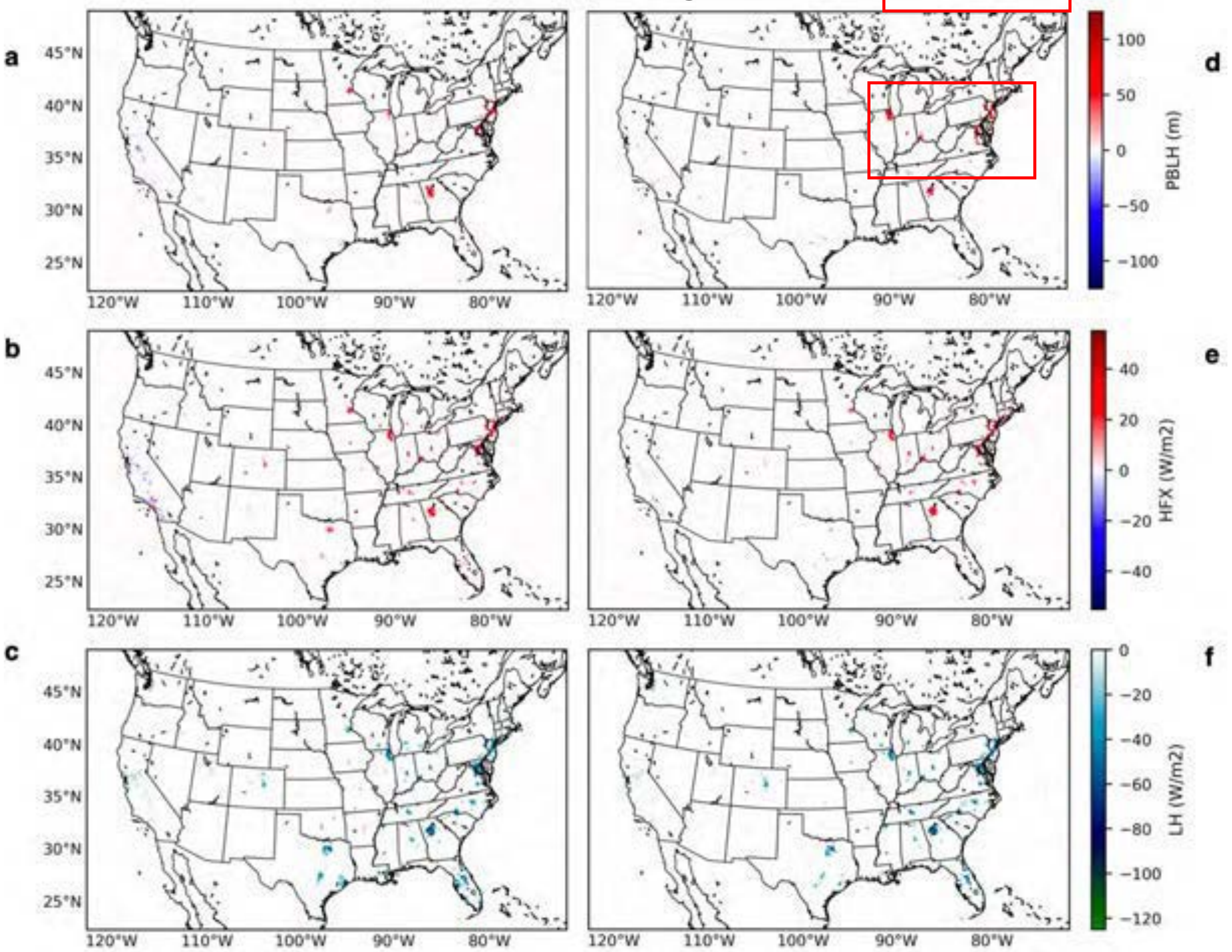

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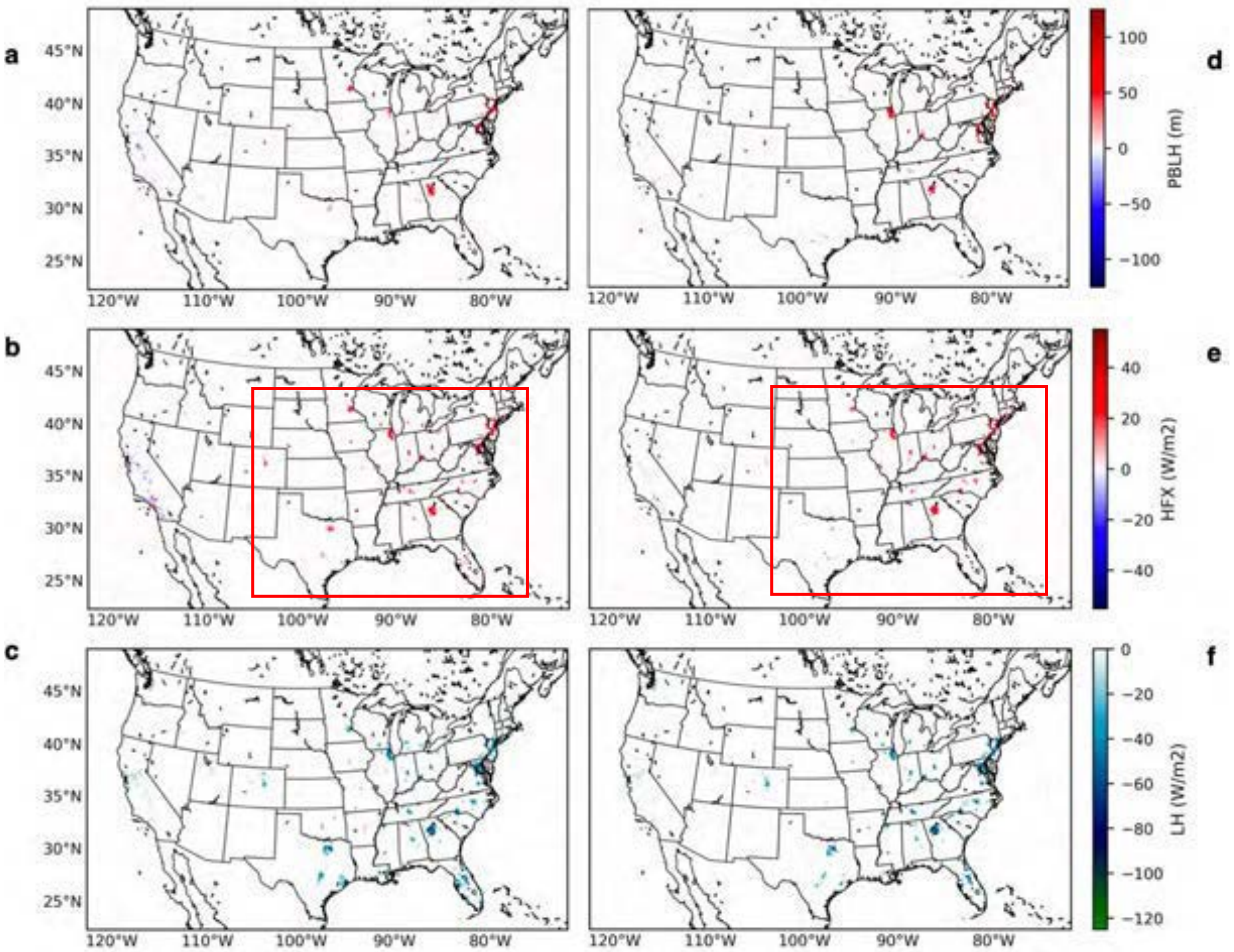

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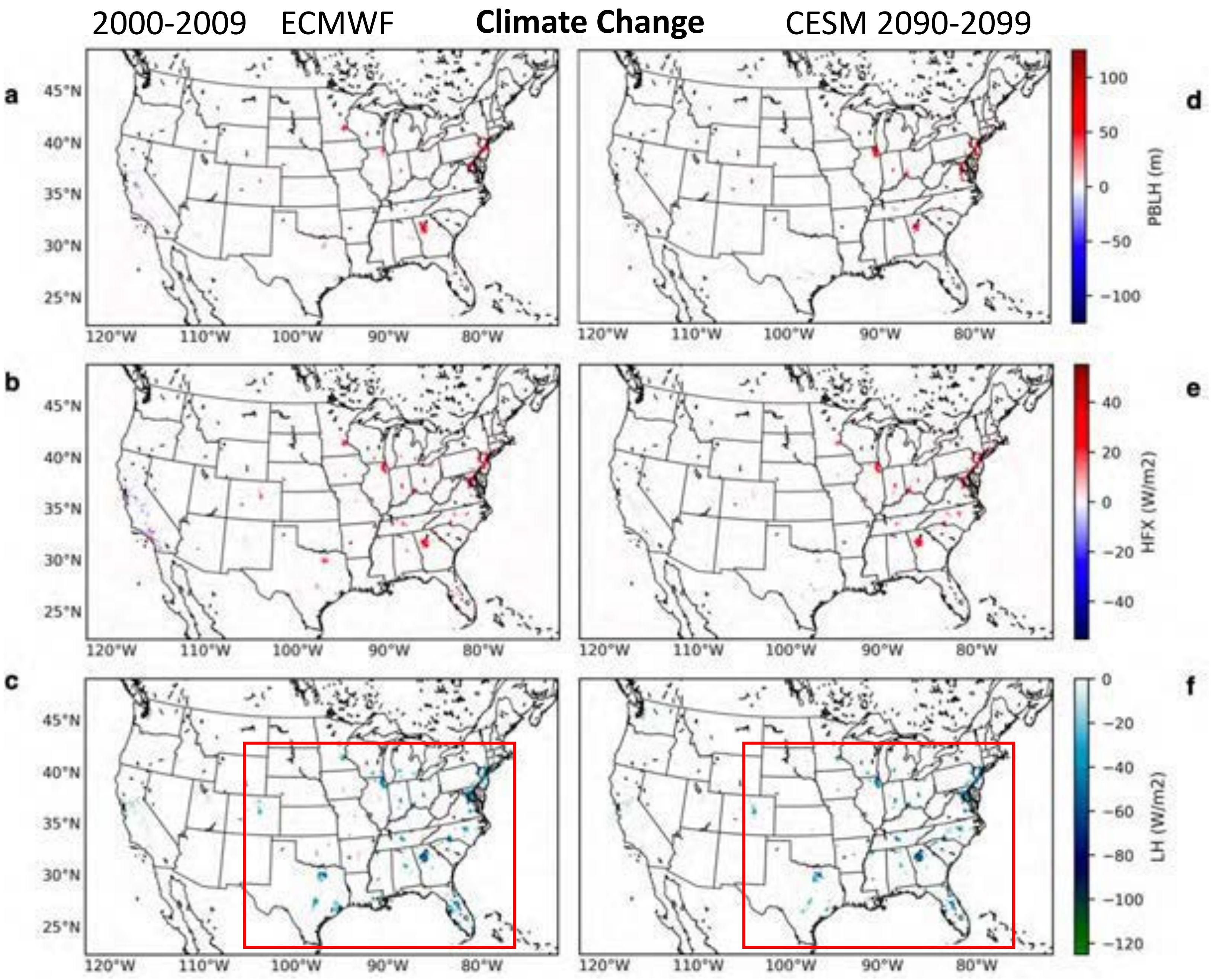

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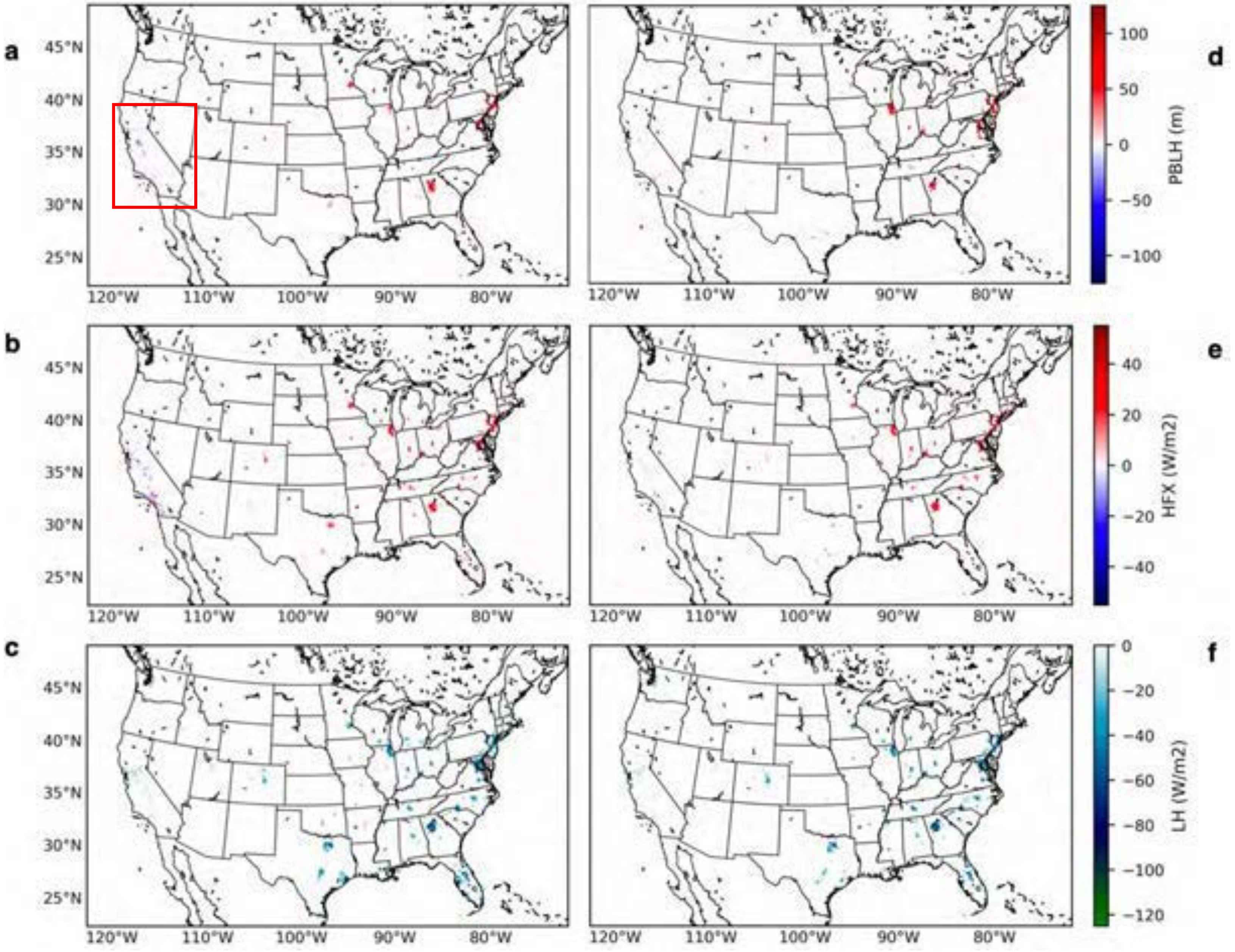

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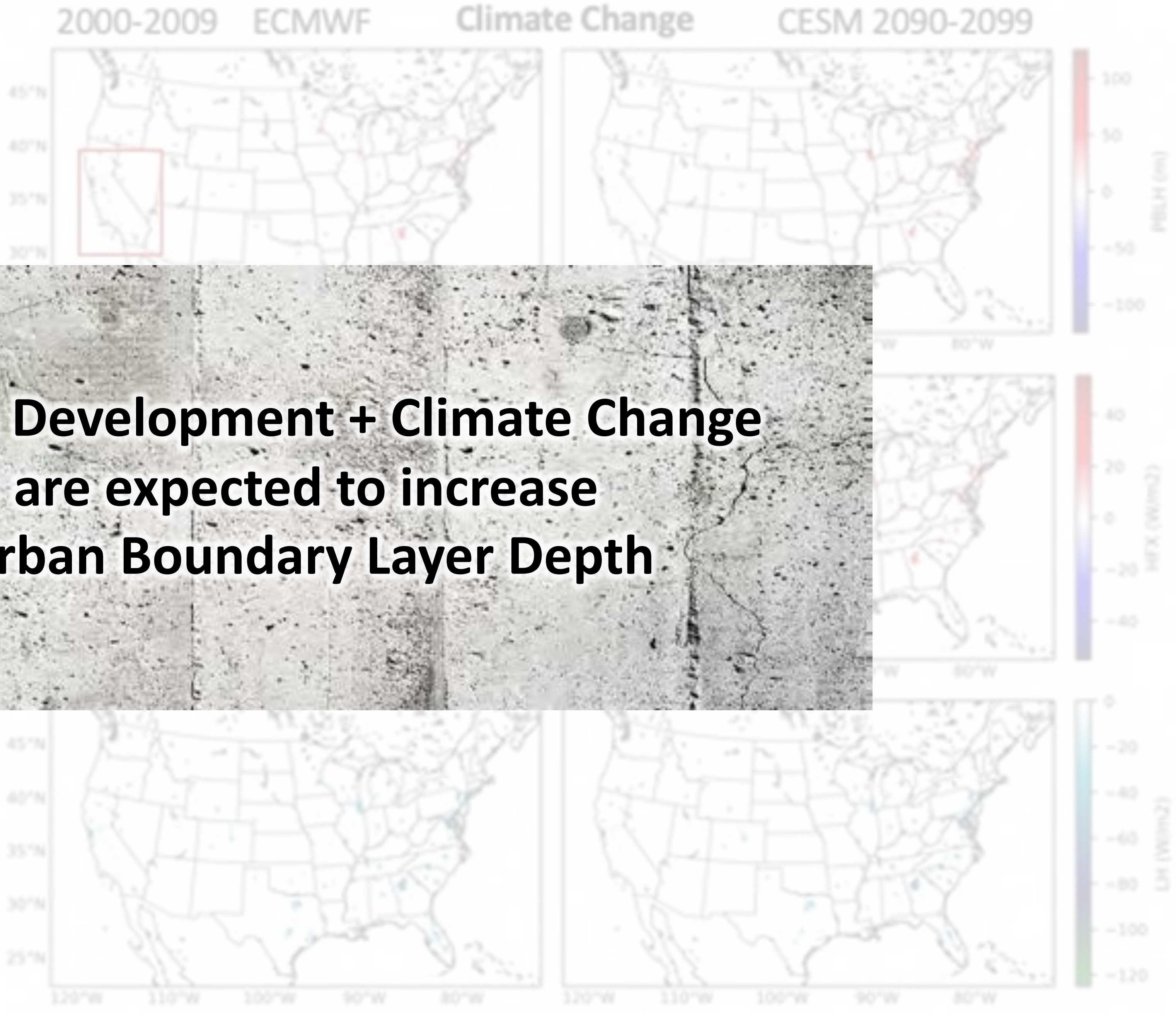
- ⬆ Ground Heat Flux

Greater changes in Eastern CONUS

Transition from arid to urban landscapes (California)

Climate Change exacerbates Urban Development impacts

Urban Development + Climate Change are expected to increase Urban Boundary Layer Depth



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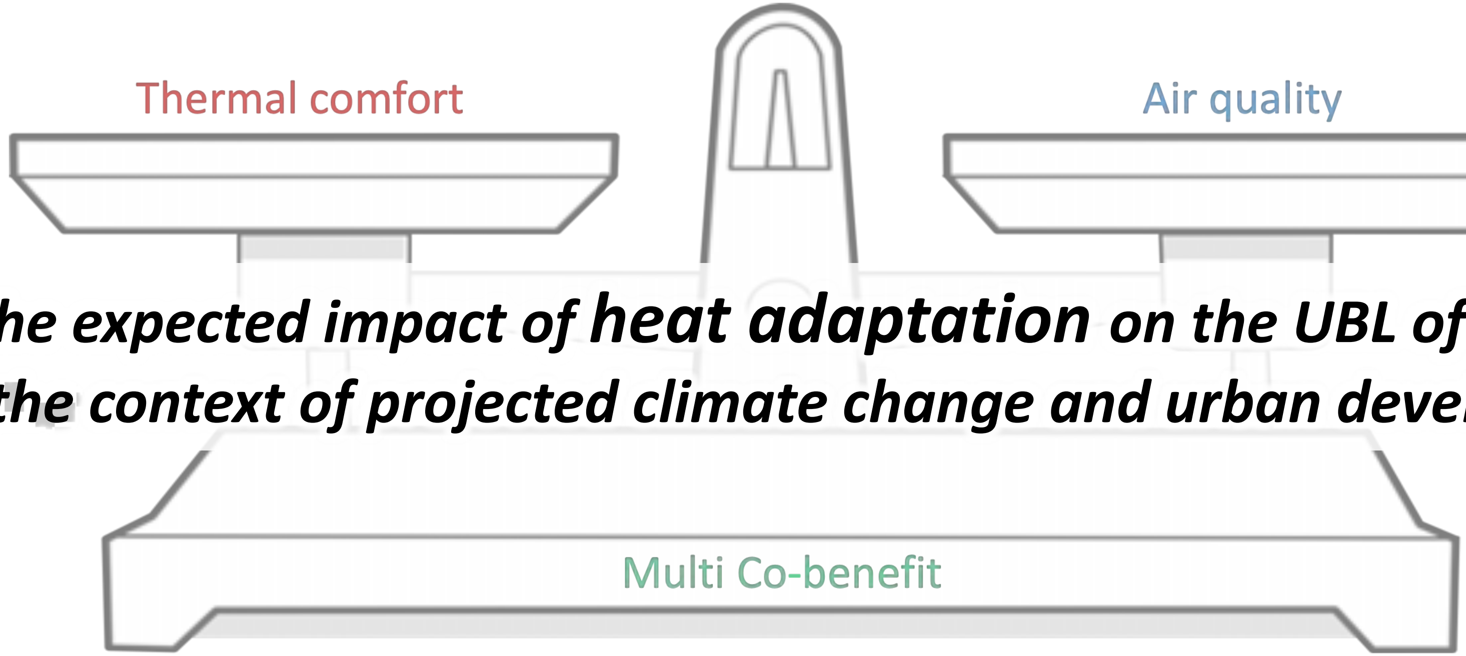
Our research question



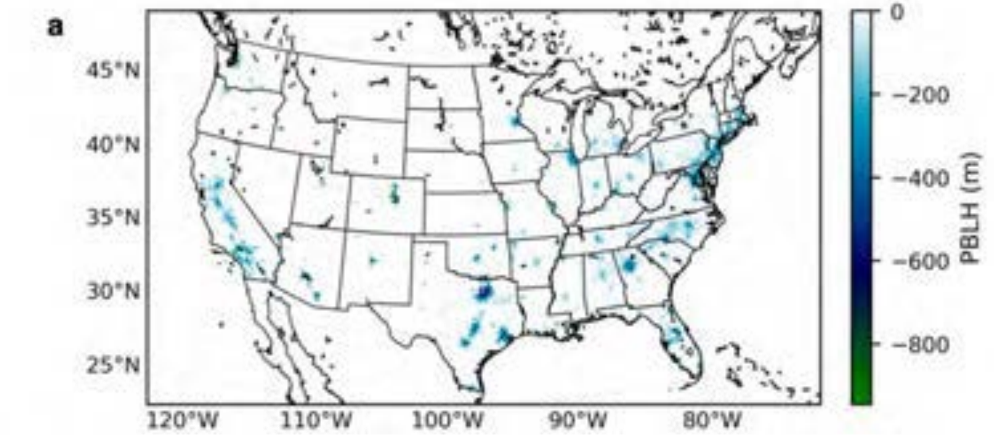
What is the expected impact of* heat adaptation *on the UBL of American cities in the context of projected climate change and urban development?

Results (JJA - 14:00 MST)

Full Adaptation
Cool R. + Green R. + Street Trees

- UBL Depth (PBLH)

CESM RCP8.5 2090-2099



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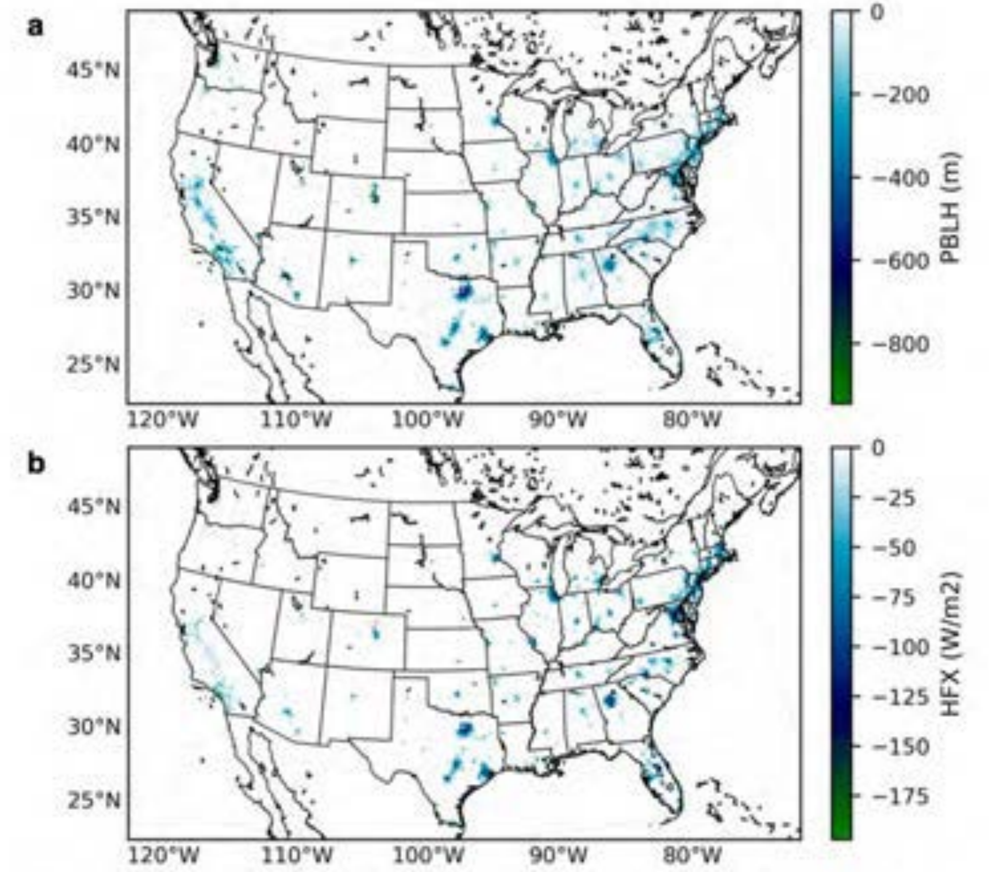

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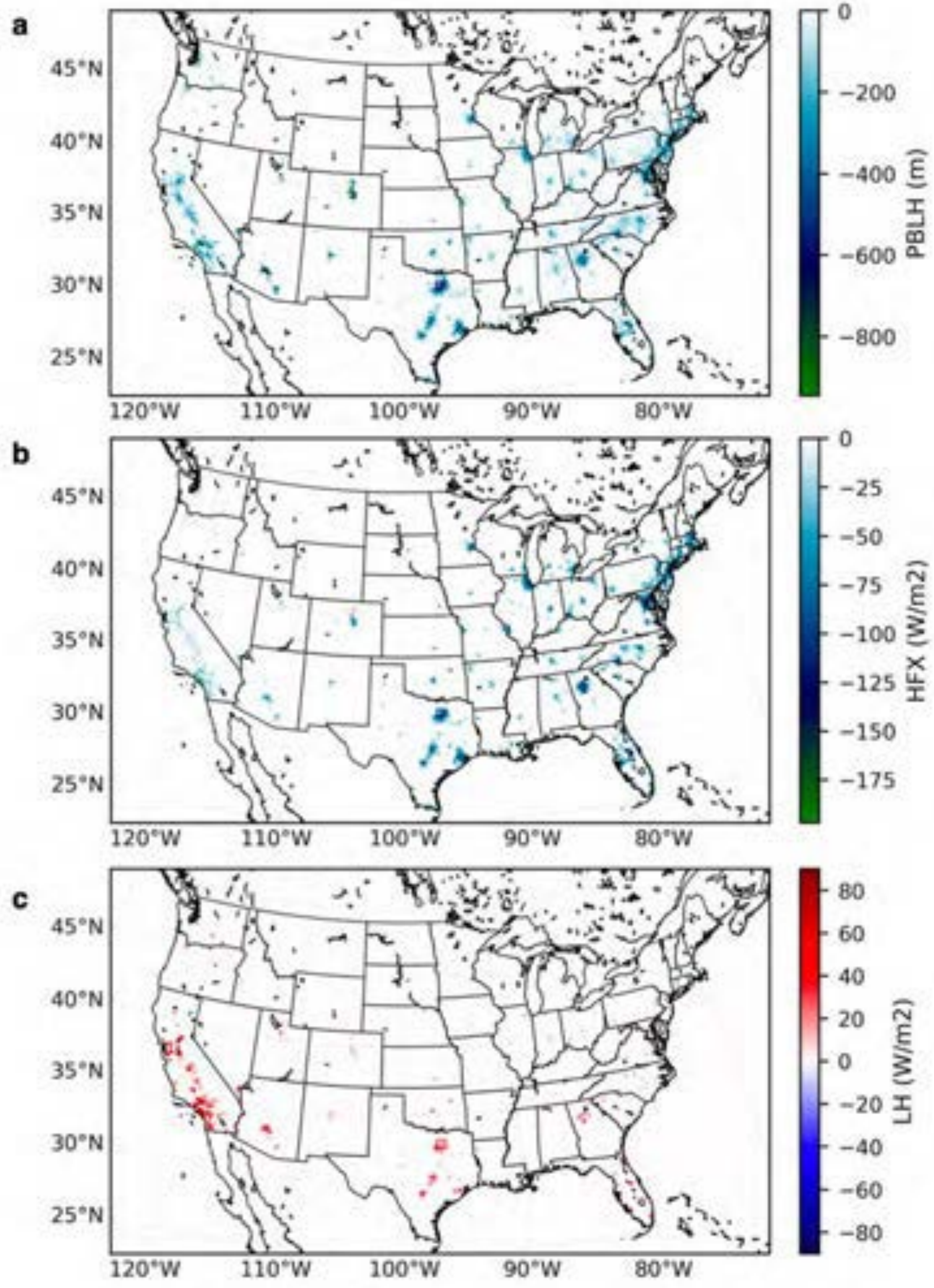

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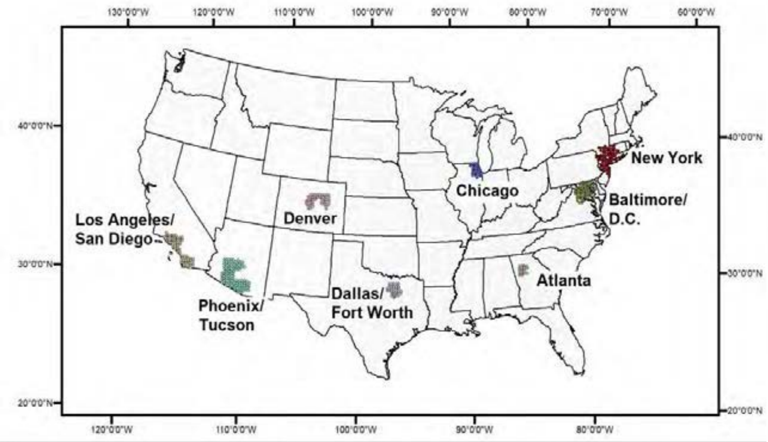

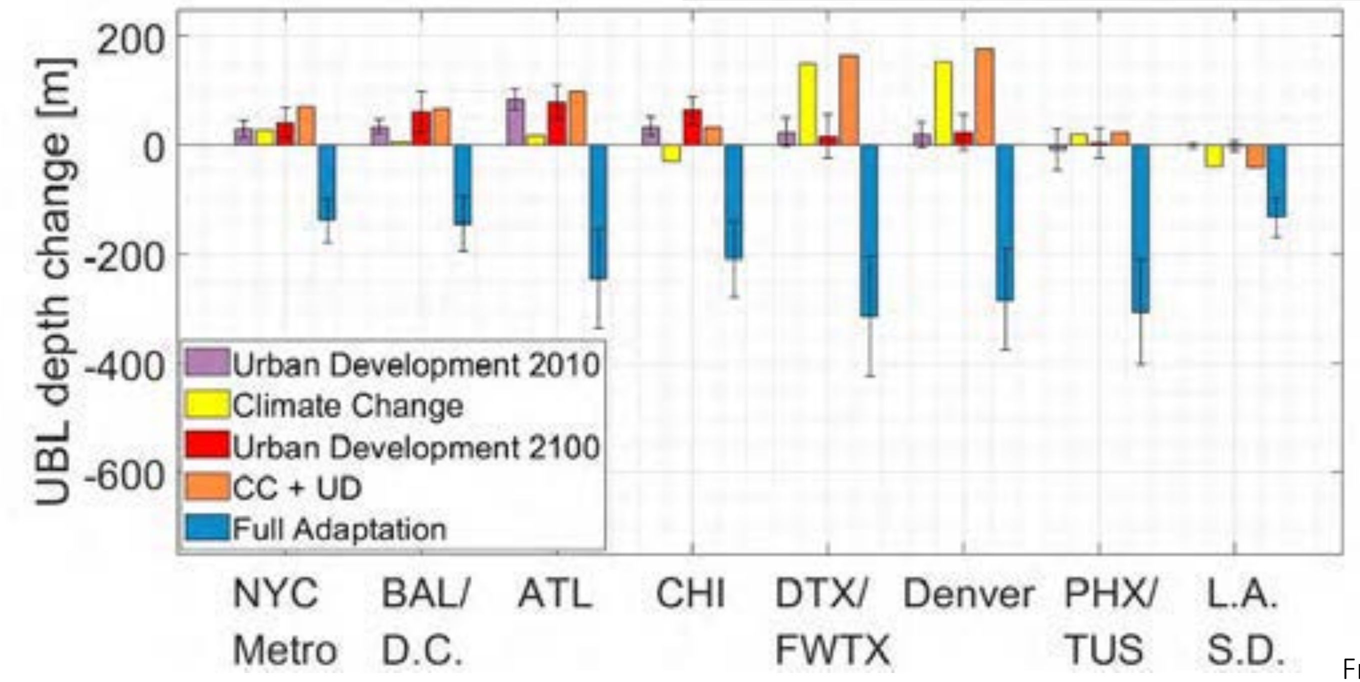

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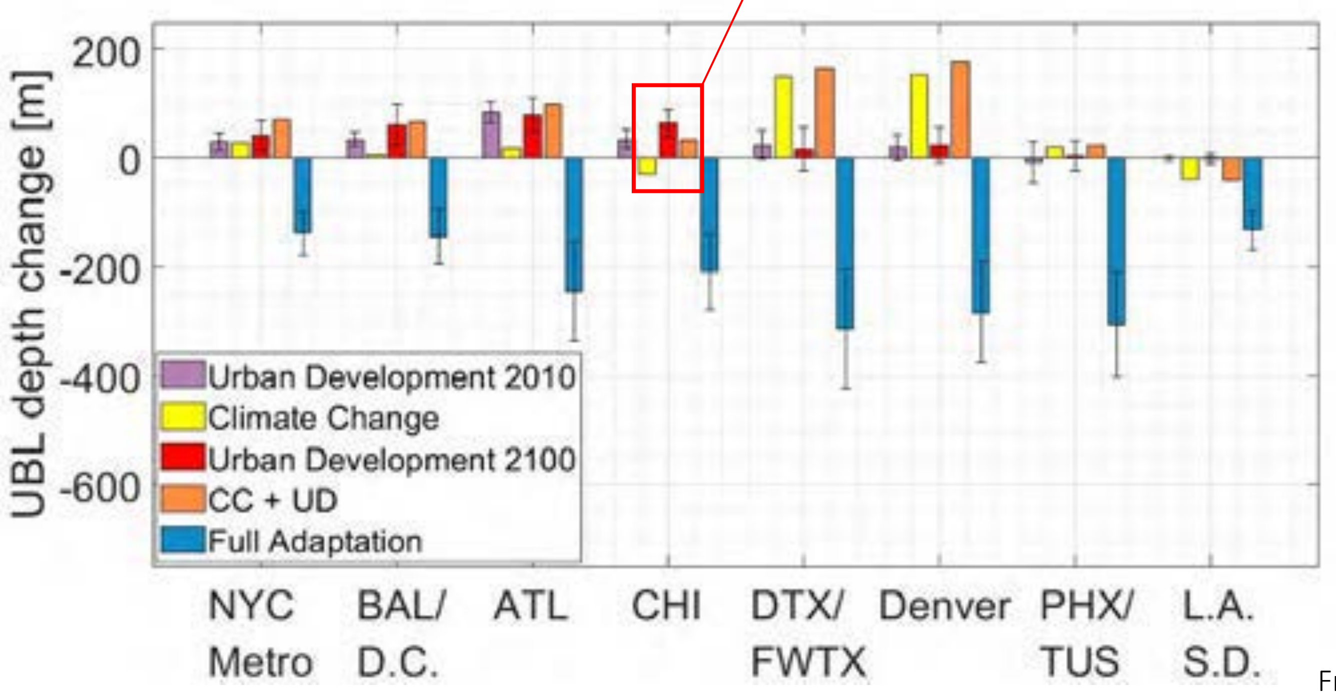
Climate Change and Urban Development impacts sum linearly



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Results (JJA - 14:00 MST)

Full Adaptation

Cool R. + Green R. + Street Trees

Climate Change and Urban Development impacts sum linearly

Full Adaptation UBL reduction exceeds UD and CC increases

- UBL Depth (PBLH)
- Sensible Heat Flux (HFX)
- Latent Heat Flux (LH)
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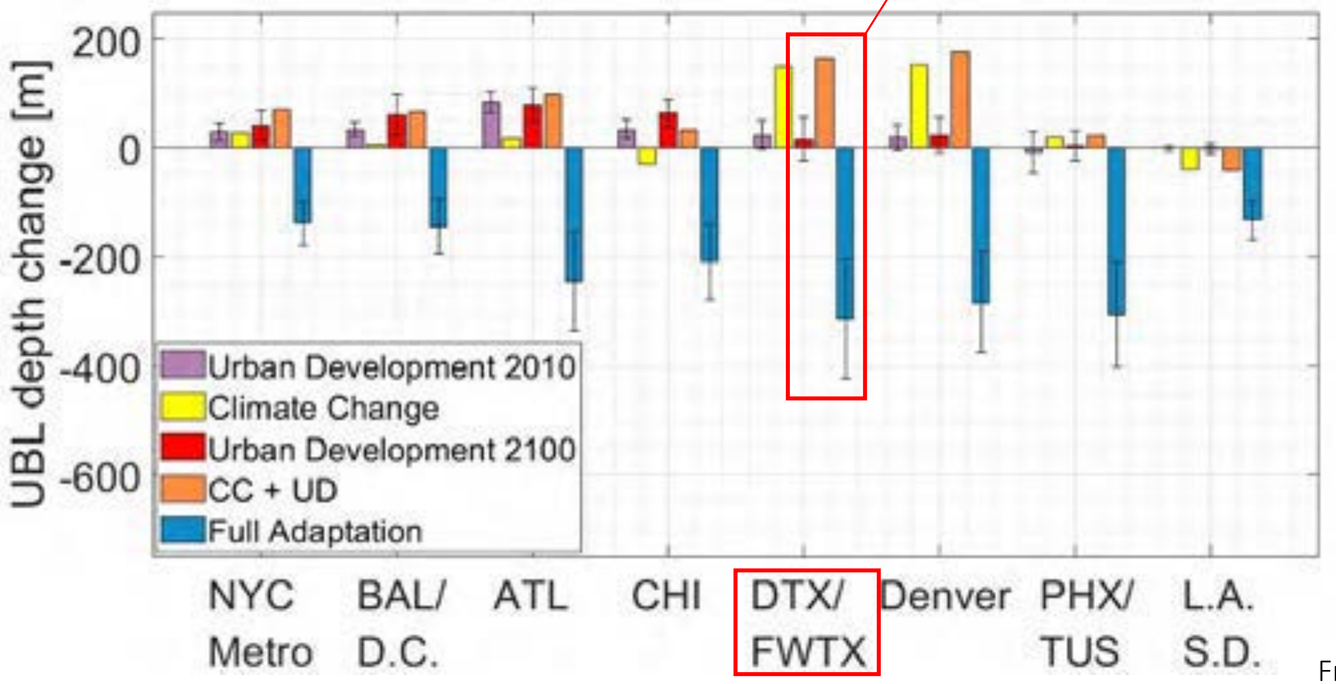

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UBL Depth (PBLH)

Sensible Heat Flux (HFX)

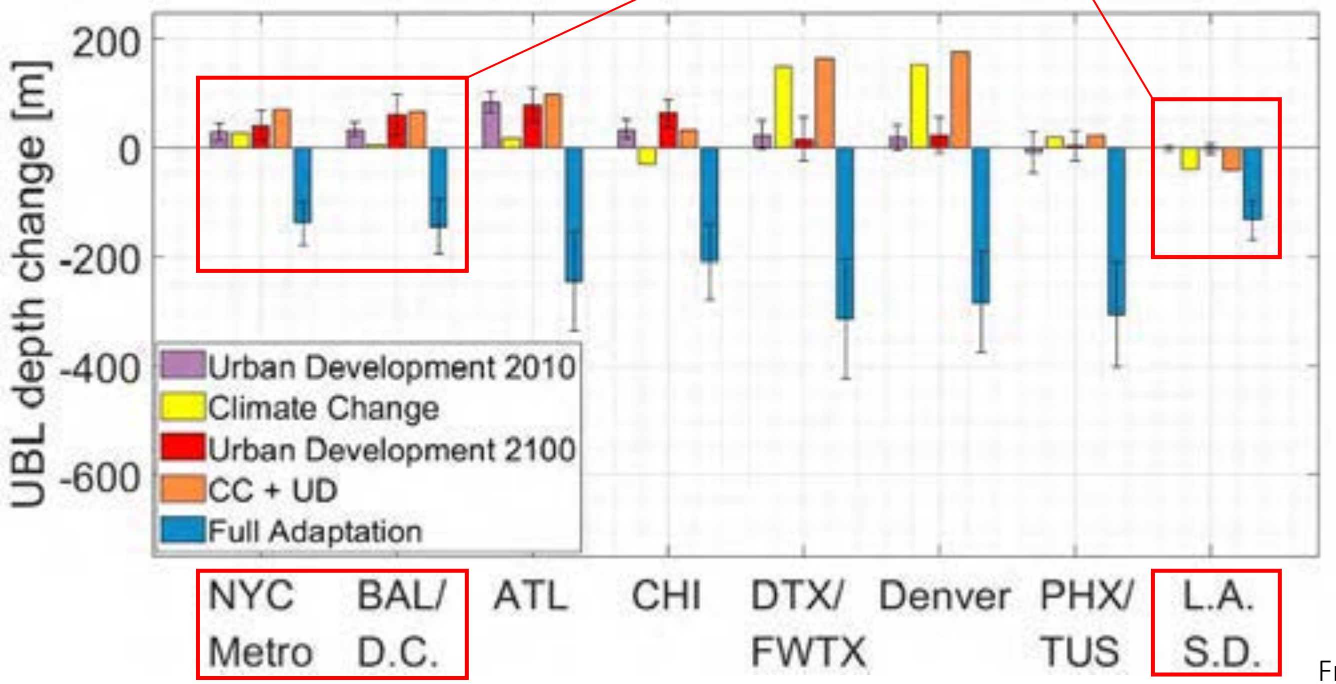
Latent Heat Flux (LH)

Ground Heat Flux

Climate Change and Urban Development impacts sum linearly

Full Adaptation UBL reduction exceeds UD and CC increases

Greater impacts inland
Lesser in coastal cities



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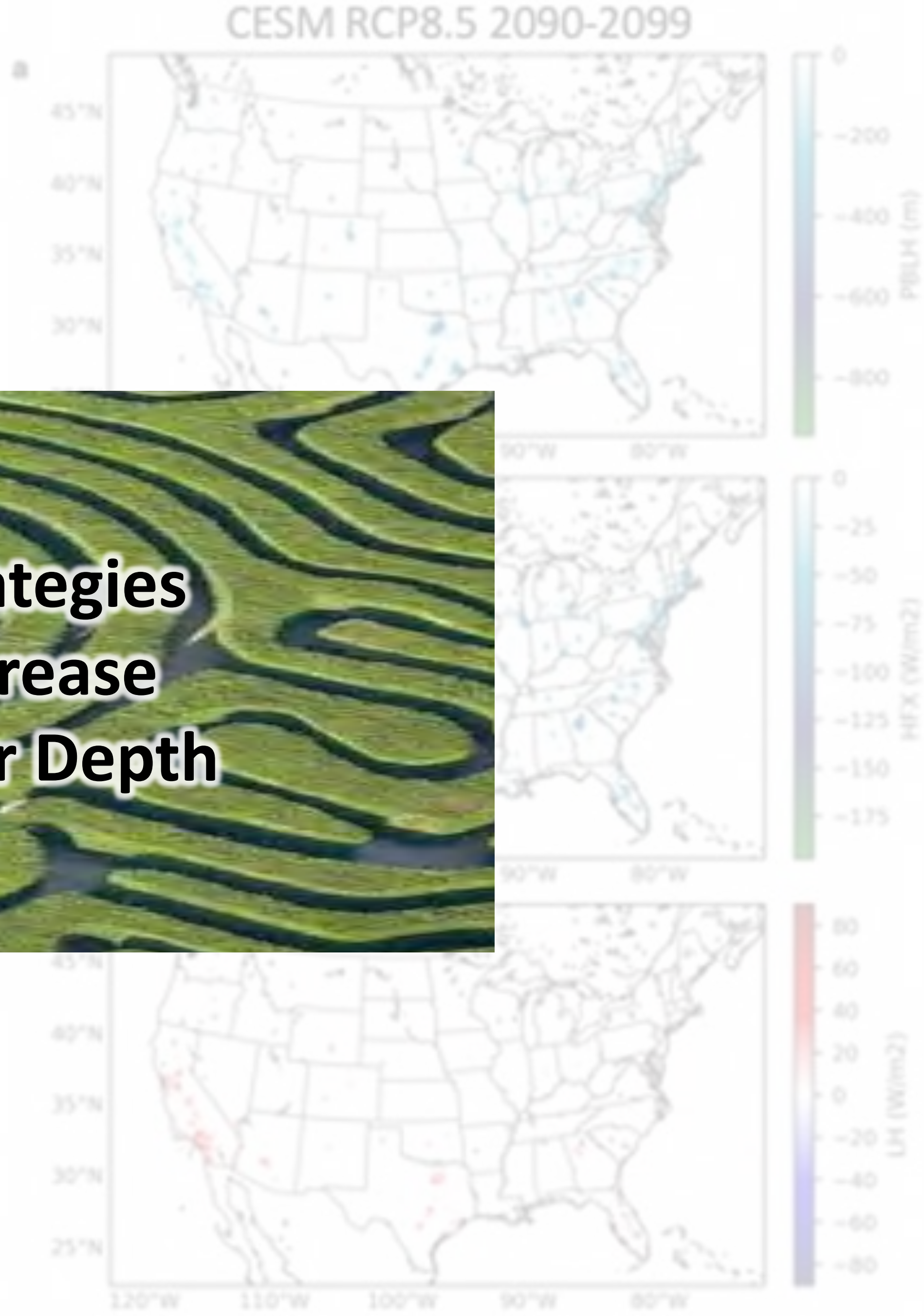

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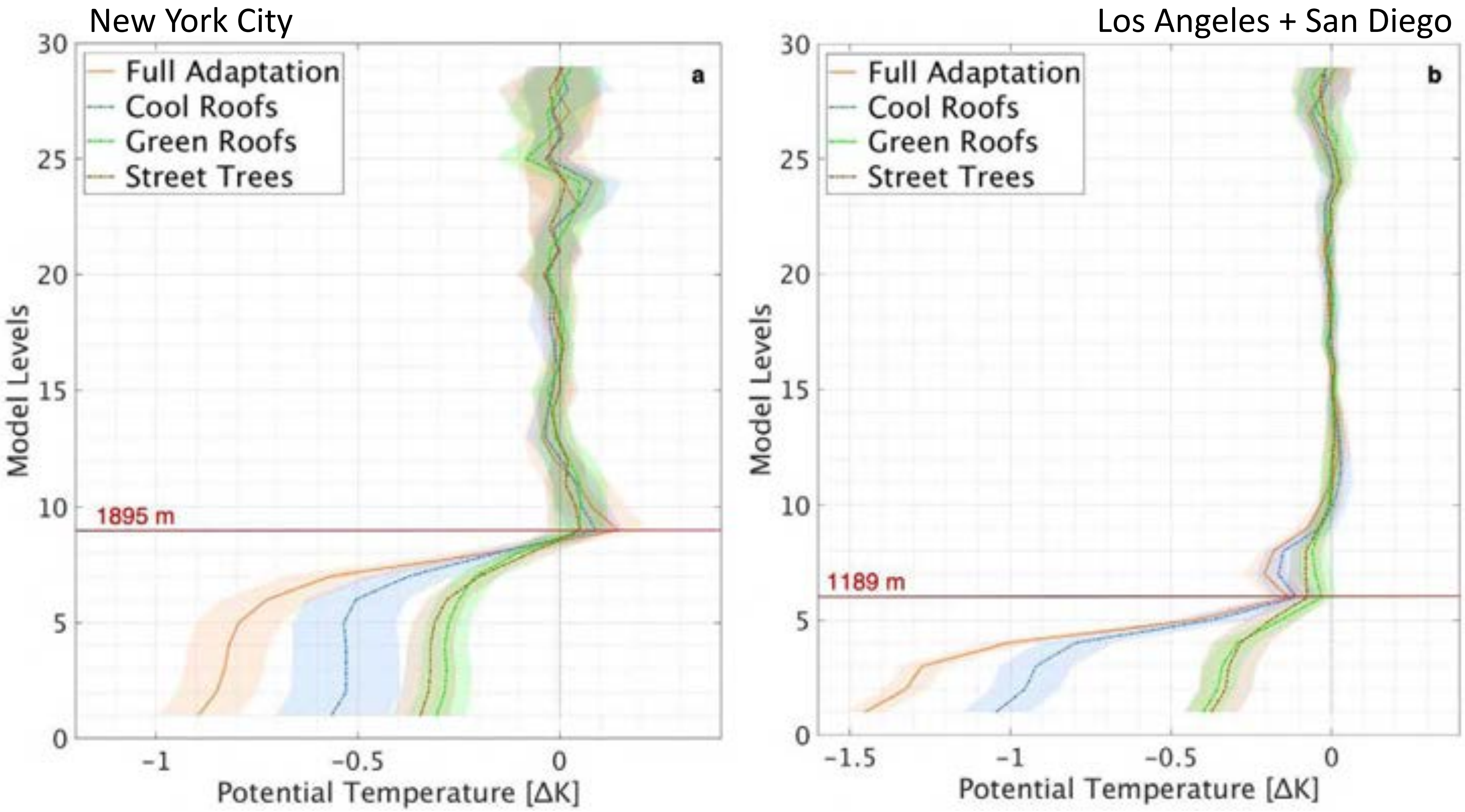
Results (JJA - 14:00 MST)
ICLUS 2100 + CESM RCP8.5 2090-2099

Full Adaptation
Cool Roofs + Green Roofs + Street Trees



From Brandi et al. 2021

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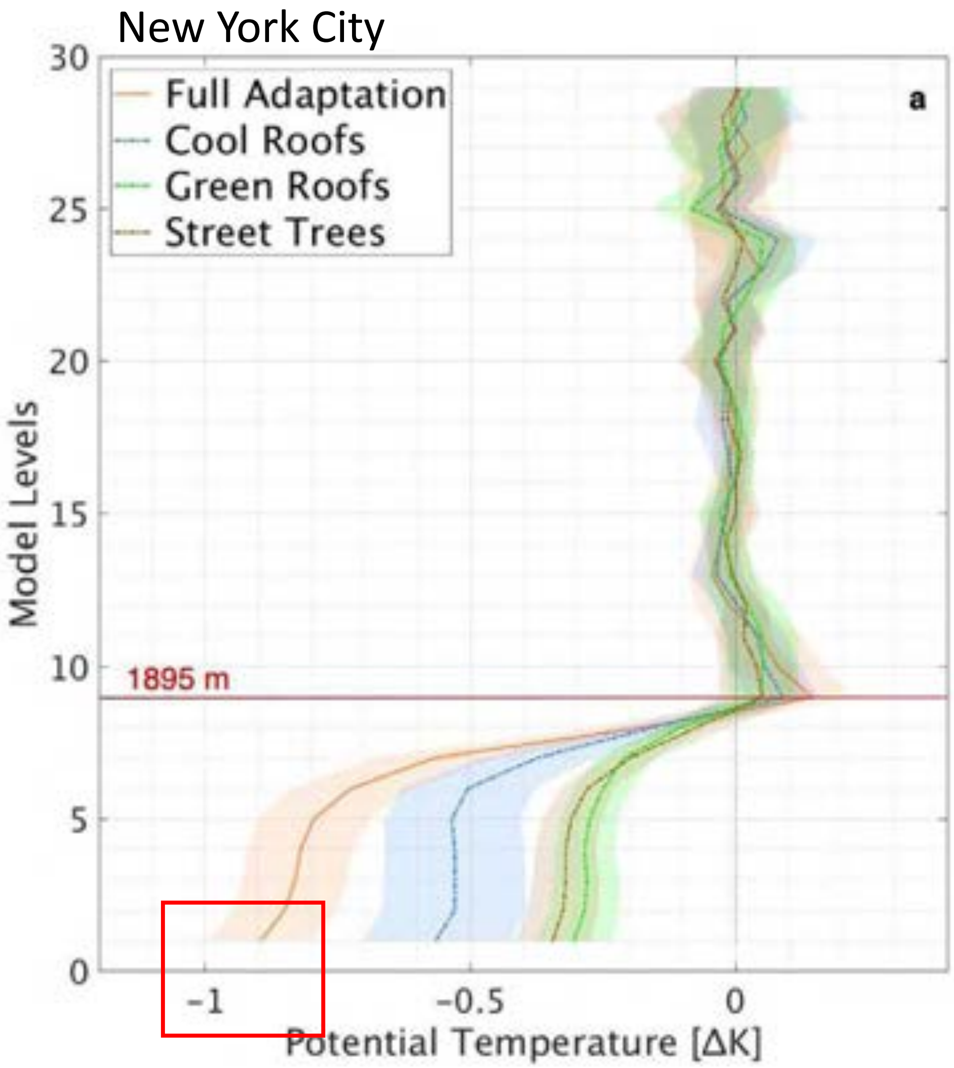

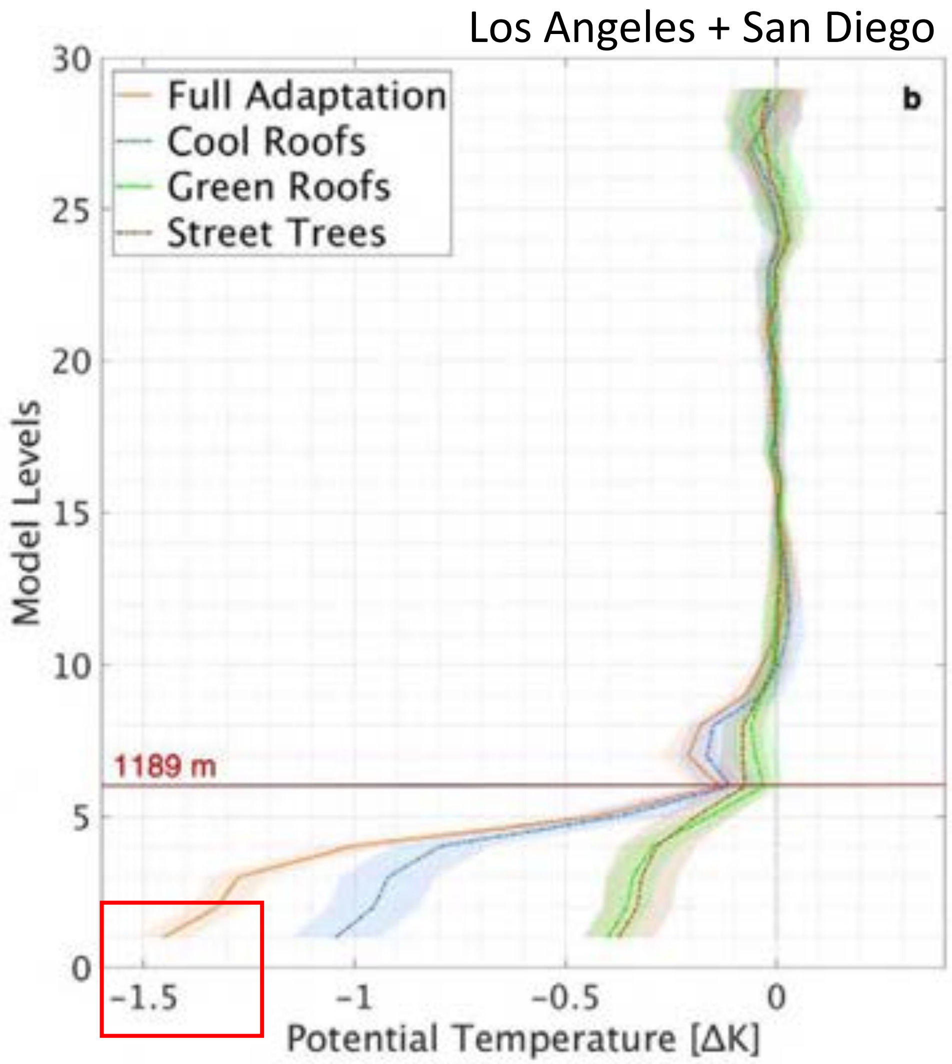

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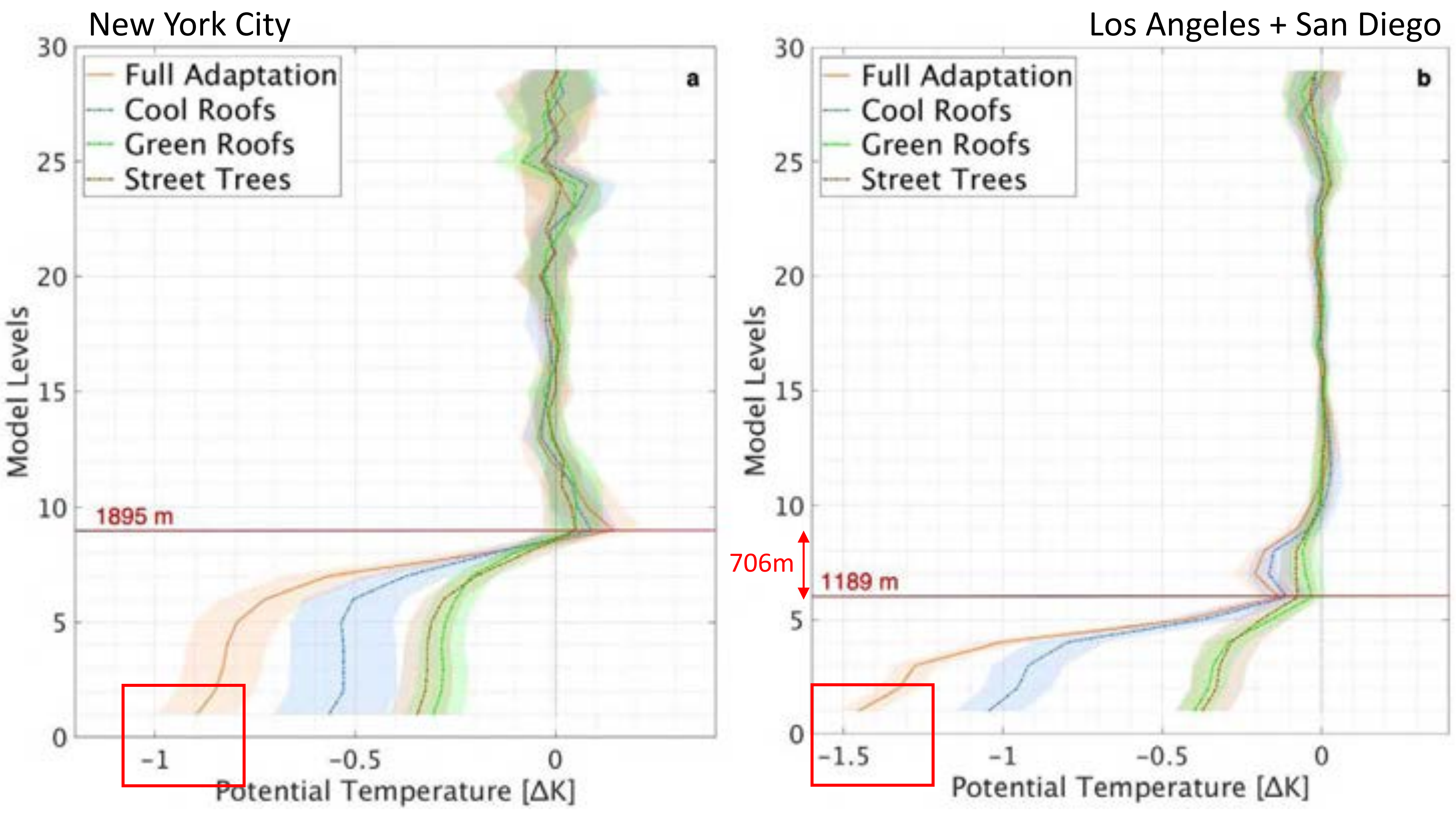

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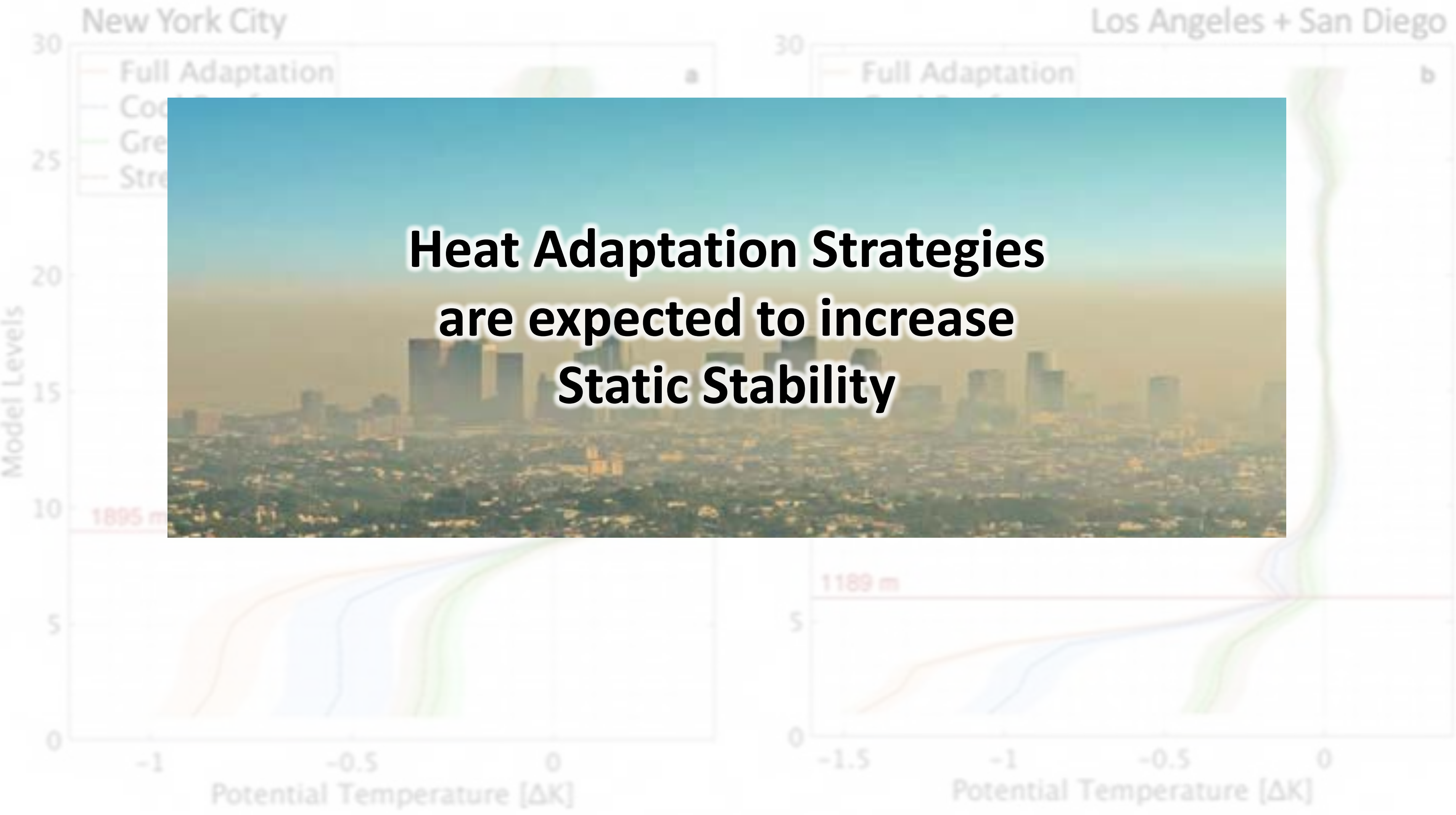

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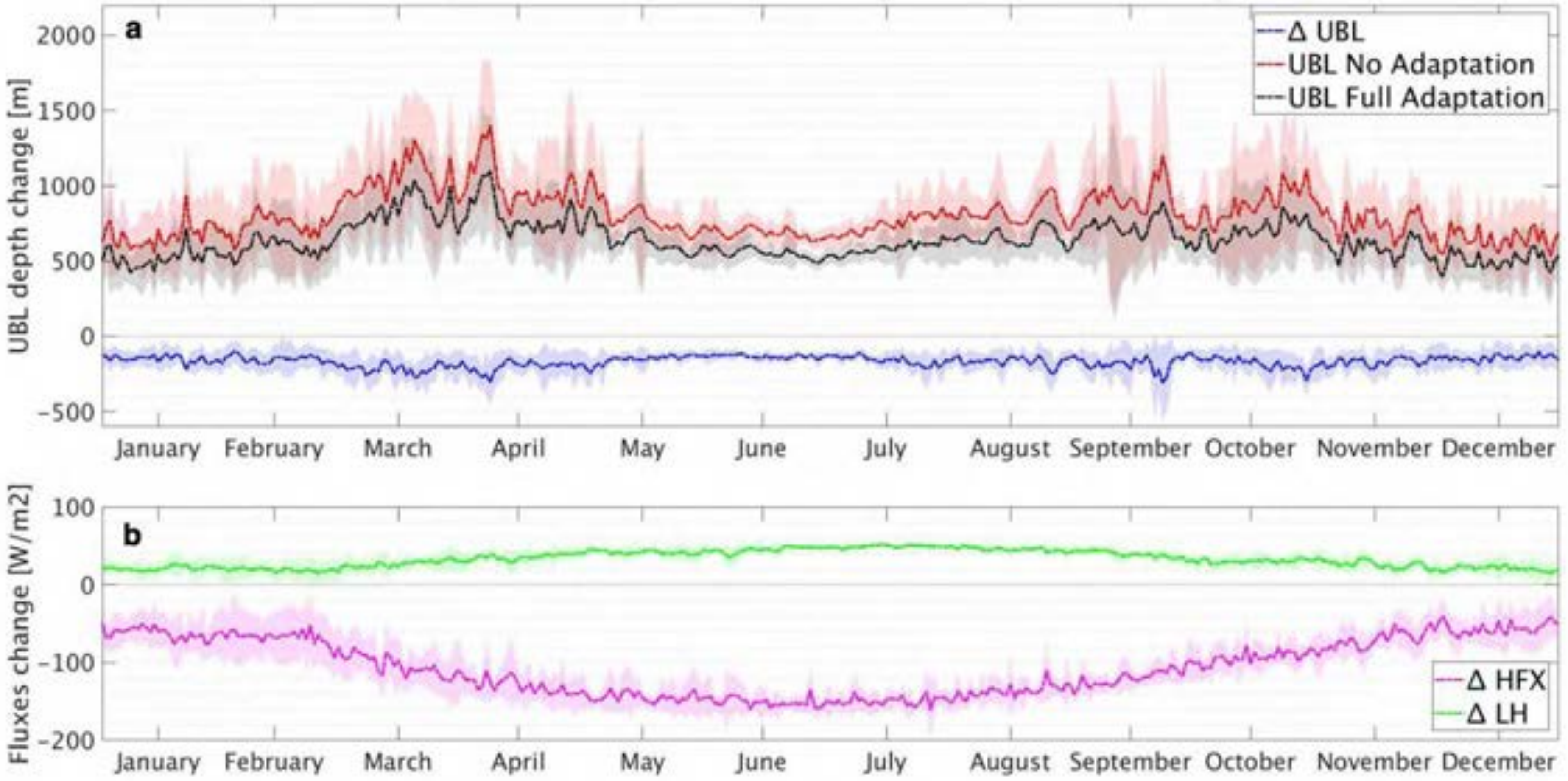
Peak Values

UBL Depth change
Δ ≅ −100 m

Sensible Heat change
ΔHFX ≅ −160 W/m^2

Latent Heat change
ΔLH ≅ 50 W/m^2

Los Angeles + San Diego



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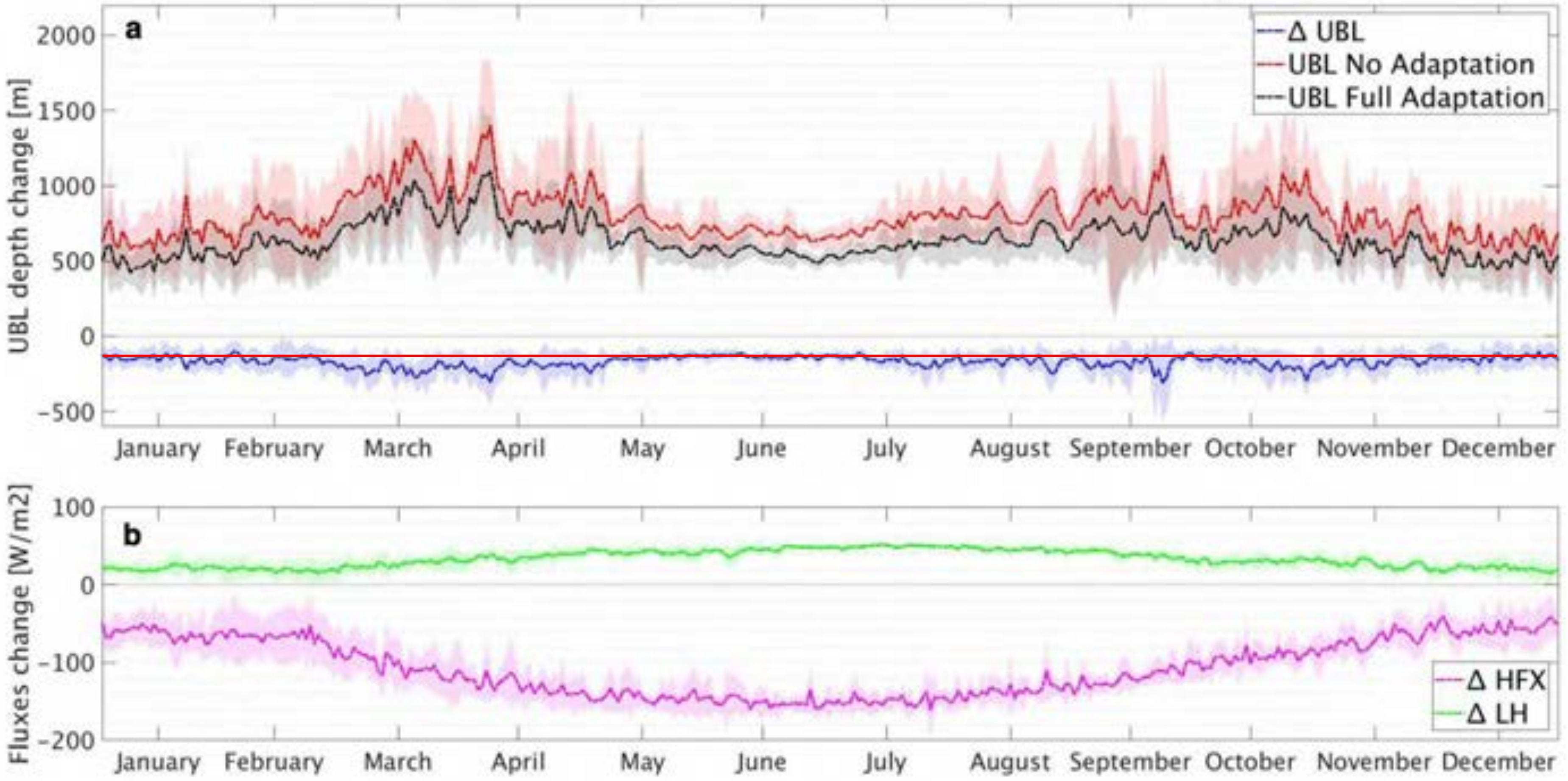

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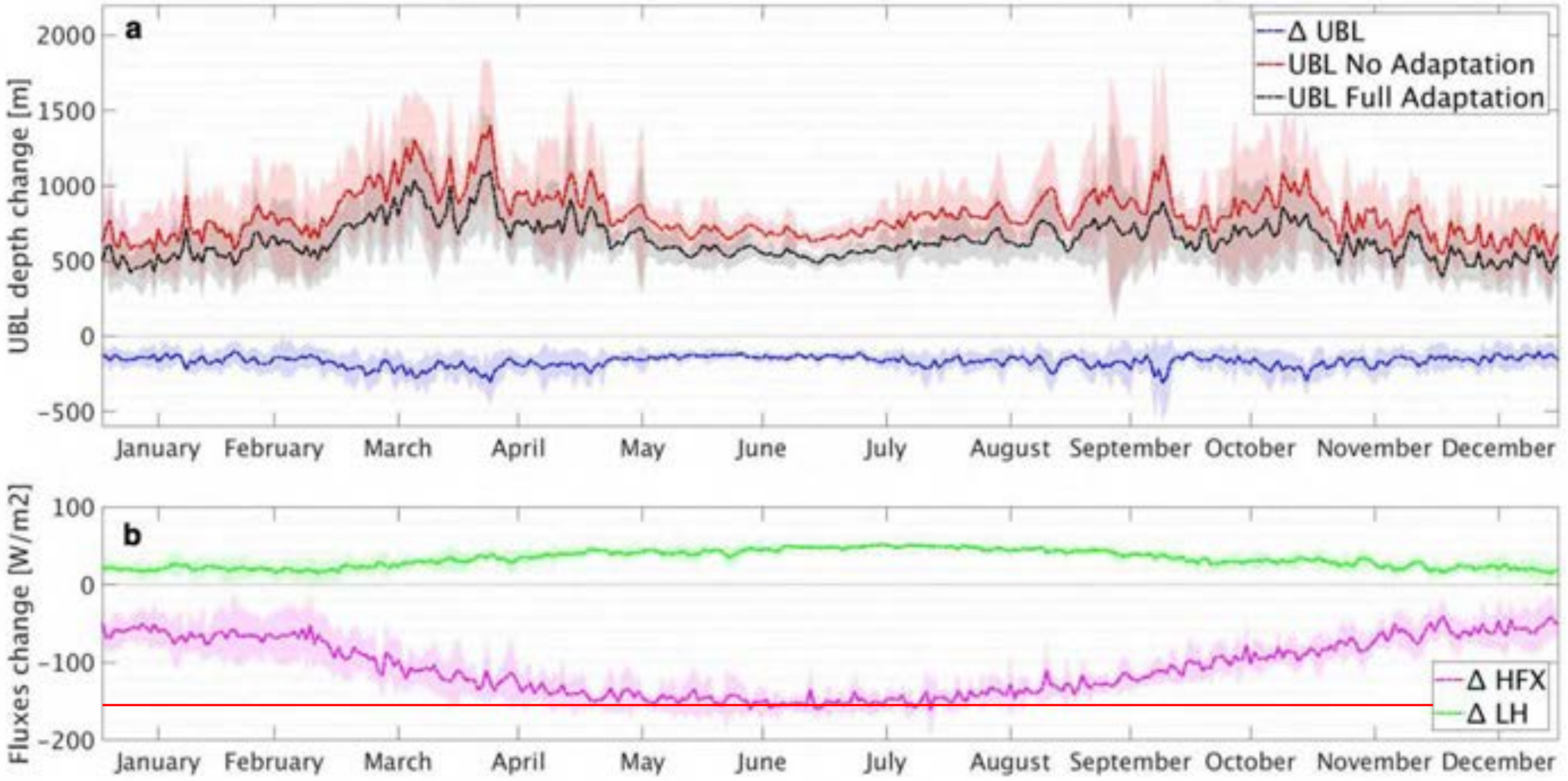

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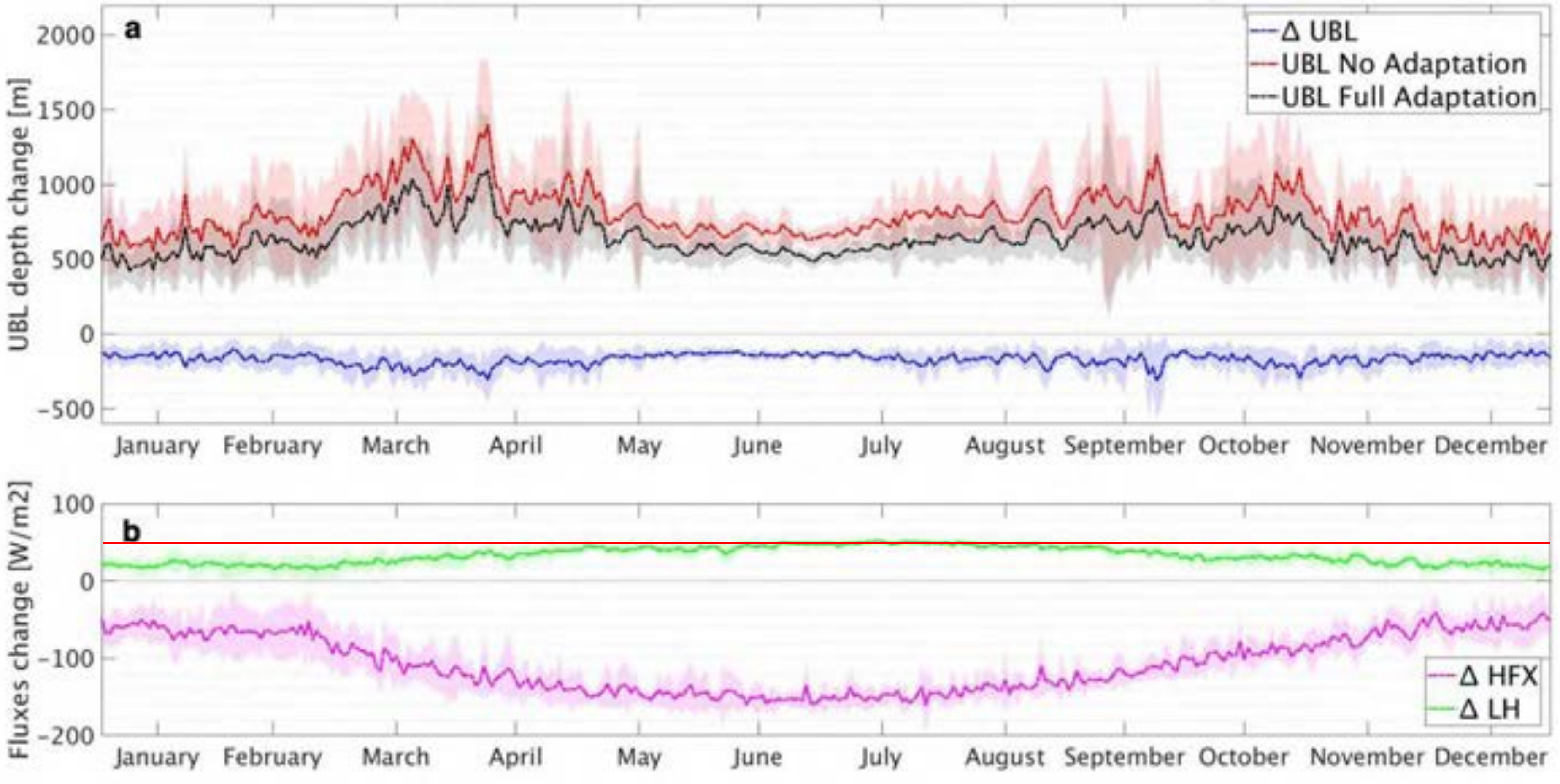

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ICLUS 2100 + CESM RCP8.5 2090-2099

Full Adaptation

Cool Roofs + Green Roofs + Street Trees

New York City

Peak Values

UBL Depth change

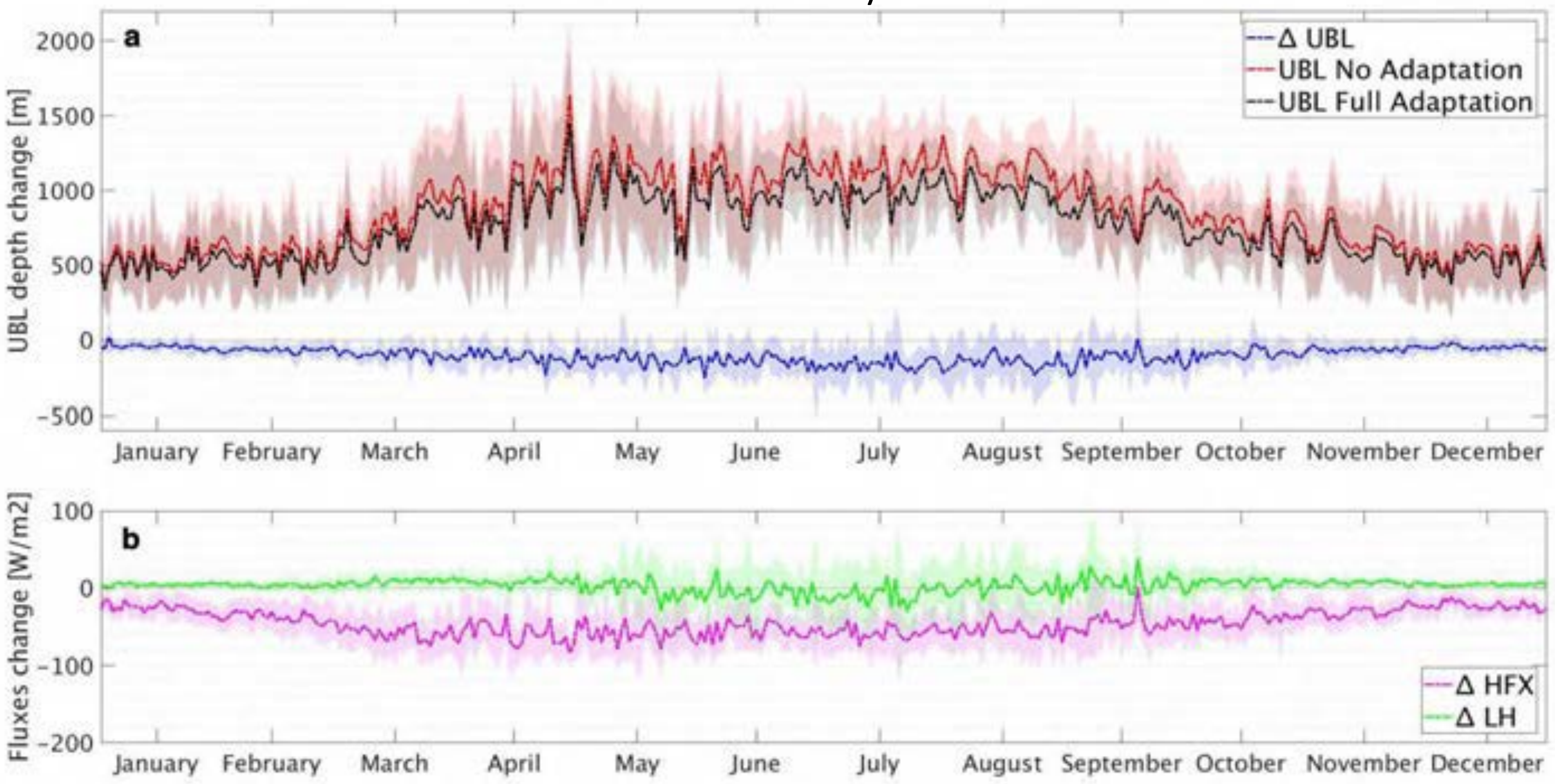
Δ ≅ −180 m

Sensible Heat change

Δ ≅ −60 W/m^2

Latent Heat change

Δ ≅ 0 W/m^2



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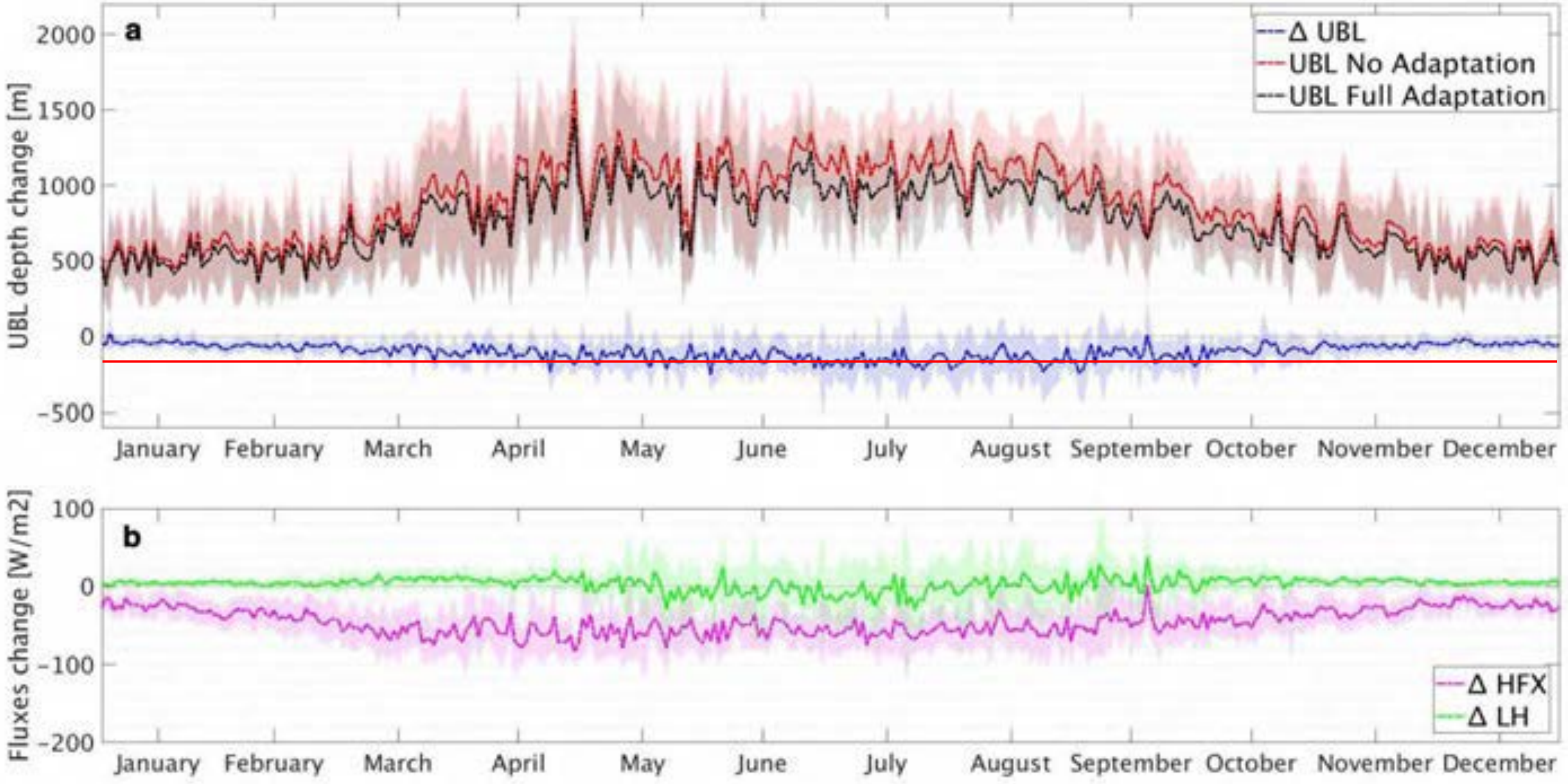

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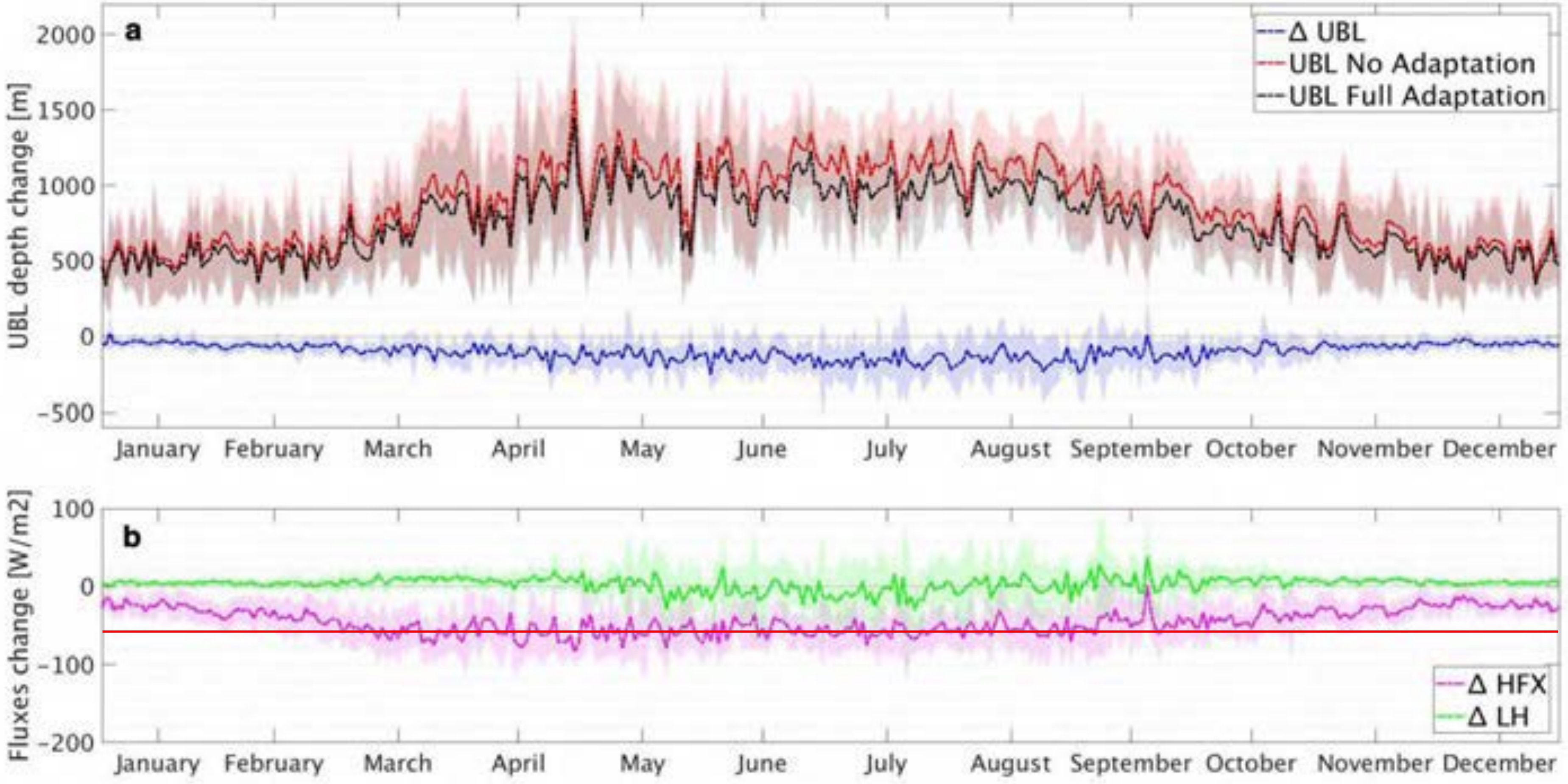

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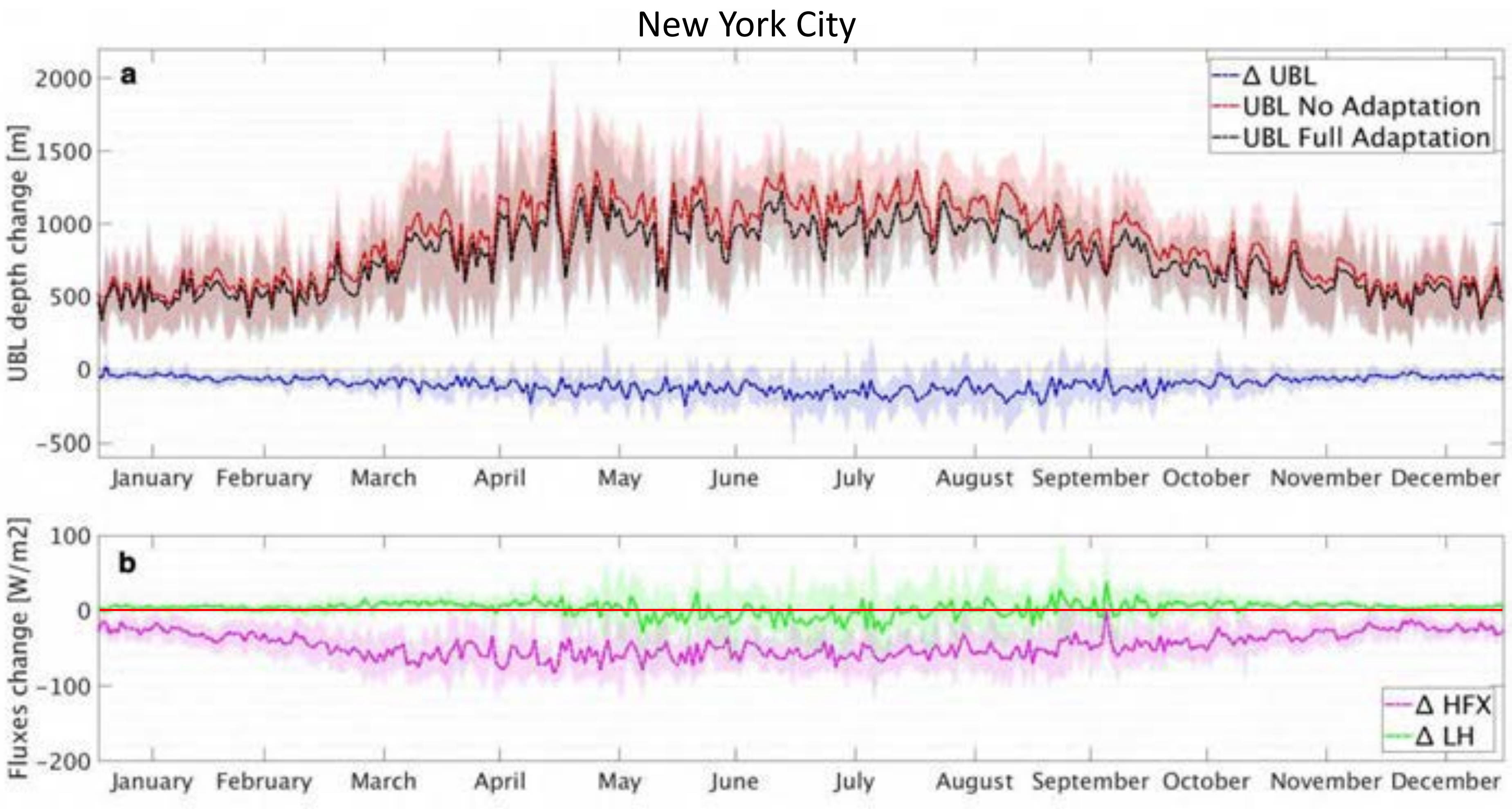

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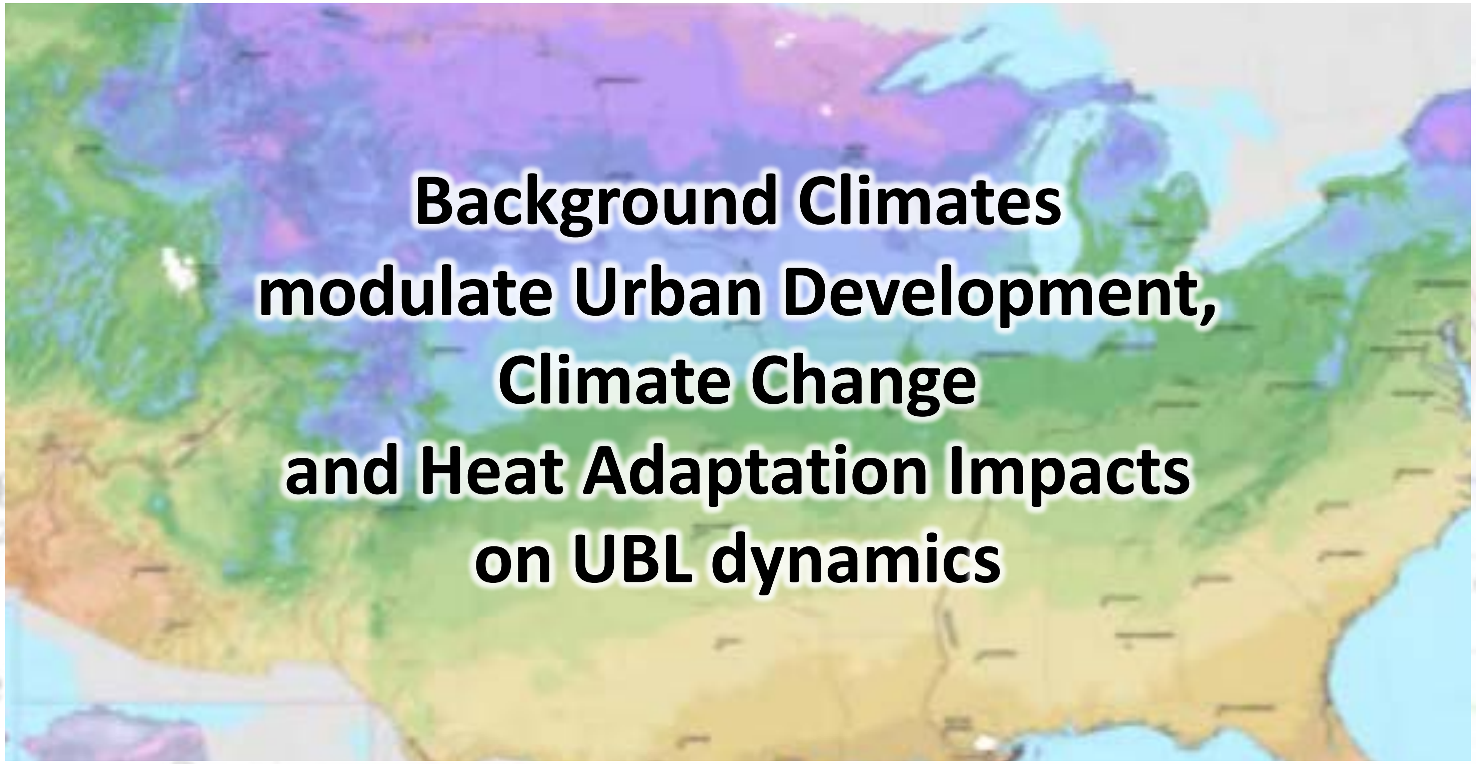

Conclusions (Brandi et al. 2021)

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Interaction between landscape change and background climate has important consequences on UBL dynamics

UBL depth
Static Stability
Subsidence

→ Downward compression of convective mixing → Potential for higher pollutant concentration at pedestrian level

Need for thorough **evaluation of tradeoffs between achieving thermal comfort and preserving air quality in urban environments** when designing and implementing landscape modifications

ASU School of Geographical Sciences and Urban Planning
Arizona State University

Thank you

abrandi@asu.edu

ASU
Urban Climate Research Center
Arizona State University

References

Krayenhoff, E. S., Broadbent, A. M., Zhao, L., Georgescu, M., Middel, A., Voogt, J. A., ... & Erell, E. (2021). Cooling hot cities: A systematic and critical review of the numerical modelling literature. *Environmental Research Letters*.

Stull, R. B. (1988). *An introduction to boundary layer meteorology* (Vol. 13). Springer Science & Business Media.

Broadbent, A. M., Krayenhoff, E. S., & Georgescu, M. (2020). The motley drivers of heat and cold exposure in 21st century US cities. *Proceedings of the National Academy of Sciences*, *117*(35), 21108-21117.

Al-Obaidi, Karam & Ismail, Mazran & Rahman, Abdul. (2014). Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review. Frontiers of Architectural Research. 3. 10.1016/j.foar.2014.06.002.

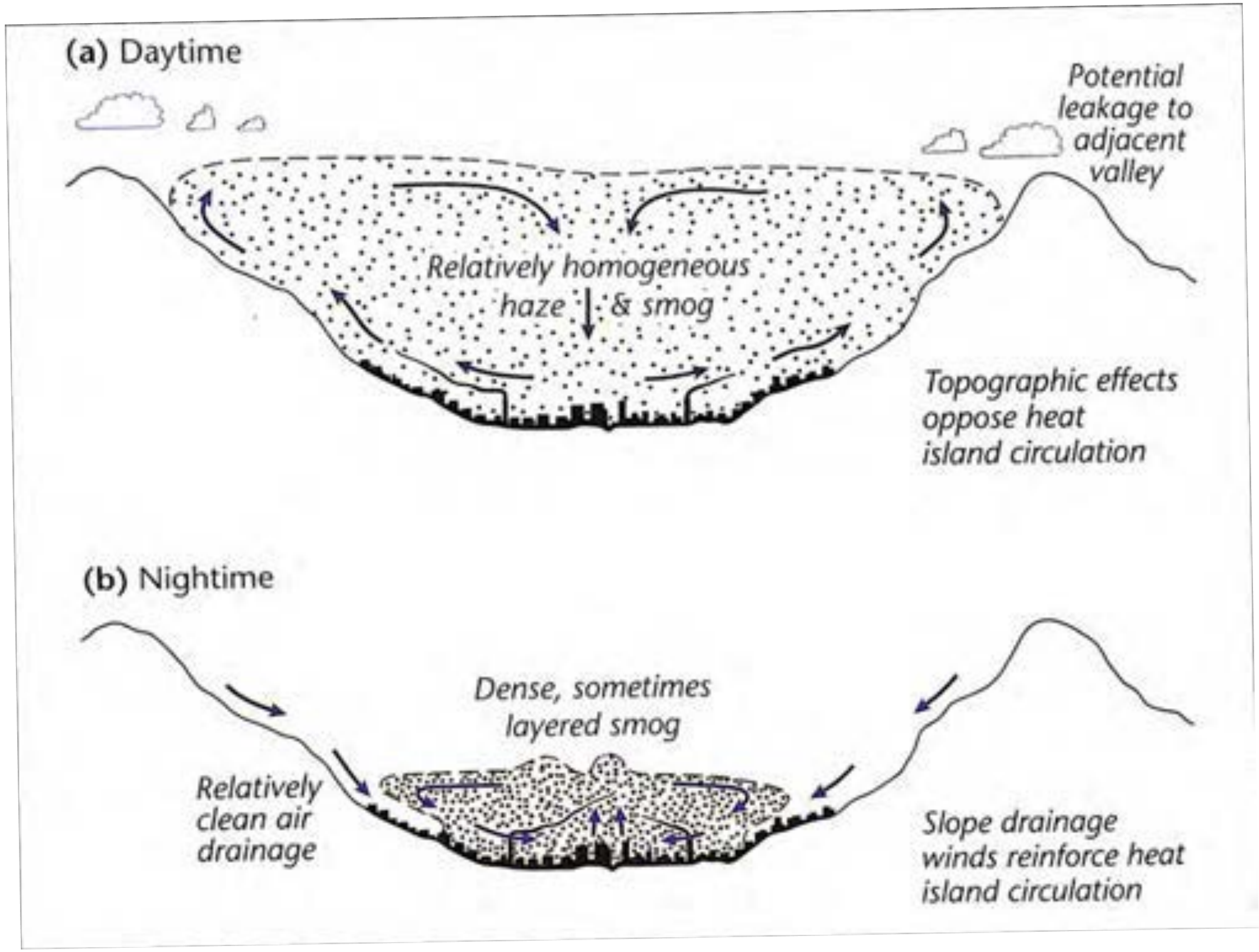
Liu, Xin & Chui,. (2019). Evaluation of Green Roof Performance in Mitigating the Impact of Extreme Storms. Water. 11. 815. 10.3390/w11040815.

Livesley, S. J., McPherson, E. G., & Calfapietra, C. (2016). The urban forest and ecosystem services: impacts on urban water, heat, and pollution cycles at the tree, street, and city scale. *Journal of environmental quality*, *45*(1), 119-124.

Fernando, H. J. S. (2010). Fluid dynamics of urban atmospheres in complex terrain. *Annual review of fluid mechanics*, *42*, 365-389.

Brandi, A., Broadbent, A. M., Krayenhoff, E. S., & Georgescu, M. (2021). Influence of projected climate change, urban development and heat adaptation strategies on end of twenty-first century urban boundary layers across the Conterminous US. *Climate Dynamics*, 1-17.

Future work



From Oke et al. 2017

BL instability favors
Upward motion

UHIC ~ Thermal

BL stability favors
Downward motion

Thermal > UHIC

Future work

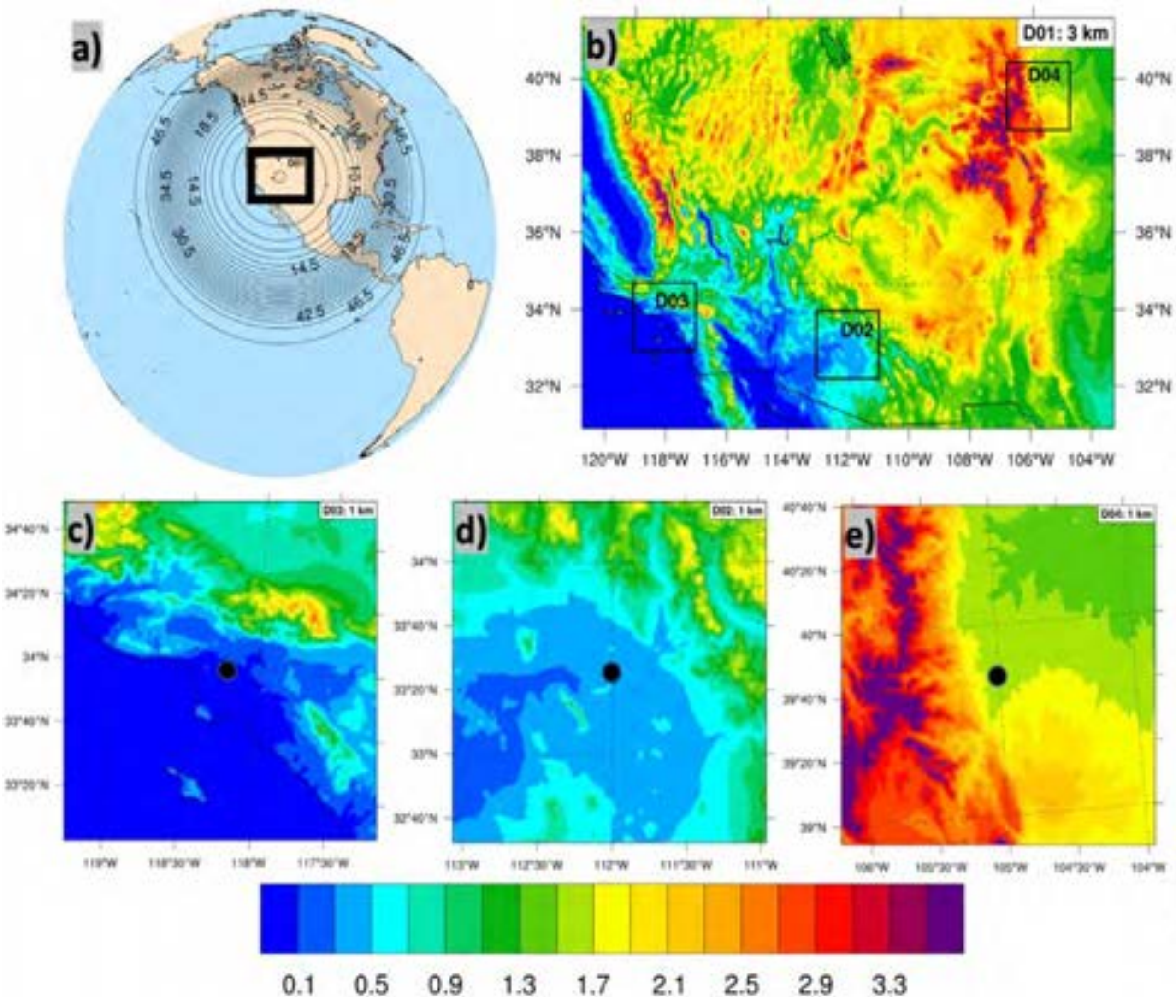


Figure 2. Domain configurations for the MPAS-WRF nested simulations: **a)** approximate grid spacing for the rotated MPAS 60km-to-3km variable resolution mesh centered at 36.6N, 112W. The bold rectangle indicates the parent WRF (D01) domain. The contour interval is 2km and the value of the innermost contour inside the rectangle is 2km; **b)** the parent WRF domain (D01) to be driven by MPAS with a grid spacing of 3km. The bold squares indicate the nested WRF domains driven by domain D01; **c)**, **d)**, and **e)** are the nested WRF domains D02, D03, and D04, centered on Phoenix, Los Angeles and Denver, respectively, with a grid spacing of 1km. The shading in the WRF domains represents terrain elevation in units of kilometers; the filled black circles superimposed in **c) - e)** denote city centers.

Air quality and Climate Change

More frequent stagnation events ⇨ Negative impact on local circulation systems

Projected higher temperatures will increase pollutant concentrations
Increased BVOCs (Biogenic Volatile Organic Compounds) emissions

Ozone (O_3)

Facilitated photodissociation processes

Projected increase in methane (CH_4) concentration might overcome NO_x reduction

Particulate Matter ($PM_{2.5}$ – PM_{10})

Increased frequency and duration of wildfires

Persisting drought events ⇨ Soil erosion ⇨ Dust storms

Air Pollution

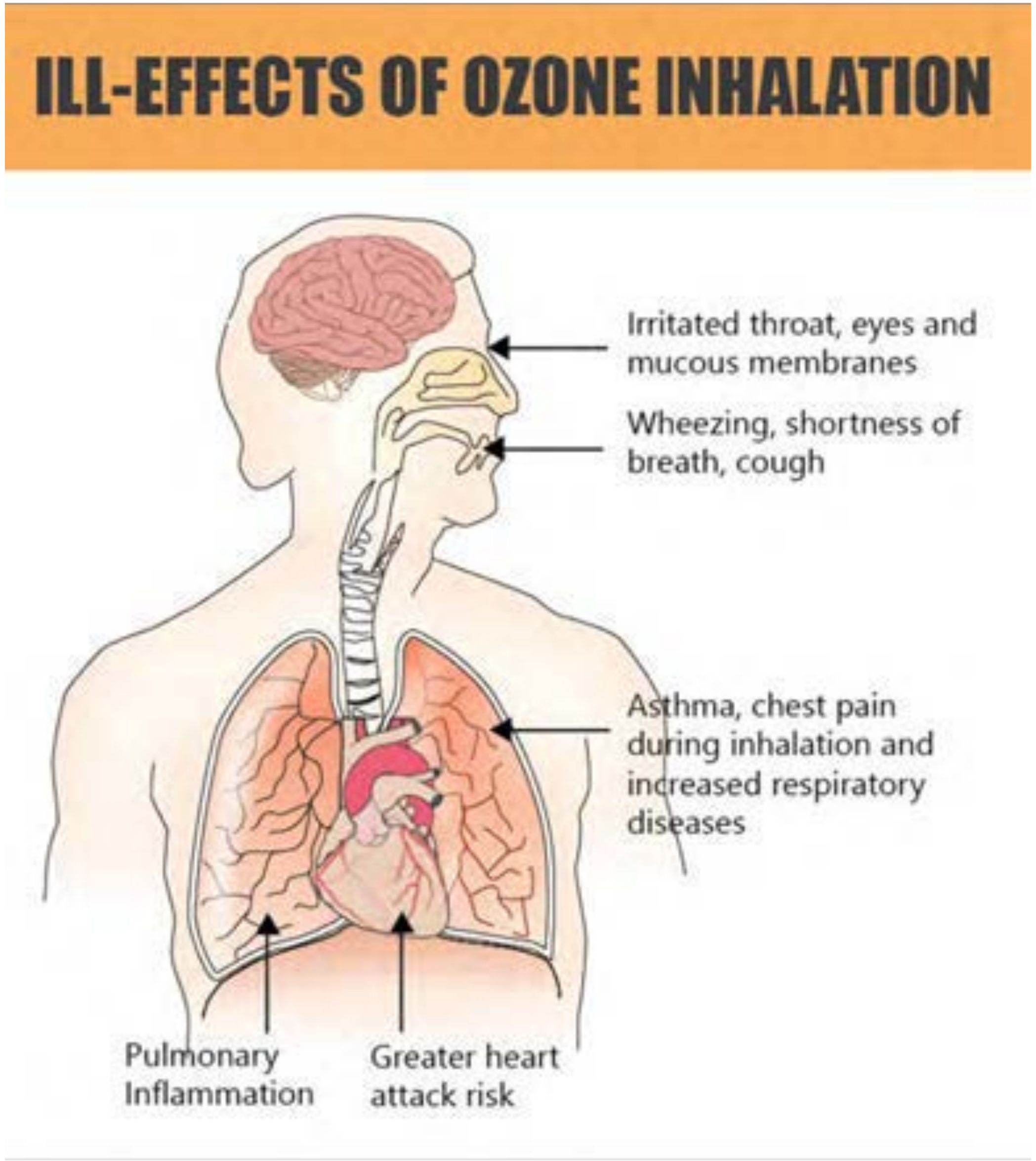
Ozone (O_3)

Photodissociation

$NO_2 + h\nu \rightarrow NO + O$
$O + O_2 + M \rightarrow O_3 + M$

Mostly daytime reaction (needs UV radiation)
Favored by higher temperature

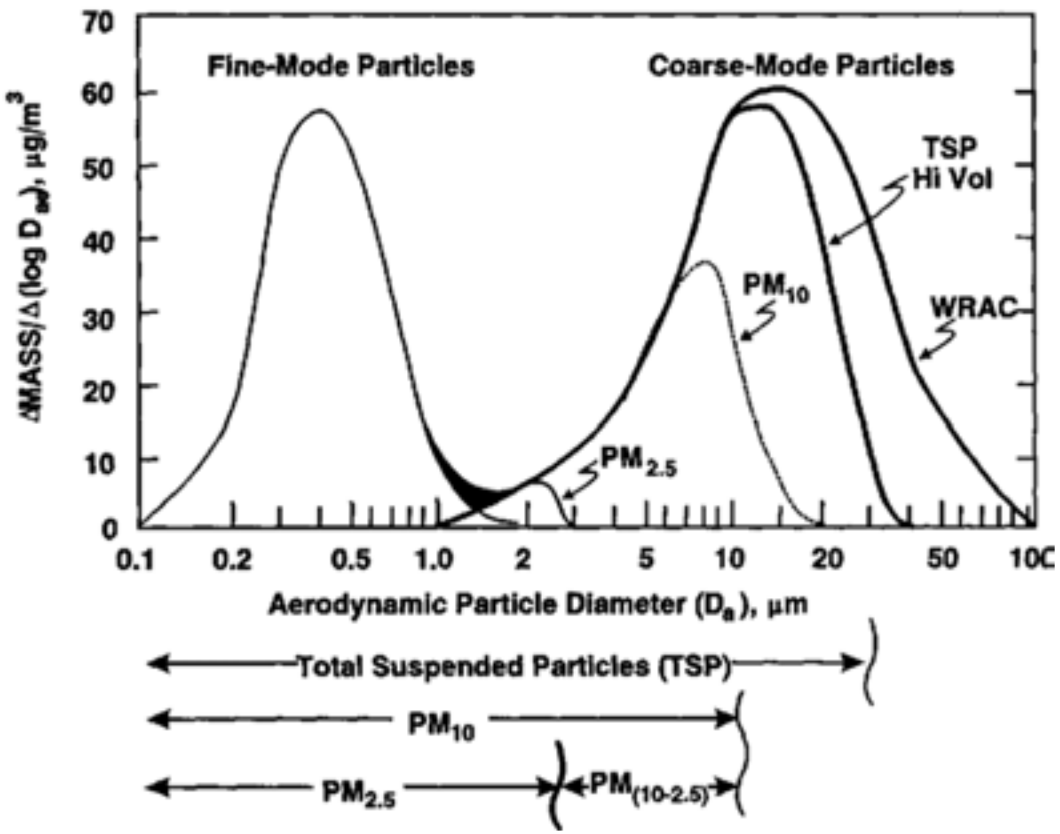
Powerful oxidant
Attacks C=C double bonds
abundant in rubber, plants, human body membranes,
especially in the lungs and the heart



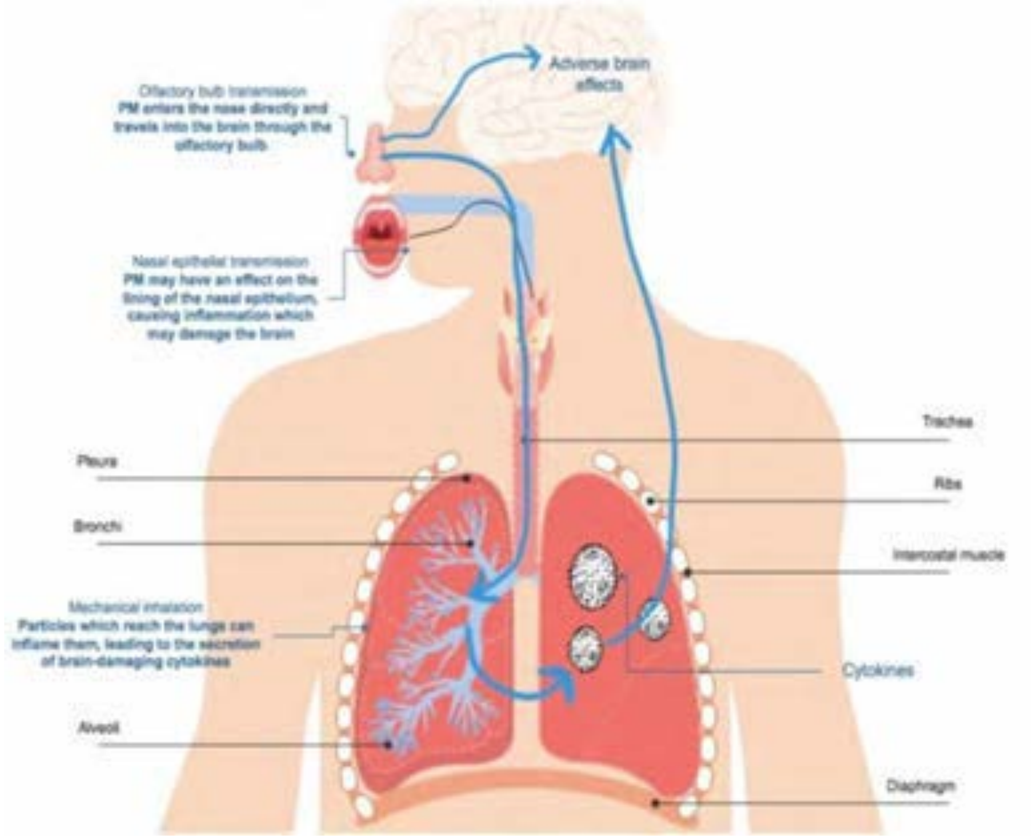
https://www.sleepaider.com/articles/health-effects-of-ozone-pollution.22/

Air Pollution

Particulate Matter ($PM_{2.5}$ – PM_{10})



Schematic representation of the size distribution of particulate matter in ambient air (USEPA 1996) - "Chapter 7.3 Particulate Matter"



Han, Hyun Jee & Shrubsole, Clive. (2018)

Edith de Guzman

Director and Co-founder, LA Urban Cooling Collaborative

Ph.D. Candidate, UCLA Institute of the Environment and Sustainability

@edithbdeguzman

Cooler and Healthier: Reducing Heat-Health Risk Using Urban Forestry & Stakeholder Engagement

COOLER AND HEALTHIER:
Reducing heat-health risk using urban forestry and stakeholder engagement

September 8, 2021 | UCLA Climate Adaptation Research Symposium

Edith de Guzman | UCLA Institute of the Environment & Sustainability and
Los Angeles Urban Cooling Collaborative

What I'll cover:

1. Urban forests and extreme heat
2. Challenges of urban forest stewardship
3. Behavior change study on urban forest stewardship
4. Preliminary findings
5. Next steps and implications

Photo: TreePeople

Urban forests and extreme heat

Hottest day in L.A. County's recorded history:
121°F on Sept. 6, 2020

Duplex with no trees or AC in Huntington Park:
107.4°F indoors

Source: de Guzman, E. and A. Barreca. *Evaluating the Impacts of Trees on Residential Thermal Conditions in Los Angeles Using Community Science.* Y. Chen (Ed). TreePeople. 2021. Photo: Associated Press/M. Spencer Green

Could changes we make to the urban environment cool neighborhoods and save lives?

LOS ANGELES URBAN °COOLING COLLABORATIVE

Project team

Applied Climatologists

ASU Arizona State University

California State University Northridge

Climate Resolve

Global Cool Cities Alliance

Kent State University

TreePeople

UCLA CPHD

UCLA Institute of the Environment & Sustainability

Project funded by

Forest Service U.S. Department of Agriculture

HW Harvard-Westlake School

We tested "prescriptions" of

TREE CANOPY

+

SOLAR REFLECTANCE (ALBEDO)

of roofs & pavements

Low • Moderate • High

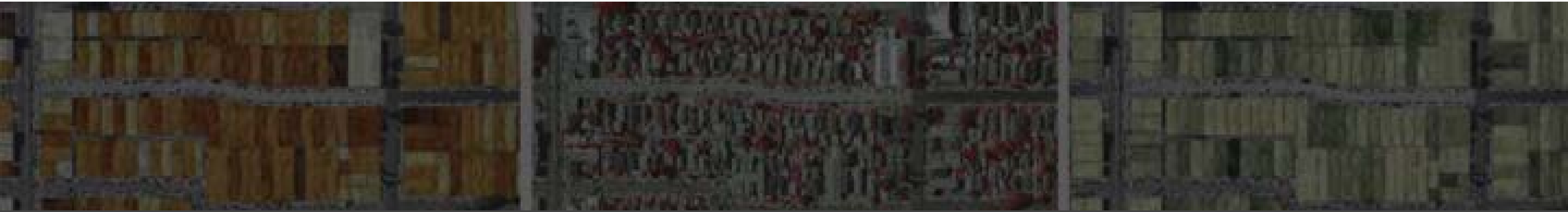
Summary of heat-health modeling results

Temperature reductions often exceeded 1.0°C (1.8°F), and up to 2.0°C (3.6°F), a life or death difference

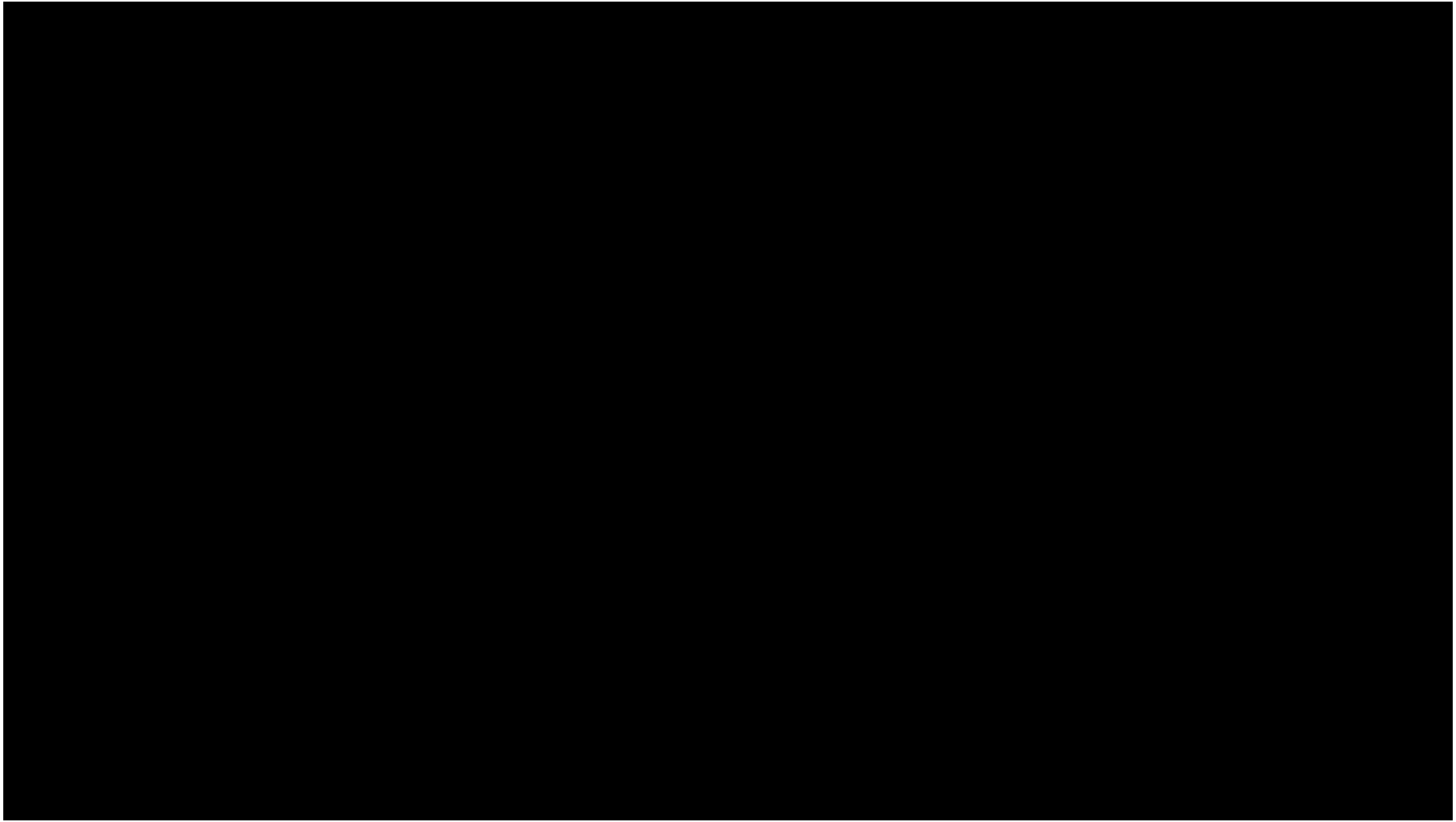
25%+ reductions in heat-related deaths are possible, saving dozens of lives during the worst heat waves

Oppressive air masses could be shifted to more benign ones

Heat impacts of climate change could be delayed ~25-60+ years



If urban forest cover can cool neighborhoods, why not just plant more trees?



Video credit: Coalition to Preserve L.A.

Challenges of urban forest stewardship

- Rainfall averages and patterns (young trees must be watered!)
- A changing climate
- Pests
- Funding for planting vs. establishment

Behavior change study on urban forest stewardship

- **Can a residential street tree stewardship program serve as a portal to increase knowledge and action around heat-health risk?**
- **Does engagement tailored to the community lead to better outcomes than one that is more generic?**
- **Are outcomes enhanced by message framing that emphasizes improvements to *environmental health* rather than *public health*?**

RESEARCH TEAM

Edith de Guzman | UCLA and LA Urban Cooling Collaborative

Dr. Erica Wohldmann and Delmy Martir | CSUN

Luis Rodriguez, Dr. Yujuan Chen, and Pam Gibson | TreePeople

Funded by

Community Based Social Marketing (CBSM)

SELECTING TARGET AUDIENCE AND BEHAVIORS

IDENTIFYING BARRIERS & BENEFITS

DEVELOPING STRATEGIES

PILOT TESTING

EVALUATION & BROAD IMPLEMENTATION

Selecting target audience & behaviors

“The public” is not an audience.

AUDIENCE:
Residents whose home is adjacent to a newly-planted street tree in the City of San Fernando

“Tree stewardship” is not a behavior.

BEHAVIOR:
Check soil moisture - weekly
Water w/ 15 gal - as needed

—

(Behaviors should be *end-state* and *non-divisible*)

Photo: TreePeople

LOS ANGELES URBAN °COOLING COLLABORATIVE

Identifying barriers & benefits

REVIEW THE LITERATURE

FOCUS GROUPS

SURVEYS

KEY FINDINGS

Trees are valued

Barriers to tree stewardship are mostly *not* structural

Perception that City is responsible for care

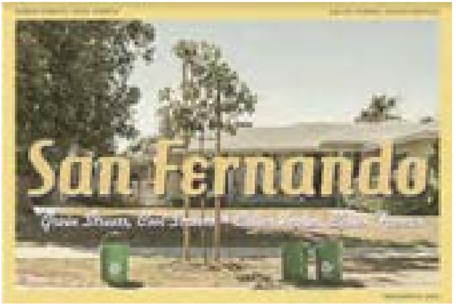
Caring for trees is thought to be expensive

Developing strategies

INSTRUCTIONAL PIECE

COMMITMENT PIECES

REMINDER PROMPTS



Pilot testing

CONTROL GROUP

Generic packet

Previously used successfully in smaller study in Huntington Park, southeast LA County

ENVIRONMENTAL HEALTH GROUP

Messaging highlights link between trees and improved environmental health

Tailored to San Fernando community

PUBLIC HEALTH GROUP

Messaging highlights link between trees and improved public health

Tailored to San Fernando community

Pilot testing

CONTROL GROUP

ENVIRONMENTAL HEALTH GROUP

PUBLIC HEALTH GROUP

Evaluation

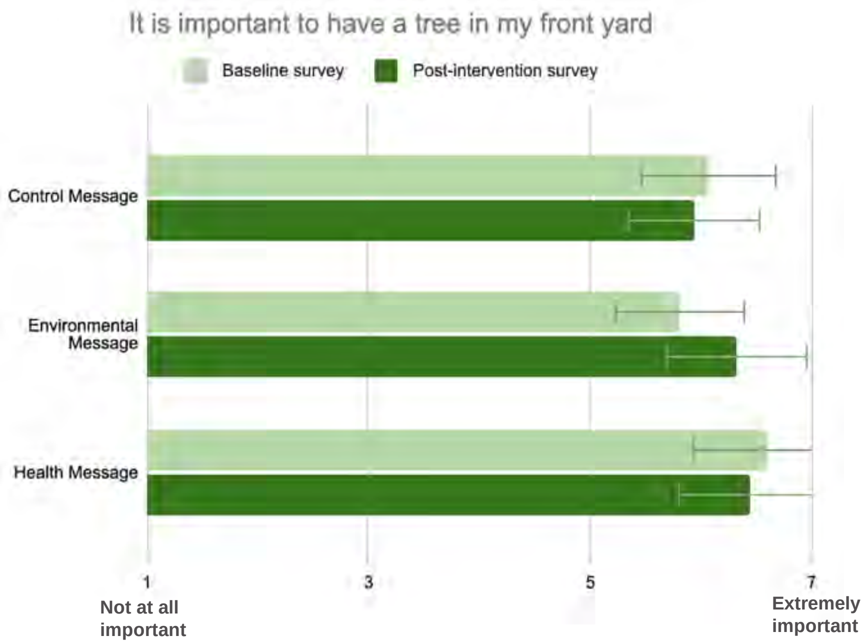
12+ WEEKS OF OBSERVATION

- Collect soil moisture readings
- Observe presence of mulch
- Observe presence of weeds
- Rate tree health
- Note other observed issues

Photo: TreePeople

Preliminary findings | VALUES AROUND TREES

Trees are highly valued, and environmental messaging helps to solidify that



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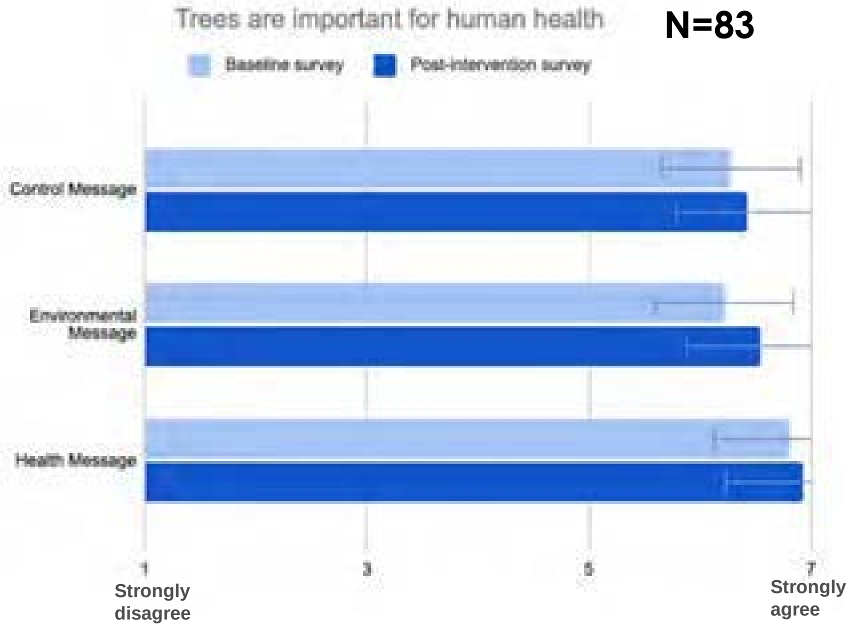
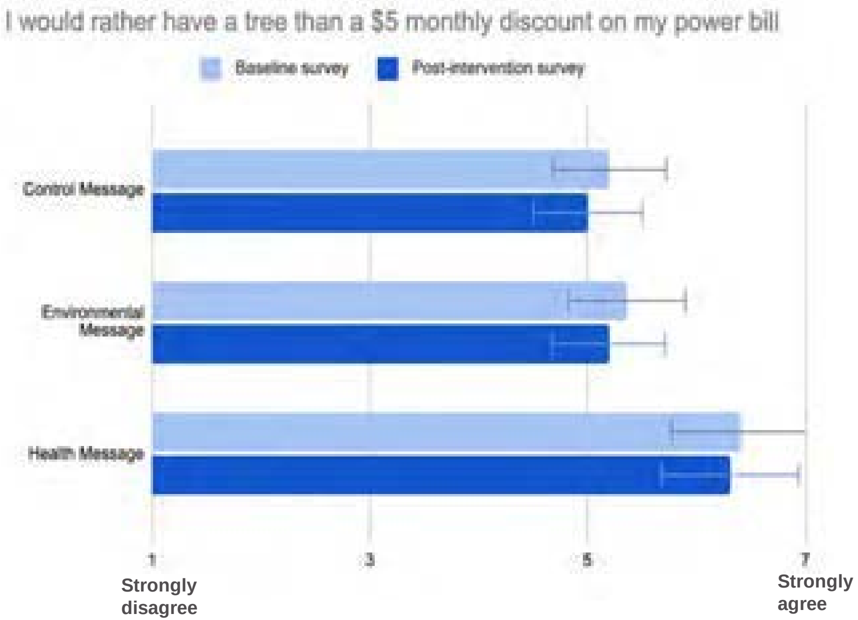


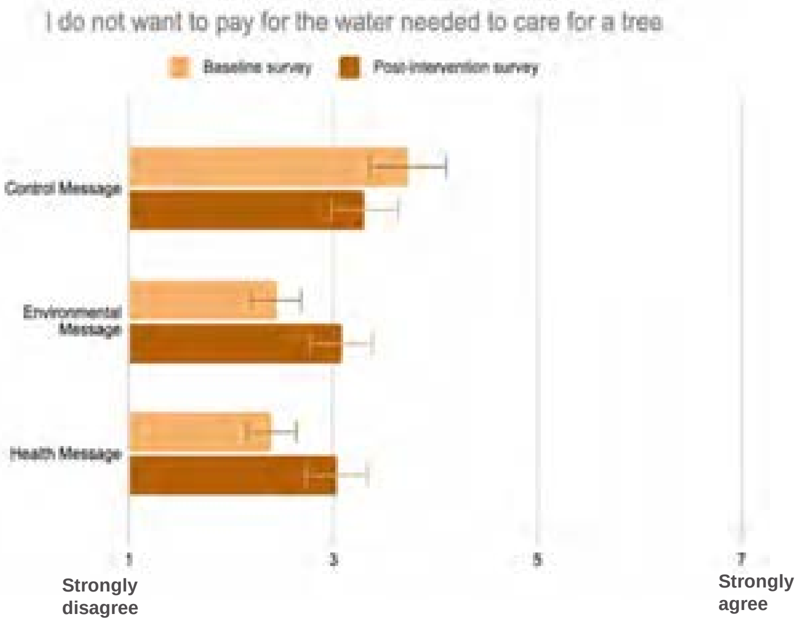
LOS ANGELES URBAN COOLING COLLABORATIVE

Preliminary findings | PAYING FOR TREE CARE

Residents are less willing to pay for watering after program engagement

N=83

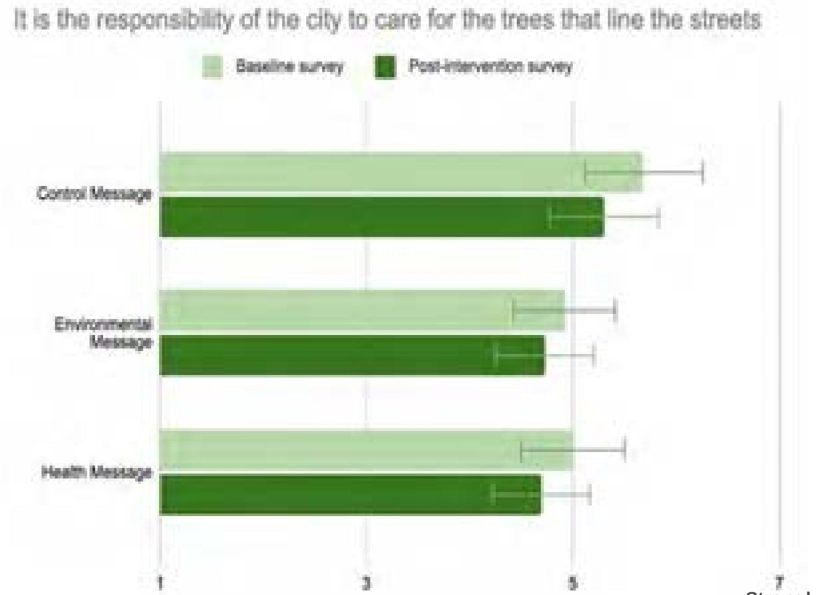




Preliminary findings | RESPONSIBILITY

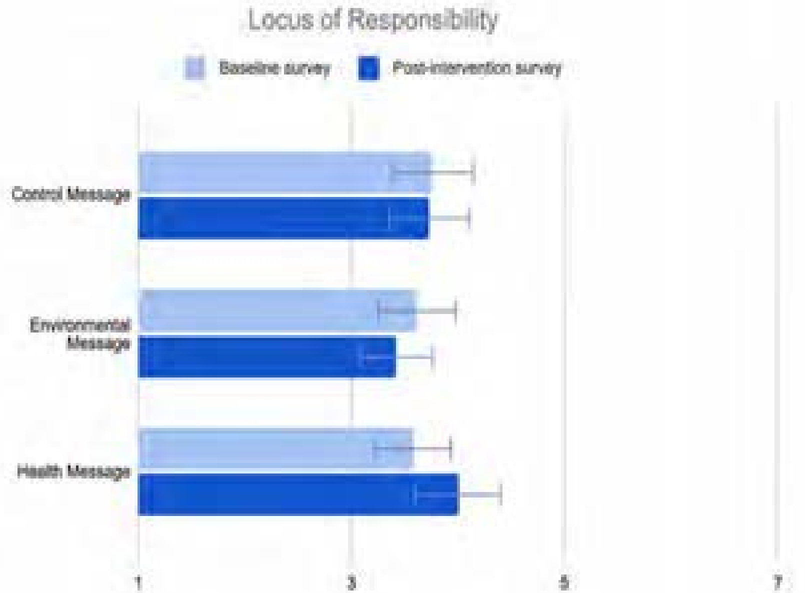
Belief that tree care is the city's responsibility is weaker after program

N=83



Strongly disagree

Strongly agree

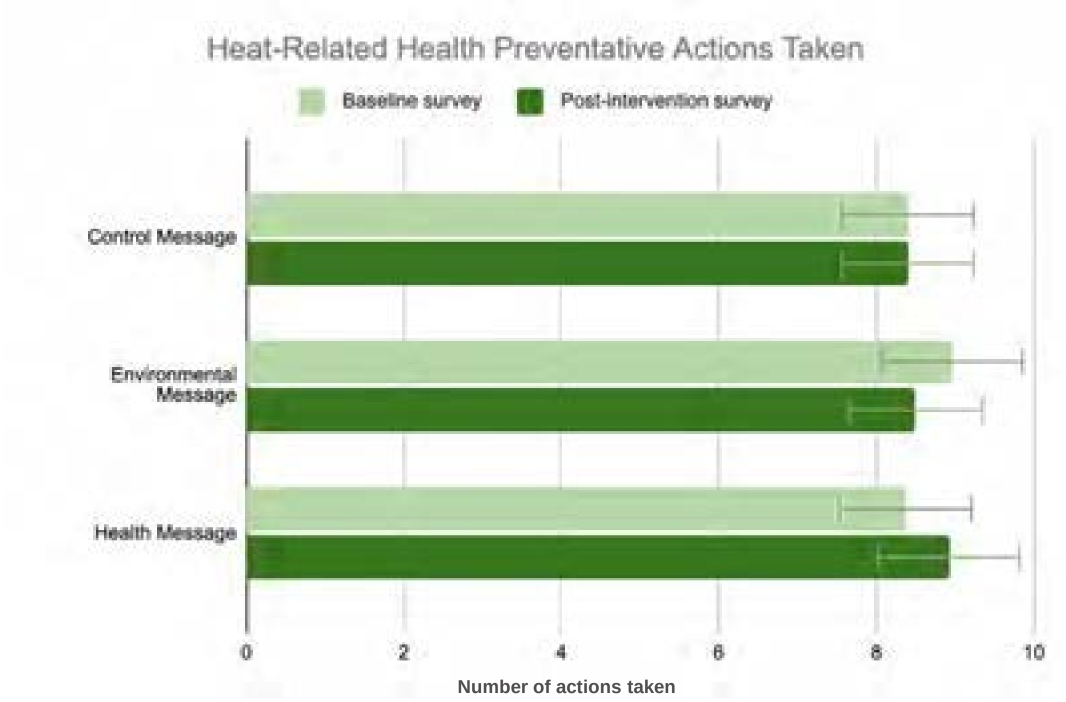


100% mine

100% government

Question: Some people think it's mainly the government's responsibility to help communities prepare for a disaster or an emergency. Other people think that it's everyone's responsibility. Using a scale of 1 to 7, do you think it is mostly the government's responsibility or mostly your own responsibility?

Preliminary findings | PROTECTIVE ACTIONS IN THE HEAT



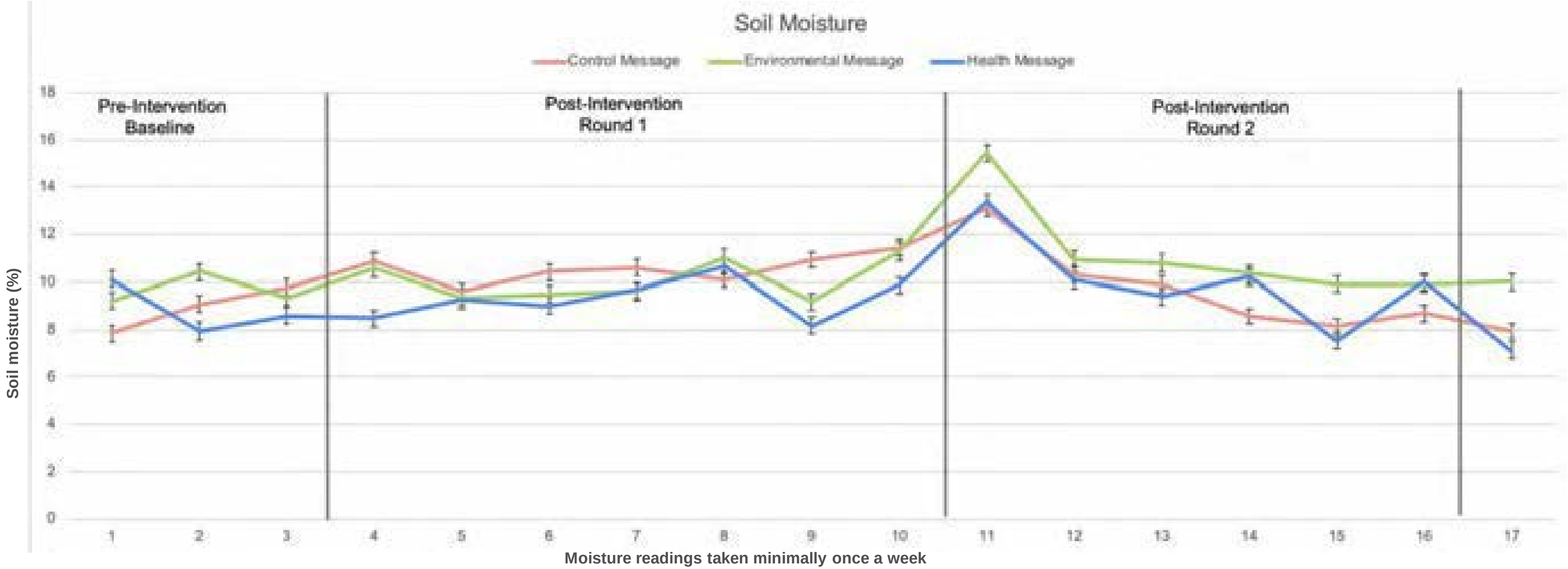
Public health messaging correlates with more protective actions taken during heat waves

N=83

Preliminary findings | SOIL MOISTURE

Environmental health messaging correlated with slightly higher soil moisture, but soil moisture is often still too low for tree health

N=115



Next steps

- Conclude survey data collection (pandemic-related delays)
- Collect additional soil moisture readings
- Conduct statistical analyses
- Compare to outcomes of prior pilot project

Implications

- In-person vs. passive engagement
- Generic messaging vs. tailored to the community
- Costs and benefits of community-based programs vs. hiring crews

THANK YOU

...and please go water a tree that needs it!

Edith de Guzman
eb3@ucla.edu | edithdeguzman.com

Kelly Turner

Assistant Professor, UCLA

Co-Director, UCLA Luskin Center for Innovation

@VKellyTurner

Hyper-Local Land Systems: Synergies and Trade-offs Between Regional Heat Island Mitigation and Pedestrian Thermal Comfort

More Than Surface Temperature: Mitigating Thermal Exposure in Hyper-Local Land Systems

V. Kelly Turner[1,2] **Morgan L. Rogers**[1] **Yujia Zhang**[3] **Ariane Middel**[4] **Florian A. Schneider**[4] **Jon P. Ocón**[2] **Megs Seely**[6]

[1]Department of Urban Planning, Luskin School of Public Affairs, [2]Geography Department, College of Arts and Sciences, University of California, Los Angeles, U.S.A,. [4]School of Sustainability, College of Global Futures, [4]School of Arts, Media and Engineering, Herberger Institute for Design and the Arts, [5]Center for Global Discovery and Conservation Science, Arizona State University, [6]School of Geographical Sciences and Urban Planning, College of Liberal Arts and Sciences,, Phoenix, Arizona, USA

Cities are hotter because of how we build them, and they could be cooler if we build them differently

Regional Urban Heat Island

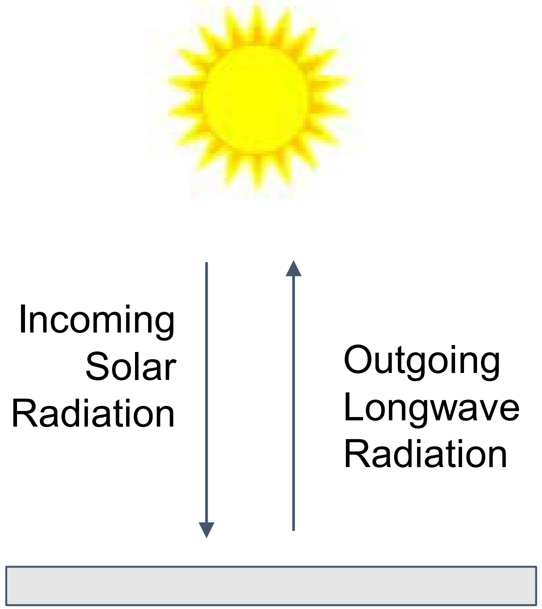
Cities are hotter than proximate undeveloped areas

Low Albedo

Hot Surface

High Albedo

Cool Surface



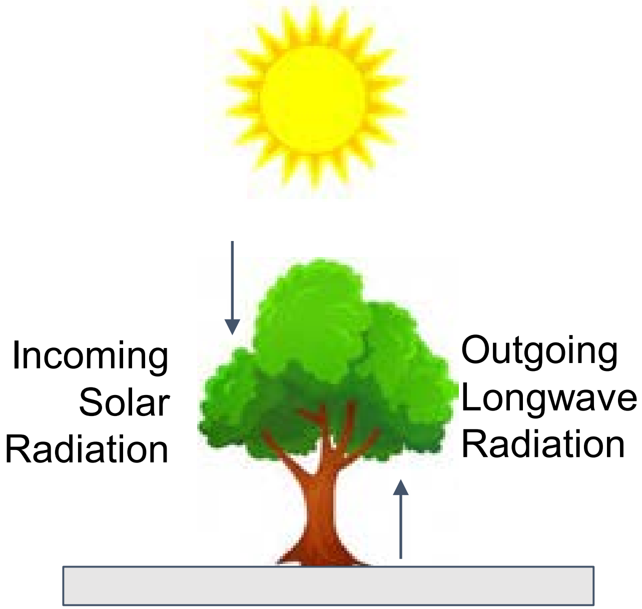
Albedo

Moderates how much incoming solar radiation is radiated back as outgoing longwave radiation

Cities are hotter because of how we build them, and they could be cooler if we build them differently

Human Thermal Comfort

Micro conditions influence the h[illegible]t

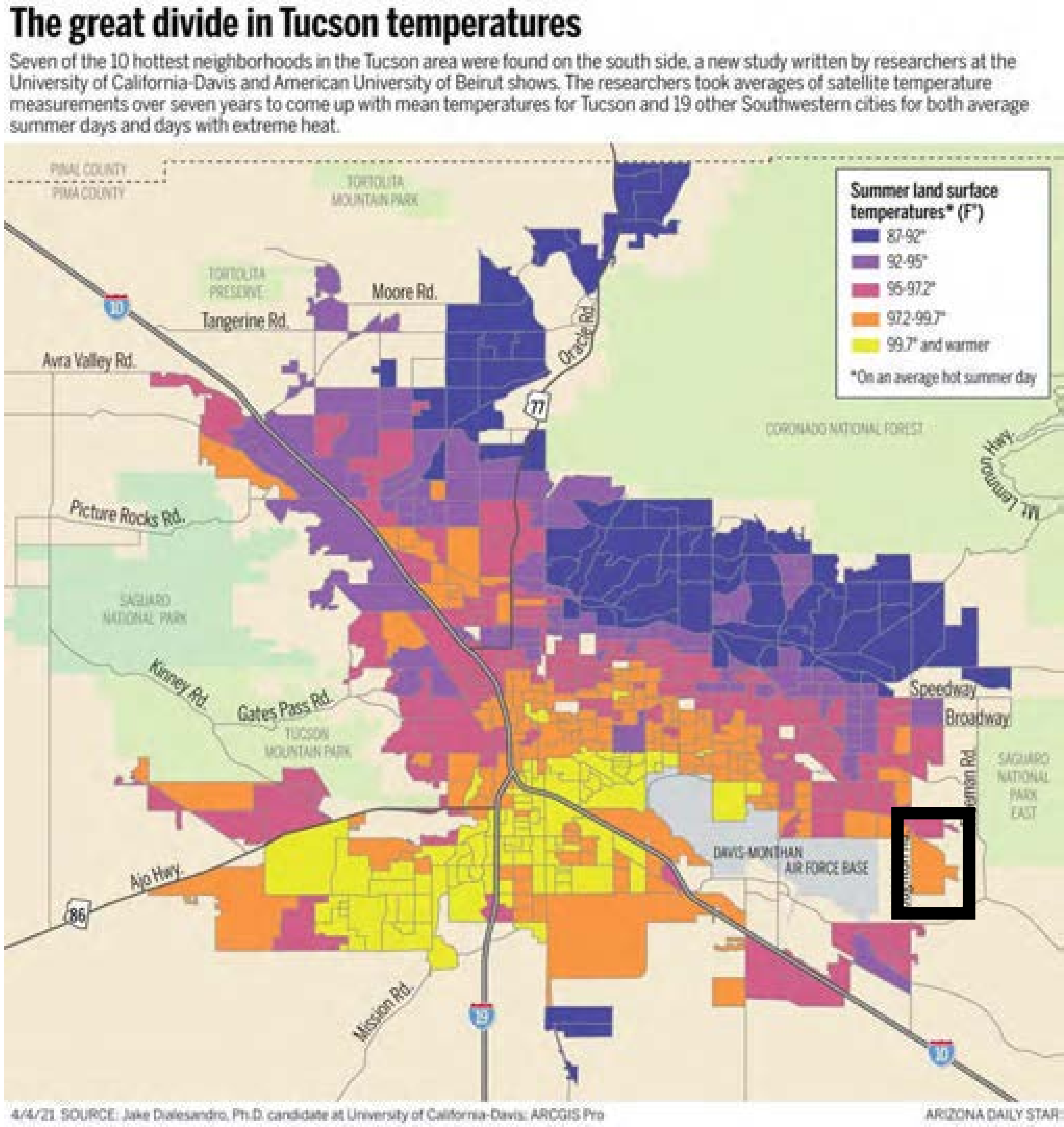


Mean Radiant Temperatures

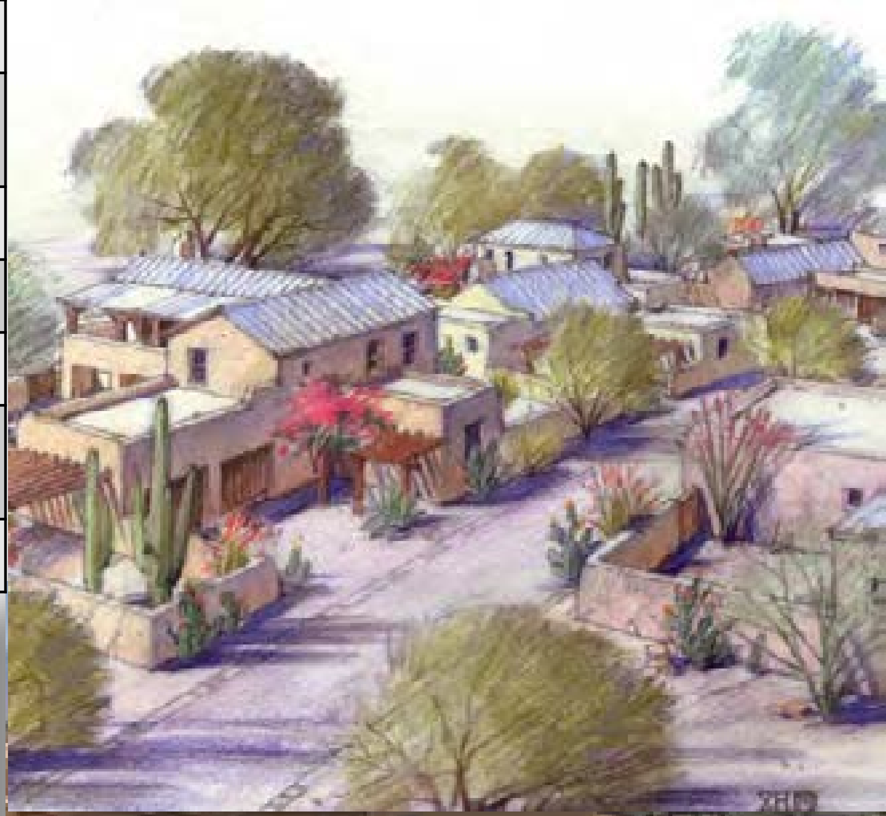
Net thermal exchange between a body and the objects that surround it.

Is surface temperature a good proxy for thermal comfort?

1. Diurnal variation?
2. Predicting simulated temperature? (Compared to sun exposure)
3. Relationship to land features? (Compared to MRT)



CIVANO (Tucson, AZ)	
Approach to sustainable urbanism	Solar Energy, New Urbanism
Biophysical Context	Arid
Development Type	Public-private
Size (Acres)	1145
Number of Households at Build Out	2600
Development Start	1981



Comparing Measures of Temperature

- Remote Sensing (RS)
  - NAIP (0.6m, Jun. 15 2019), Landsat (30m, May 27, 2019)
  - Land Cover Composition and Configuration, LST, Albedo, SAVI, LISA hotspots
- Field Observations
  - MaRTy cart 23 stop transects (May 25 2019), 7:00 – 21:00 MST
  - ST, AT, MRT
- Micro-climate simulations
  - ENVI-met
  - ST, AT, MRT
- Regression models to examine predictive power of climate variables

MaRTY – mobile biometeorology sensor – Ariane Middel SHADE Lab at ASU

Civano = Cool *Neighborhood* Microclimate

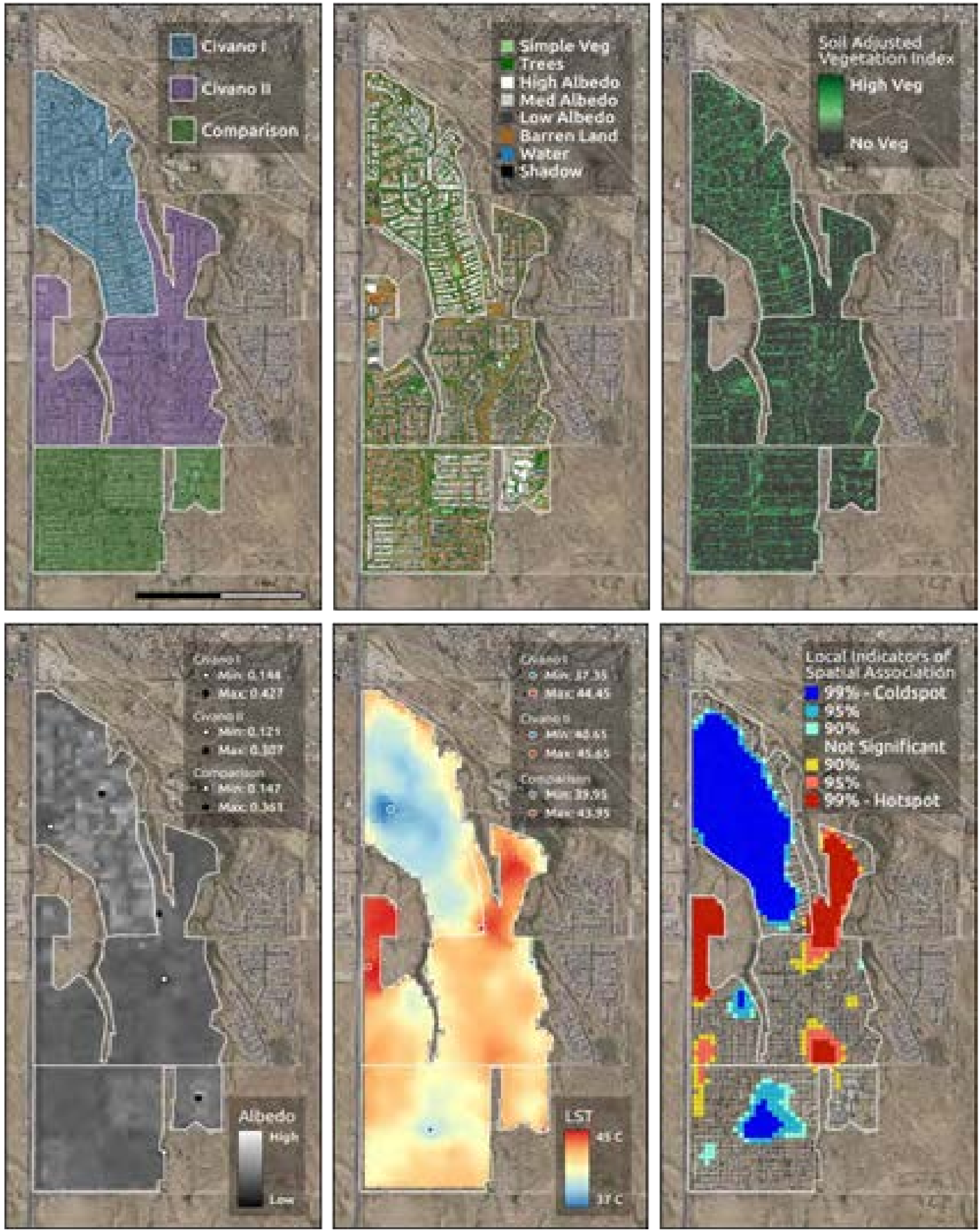
- More vegetation…

  …higher albedo…

  …most 'coldspots'

- Little variation in LST, mostly desert 'edge effect'

RS-LST at 10:00
- Min ~37 C
- Max ~44 C



Diurnal Trends

AT peaks late afternoon,
little variability between sites

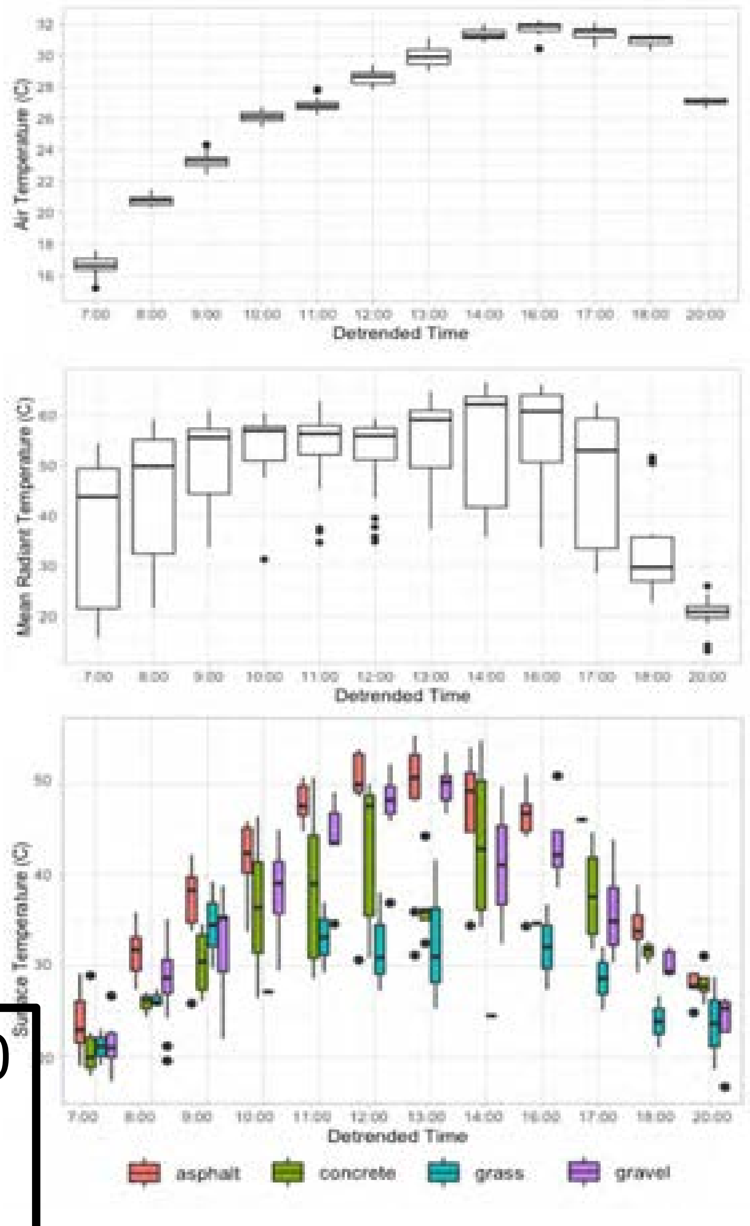
MRT high all day, lots of
variability between sites

ST peaks midday,
impervious/gravel hottest

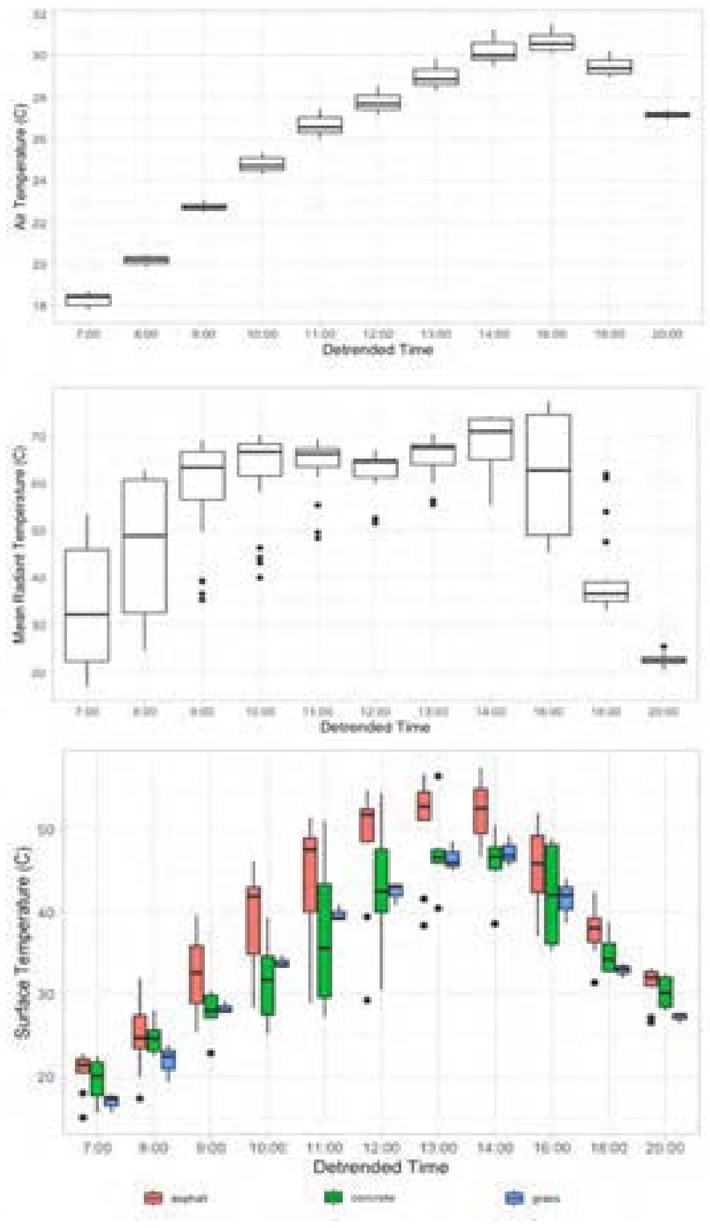
LST at 10:00
- Min ~10 C
- Max ~55 C

RS-LST at 10:00
- Min ~37 C
- Max ~44 C

Field Measurements



Simulations



Satellites provide weak estimate of simulated temperature

RS-LST		
Simulated Temperatures	R	R^2
LST_08:00	-0.49	0.24
LST_10:00	0.4	0.16
LST_12:00	0.53	0.28
LST_15:00	0.39	0.16
LST_20:00	-0.72	0.52
MRT_08:00	0.65	0.42
MRT_10:00	0.63	0.4
MRT_12:00	0.63	0.39
MRT_15:00	0.64	0.41
MRT_20:00	-0.67	0.45
AT_08:00	-0.1	0.01
AT_10:00	0.17	0.03
AT_12:00	0.25	0.06
AT_15:00	0	0
AT_20:00	-0.64	0.41

Regression results between Landsat8 LST (RS-LST) and the simulated LST, MRT and AT at hour, all models are significant at 0.001 level (2-tailed) except for AT_15.

Better predictor of MRT, than AT and LST

10:00 RS image strong, negative relationship with evening temp

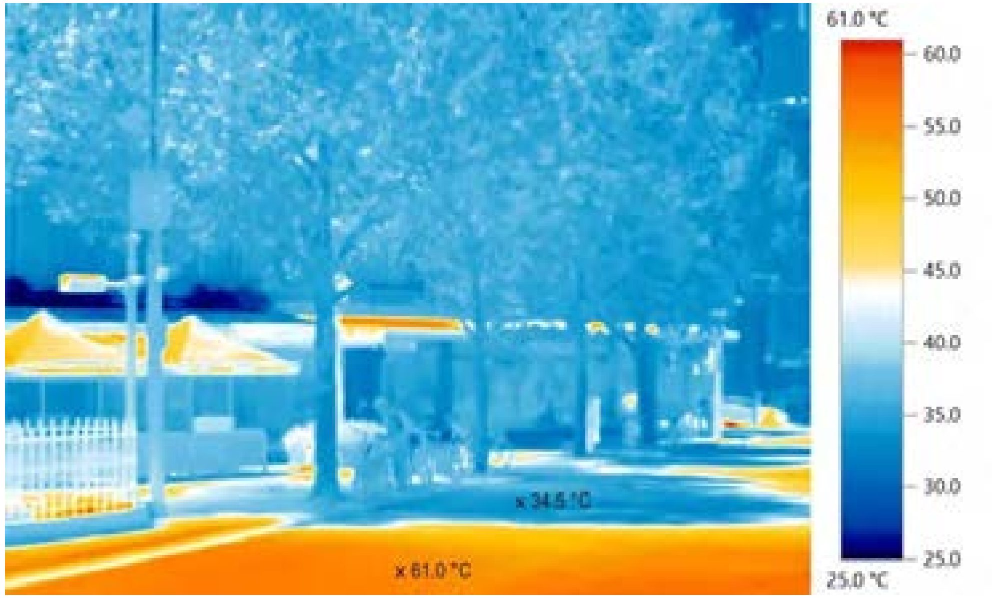
Sun exposure better predicts hyper-local temperature

Shortwave Radiation		
Simulated Temperatures	R	R^2
LST_08	0.05	0.003
LST_10	0.69	0.47
LST_12	0.76	0.58
LST_15	0.48	0.23
LST_20	na	na
MRT_08	0.99	0.98
MRT_10	0.98	0.96
MRT_12	0.85	0.73
MRT_15	0.98	0.97
MRT_20	na	na
AT_08	0.28	0.08
AT_10	0.16	0.03
AT_12	0.16	0.03
AT_15	0.07	0.01
AT_20	na	na

Regression results between simulated shortwave radiation and simulated LST, MRT and AT at hour i at 30m resolution, all models are significant at 0.001 level (2-tailed) except for AT_08 and AT_15.

As expected, strong relationship with MRT

But also, variation in midday surface temperature



Source: The City of Melbourne via The Guardian 2017

Different Urban Land Features Predict LST and MRT

RS-LST Best Predictors

- Stronger relationships overall
- Land cover variables
- % building, % impervious, % trees
- Relatively similar all day

MRT Best Predictors

- Weaker relationships overall
- Morphology variables
- % trees, mean building and tree height
- Diurnal variation

Local heat planning needs nuance

- Define heat goal
  …UHI mitigation ≠ improved thermal comfort

- Always specify temperature type
  …especially what remote sensing estimates of LST can and can't describe

- Ask when is space used
  …interventions perform differently throughout the day

Top: Phoenix Cool Pavement parking lot, Bottom: Shade Sails for Schools in the U.K.

Thank You!

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ASU

Vkturner@ucla.edu

Ed Hawkins, #showyourstripes, mean temp deviation in CA 1985-2020

Up next – 3:30-5pm PT

SESSION 4.1

The Effects of Temperatures on Behavior

SESSION 4.2

Adaptation at Home: Consumption, Building Codes, and Insurance

SESSION 4.3

Quantifying and Minimizing Water Quality Impacts

SESSION 4.4

Integrating Climate and Transportation Planning

CLIMATE ADAPTATION
RESEARCH SYMPOSIUM

MEASURING & REDUCING SOCIETAL IMPACTS

Thanks for tuning in!

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