

Modulation of Climate Risks by Intensification of Urban and Agricultural Land Uses in the Arabian Peninsula

April 3, 2024

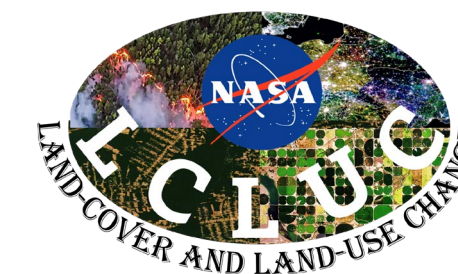
LCLUC Science Team Meeting

Cascade Tuholske

Asst. Prof. of Human-Environment Geography

Dept. of Earth Sciences, Montana State University

With Colin Raymond (Science PI, UCLA/JPL), Tarik Benmarhnia (Co-I, UCSD/Scripps), Eqi Luo (Graduate Student, MSU), Jennifer Bailey (Graduate Student, UCSD) & Anais Teyton (Graduate Student, UCSD)



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Project Team



Colin Raymond



Tarik Benmarhnia



Jennifer Bailey



Eqi Luo

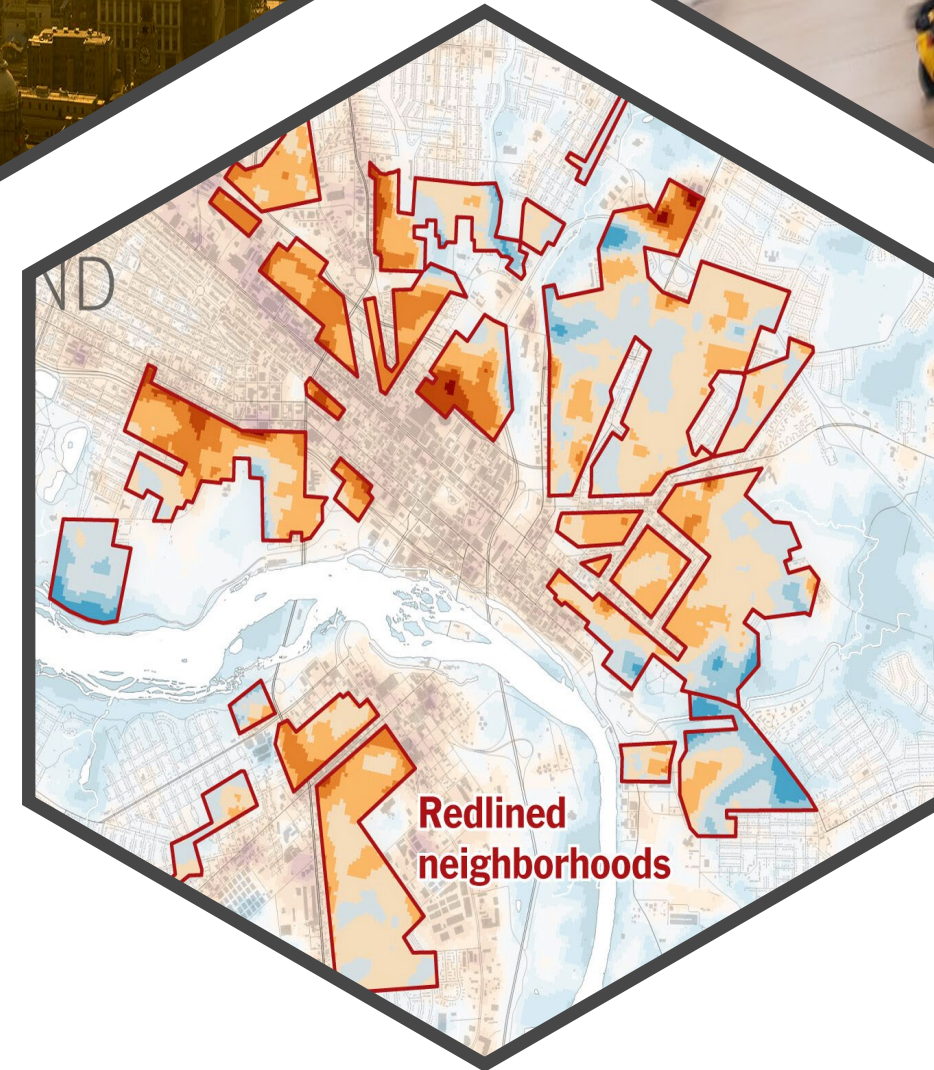


Anais Teyton

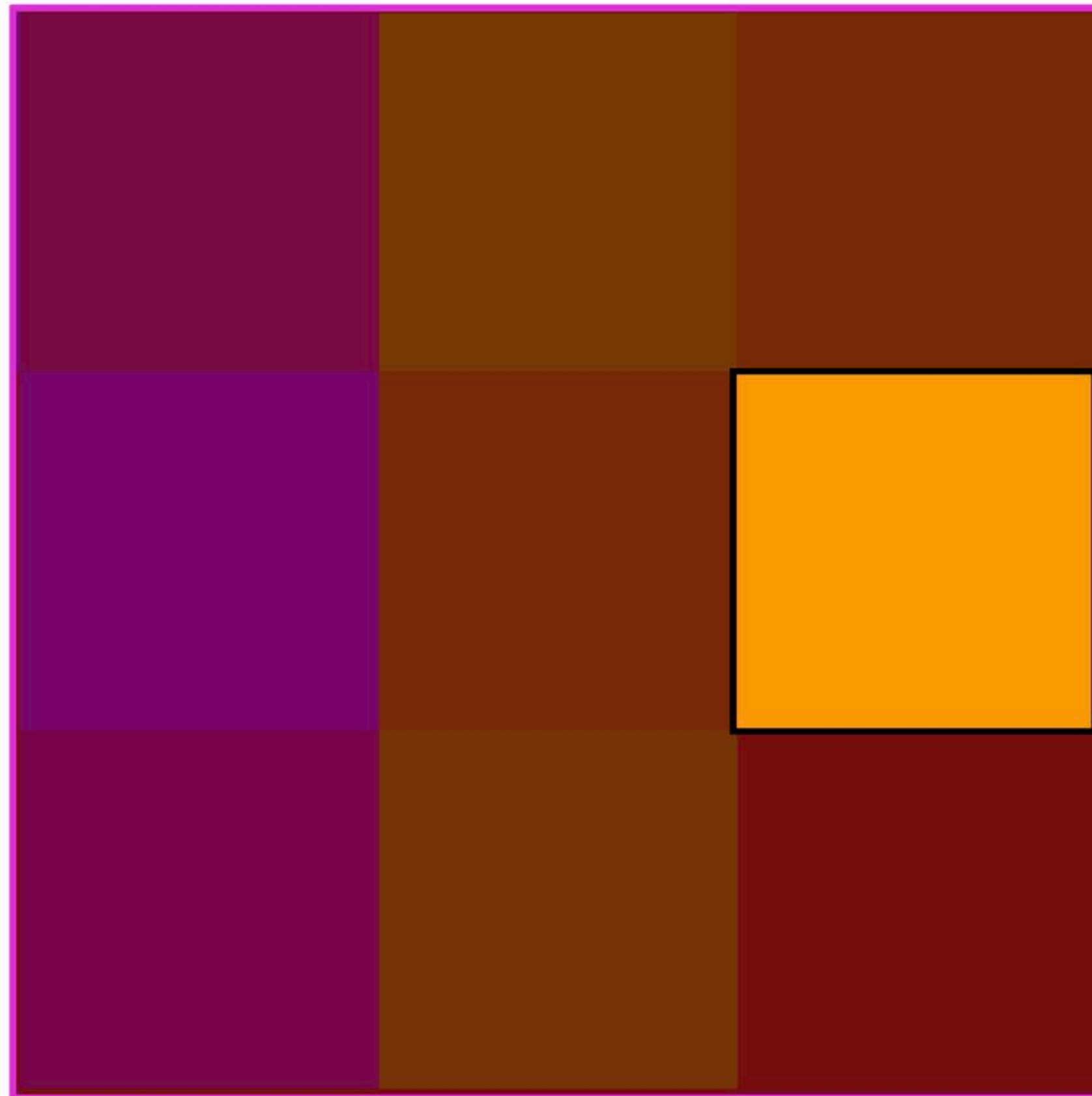
Person Name	Person role on project	Affiliation
Cascade Tuholske	Principal Investigator	Montana State University, Bozeman, USA
Colin Raymond	Co-Investigator	University of California, Los Angeles, Los Angeles, USA
Tarik Benmarhnia	Co-Investigator	University of California, San Diego, La Jolla, USA
Jens Thomsen	Collaborator	Abu Dhabi Public Health Center, Abu Dhabi, United Arab Emirates
Matei Georgescu	Collaborator	Arizona State University, Tempe, USA
Matthew McCabe	Collaborator	King Abdullah University of Science and Technology in Saudi Arabia, Thuwal, Saudi Arabia



Heat Impacts to Human Health



Interactions with Land-Cover and Land-Use Change



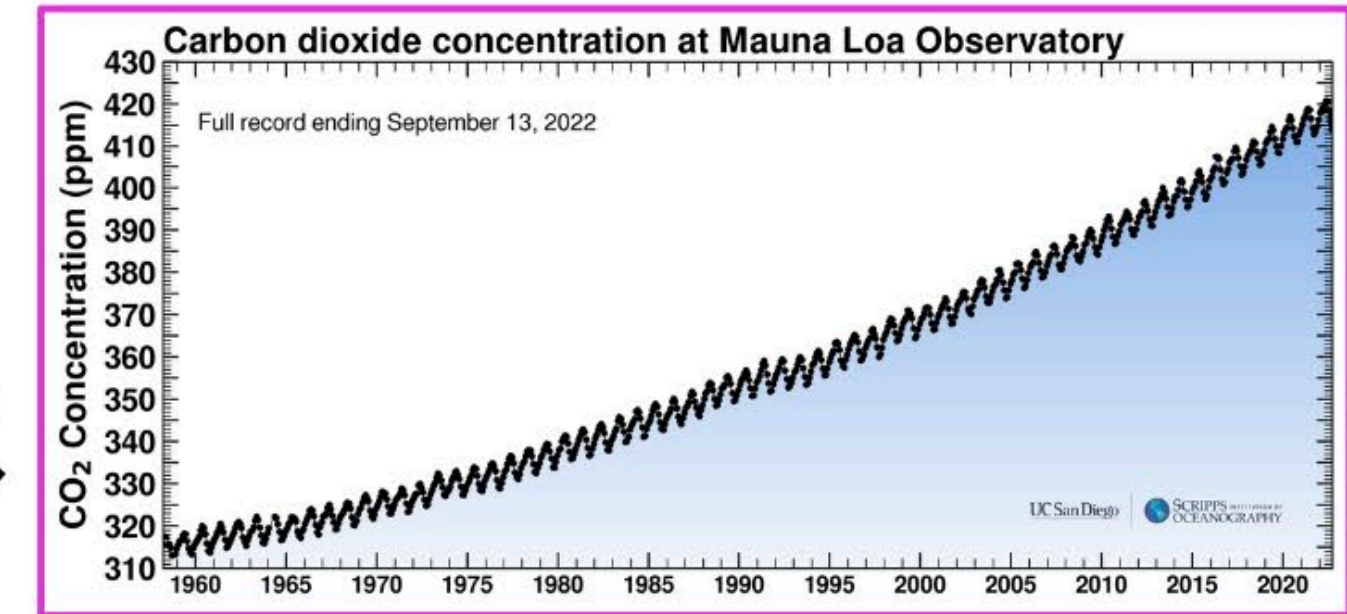
Annual Increase In Hot-Humid Days



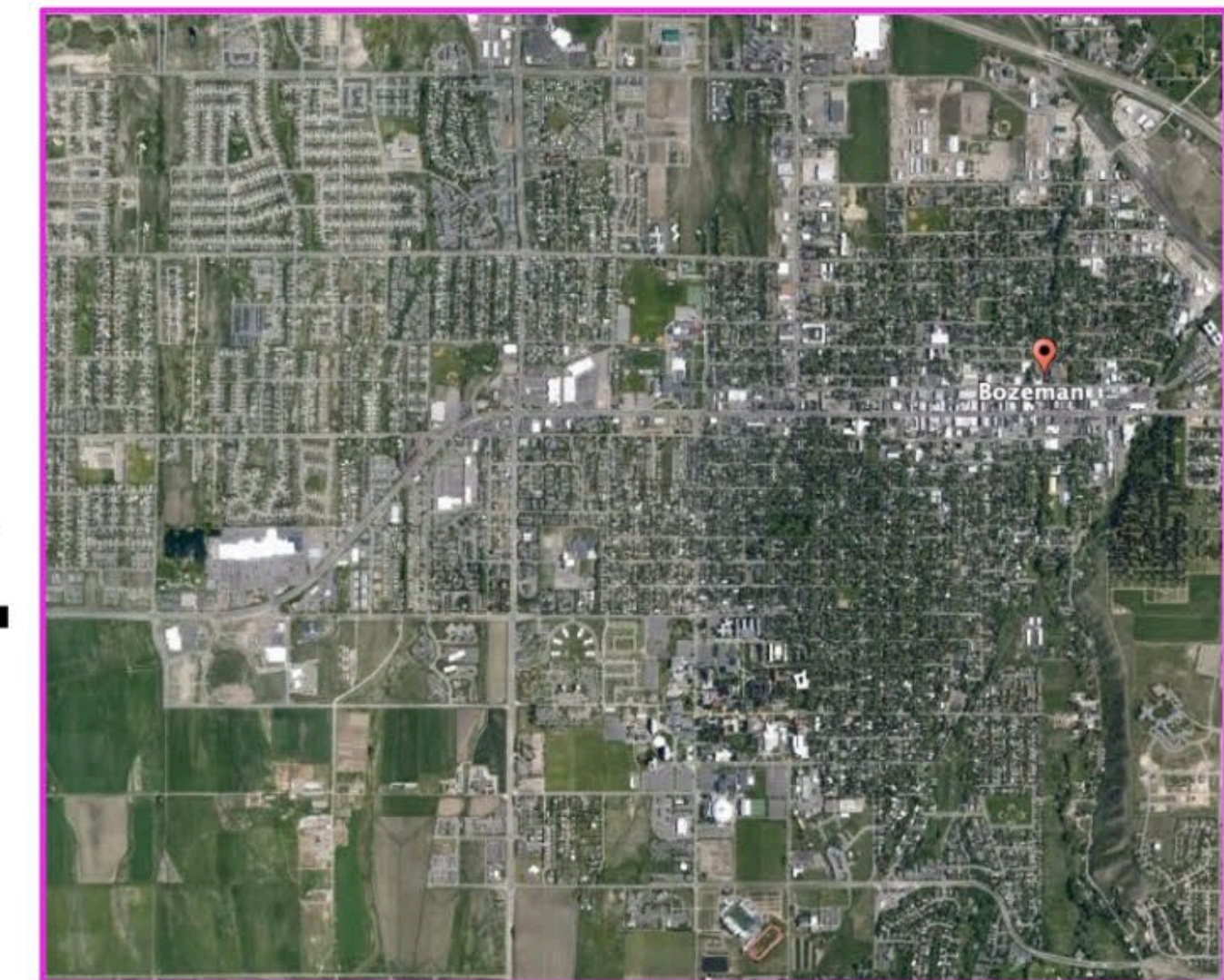
Humidity



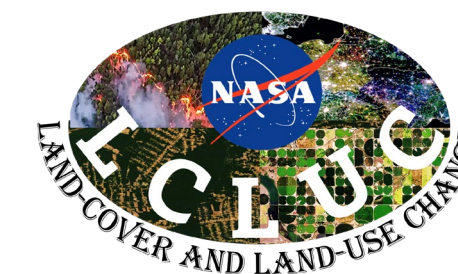
Ambient Temperatures



Climate Change

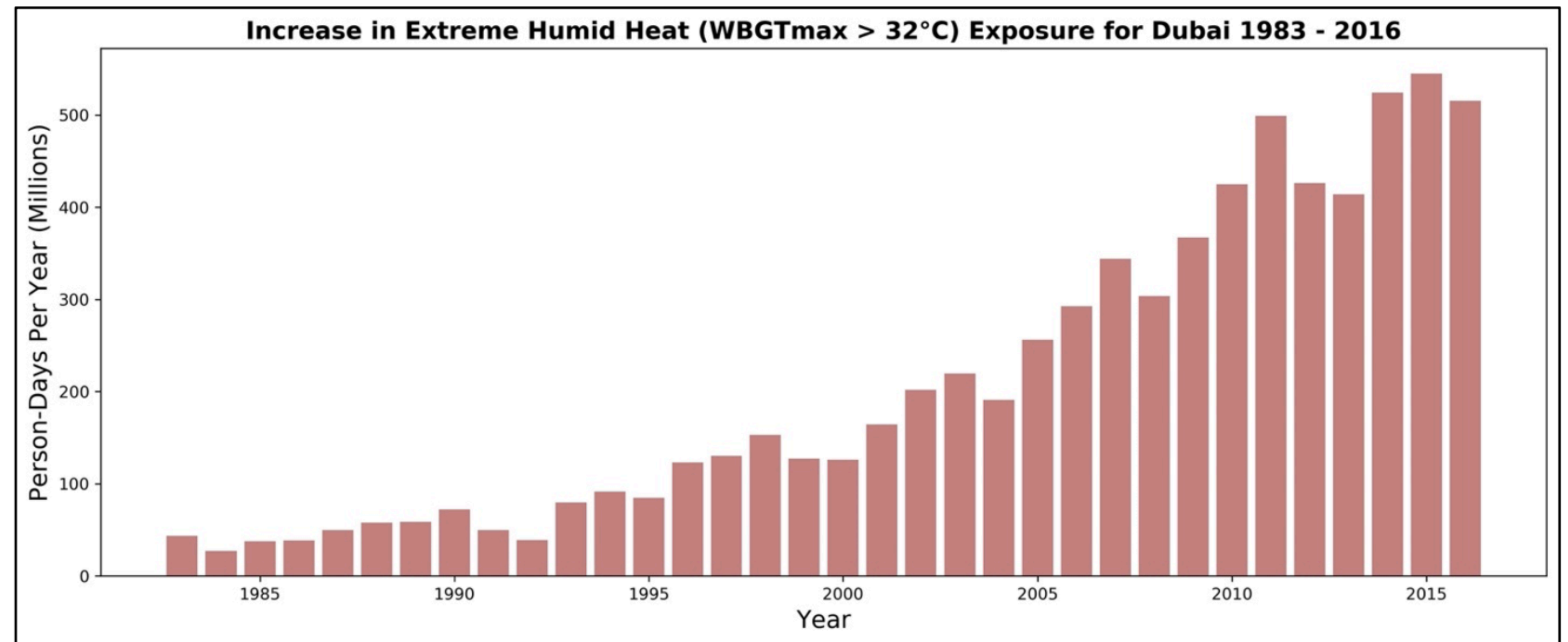


LCLUC



Knowledge Gaps

- Evidence of rapid increase in dangerous humid heat across the Arabian Peninsula.
- But limited knowledge of interactions between land-cover and land-use change (LCLUC), demographic Change, and heat impacts to human health.
- Remote sensing is a key tool to study these interactions.



Data from UHE-Daily NASA SEDAC; Tuholske *et al.* 2021. PNAS.



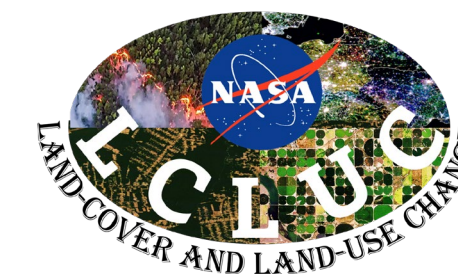
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Project Objectives

1. Map urban and agricultural LCLUC.
2. Assess effects of LCLUC on extreme humid heat.
3. Characterize the sociodemographics of exposure to humid heat and vulnerability to heat stress and attribute the associated health burden to LCLUC.
4. Quantify the effects of potential future LCLUC interventions on heat stress, water stress, and dust storms.



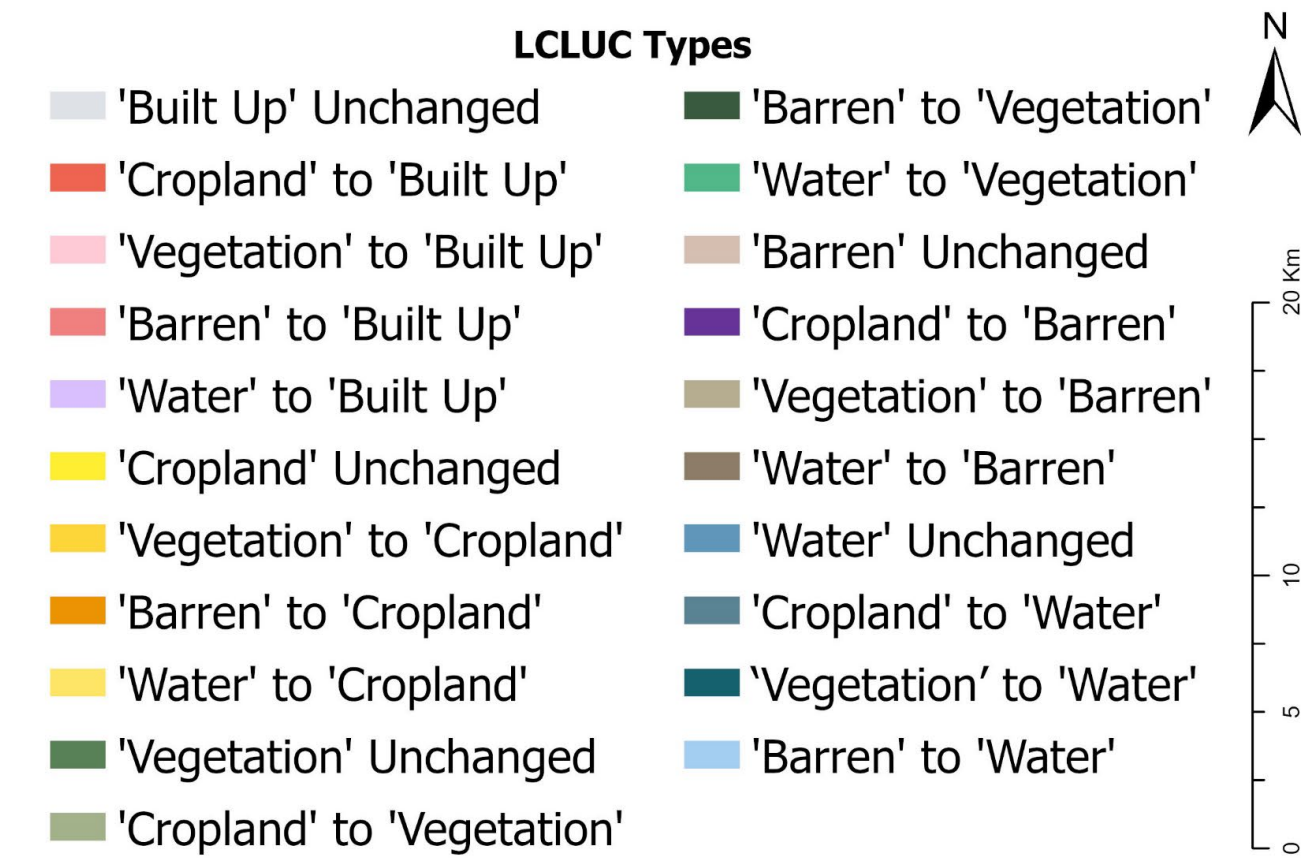
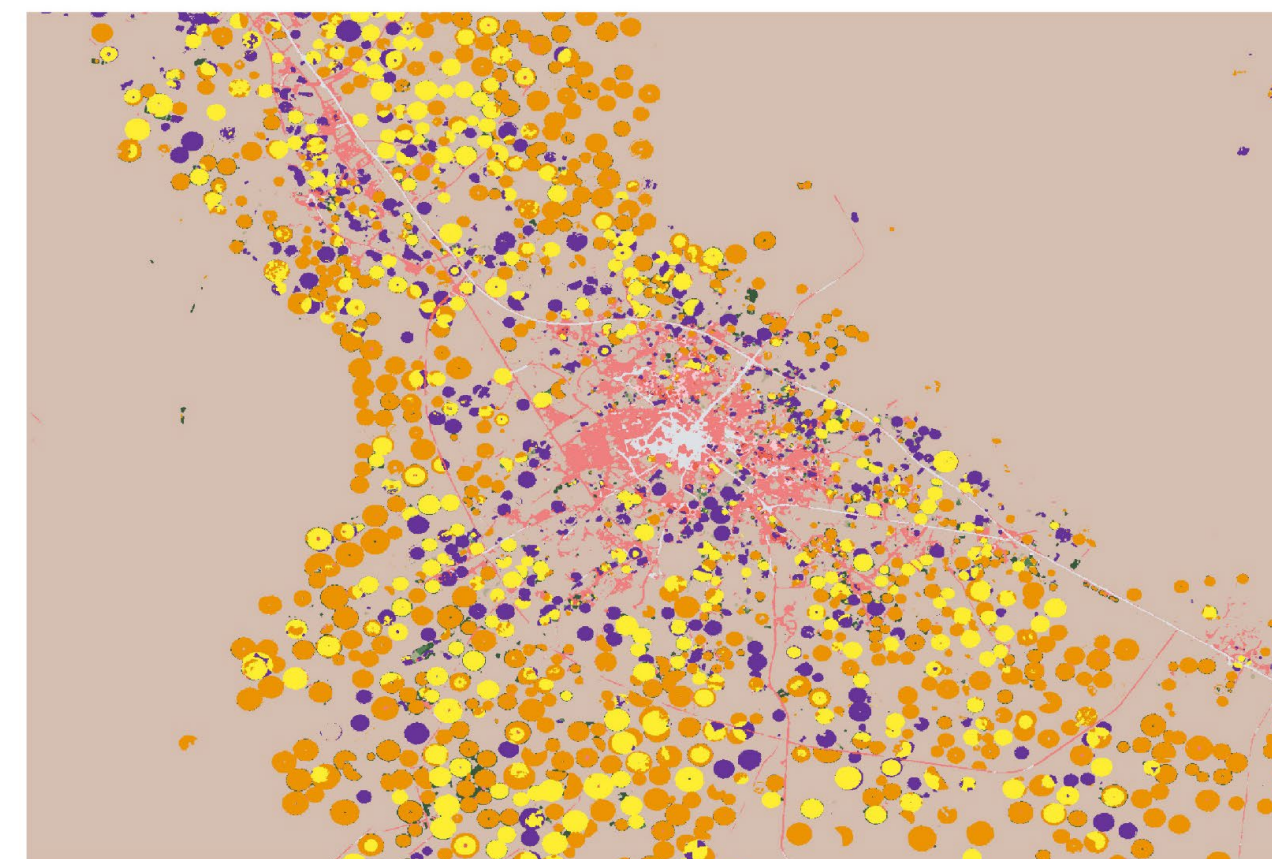
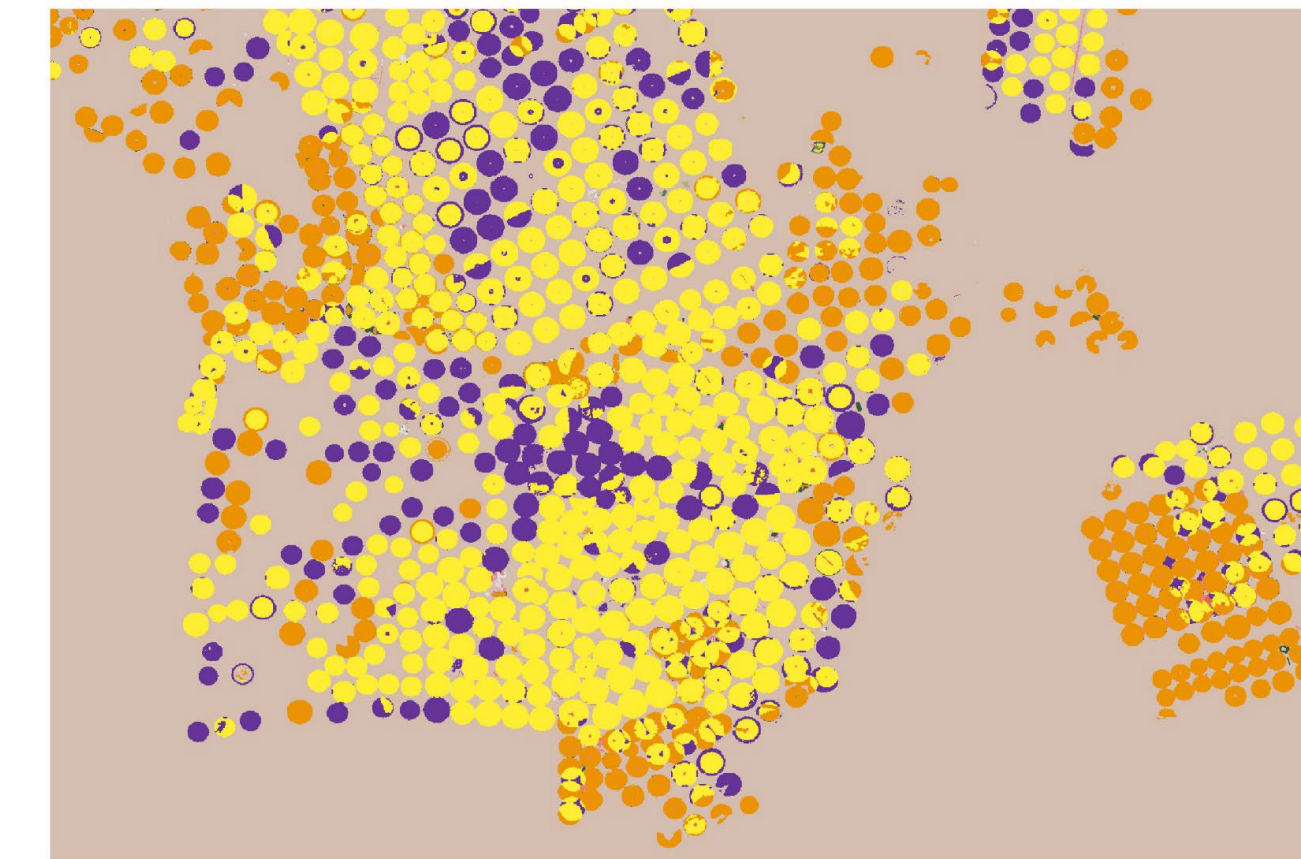
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Progress: LCLUC

- Led by Eqi Luo (MSU)
- Map LCLUC at 30m with GLAD dataset from UMD.
- Integrate with 100m population and age/sex demographic data from Worldpop.
- Integrate with land surface temperature data from Landsat.
- Assess relationship between LCLUC, demographic change, and LST.



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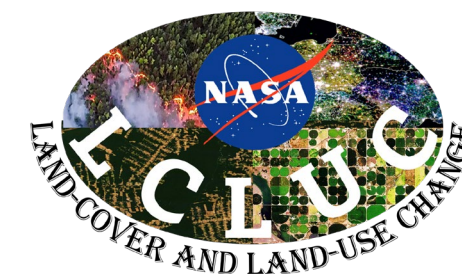
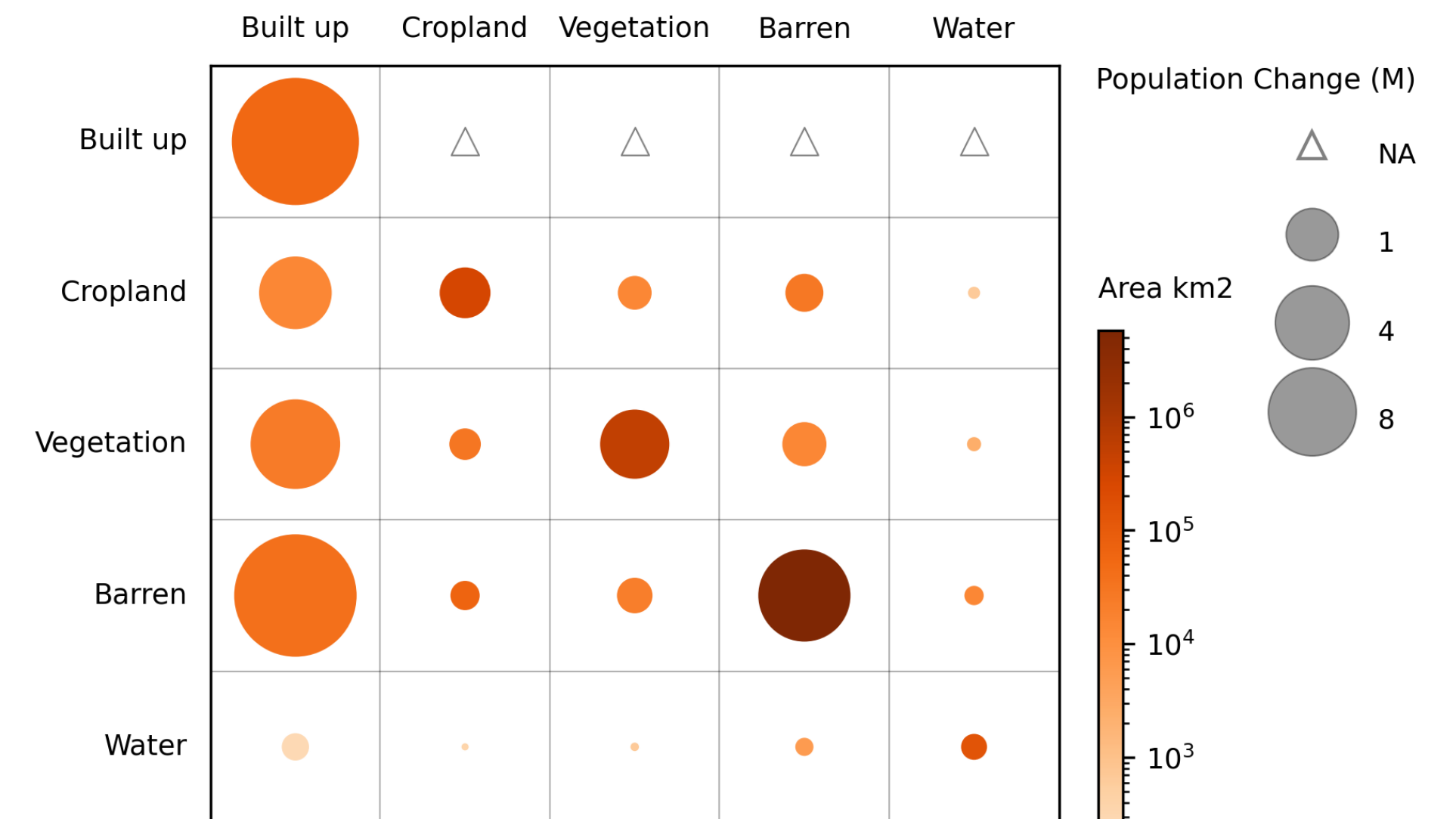
Change Matrix of LCLUC and Population from 2000 - 2020 at 30m for the Middle East

LCLUC
km2

	Built up (1)	Cropland (2)	Vegetation (3)	Barren (4)	Water (5)
Built up (1)	54,343	0	0	0	0
Cropland (2)	15,062	278,710	14,410	28,630	671
Vegetation (3)	23,692	30,914	496,752	15,188	2,497
Barren (4)	38,234	66,336	21,994	5,732,847	14,786
Water (5)	267	376	666	5,940	144,044

Δ population

	Built up (1)	Cropland (2)	Vegetation (3)	Barren (4)	Water (5)
Built up (1)	36,669,430	0	0	0	0
Cropland (2)	4,058,120	1,009,784	210,865	329,548	4,881
Vegetation (3)	9,238,436	161,875	3,359,776	585,254	8,232
Barren (4)	31,553,802	122,406	255,808	10,315,962	25,723
Water (5)	93,471	801	1,422	20,597	77,528

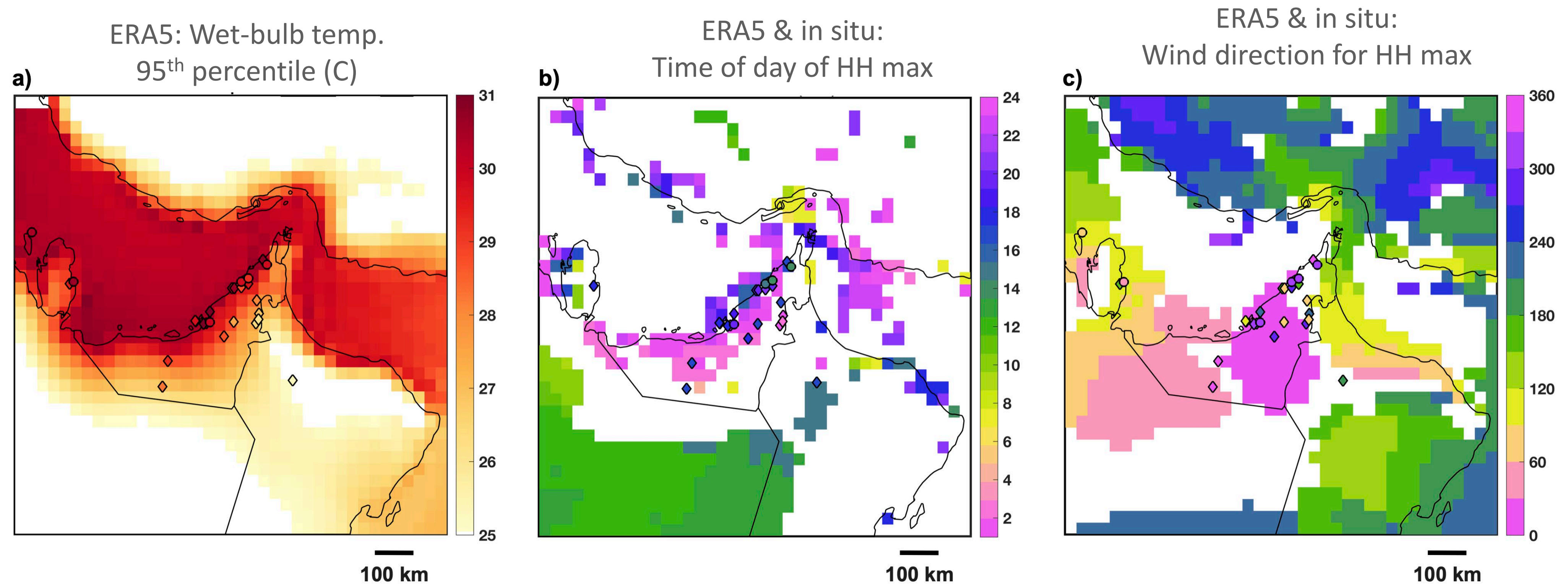


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Progress: Humid-Heat Dynamics



Raymond *et al.* In Review. Communications Earth & Environment.

Evidence that dangerous heat stress peaks in the evening or at night on coasts, bucking conventional wisdom that day temperatures are hottest...key for heat adaptations.

Figure by Colin Raymond.



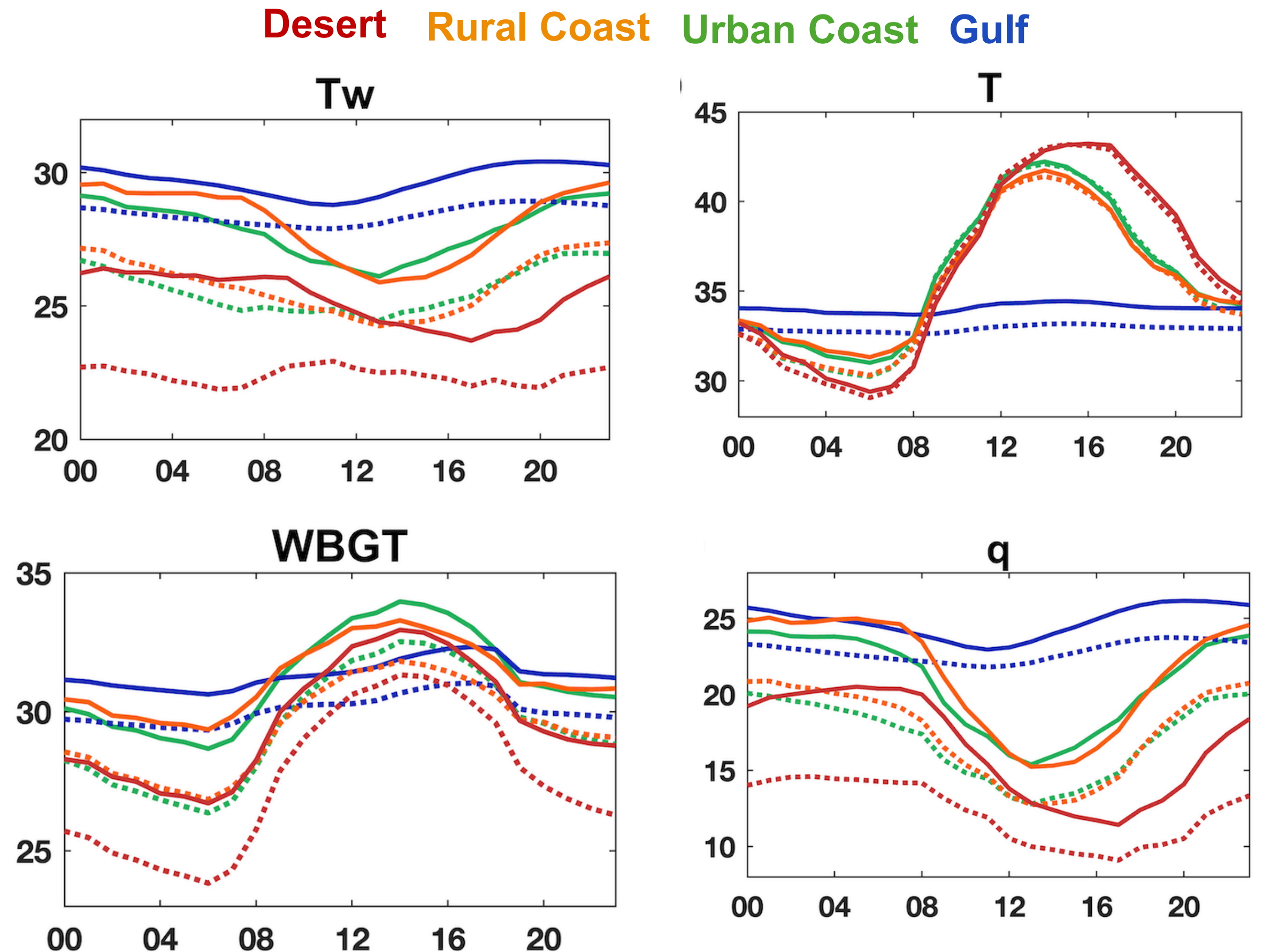
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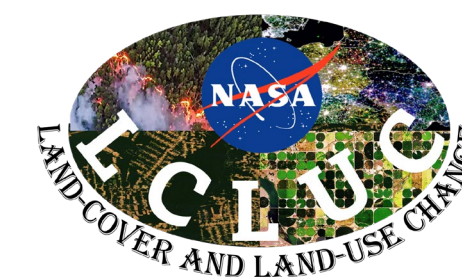


Progress: Humid-Heat Dynamics

- Fine-grained (< 1 km) spatial heterogeneity in timing of peak heat stress.
- Proximity to oceans + land cover matter.
- Heat metric also show variation: those that include radiation, peak in the afternoon.
- Key for heat action plans + infrastructure adaptations.
- Figure by Colin Raymond.



Raymond *et al.* In Review. Communications Earth & Environment.



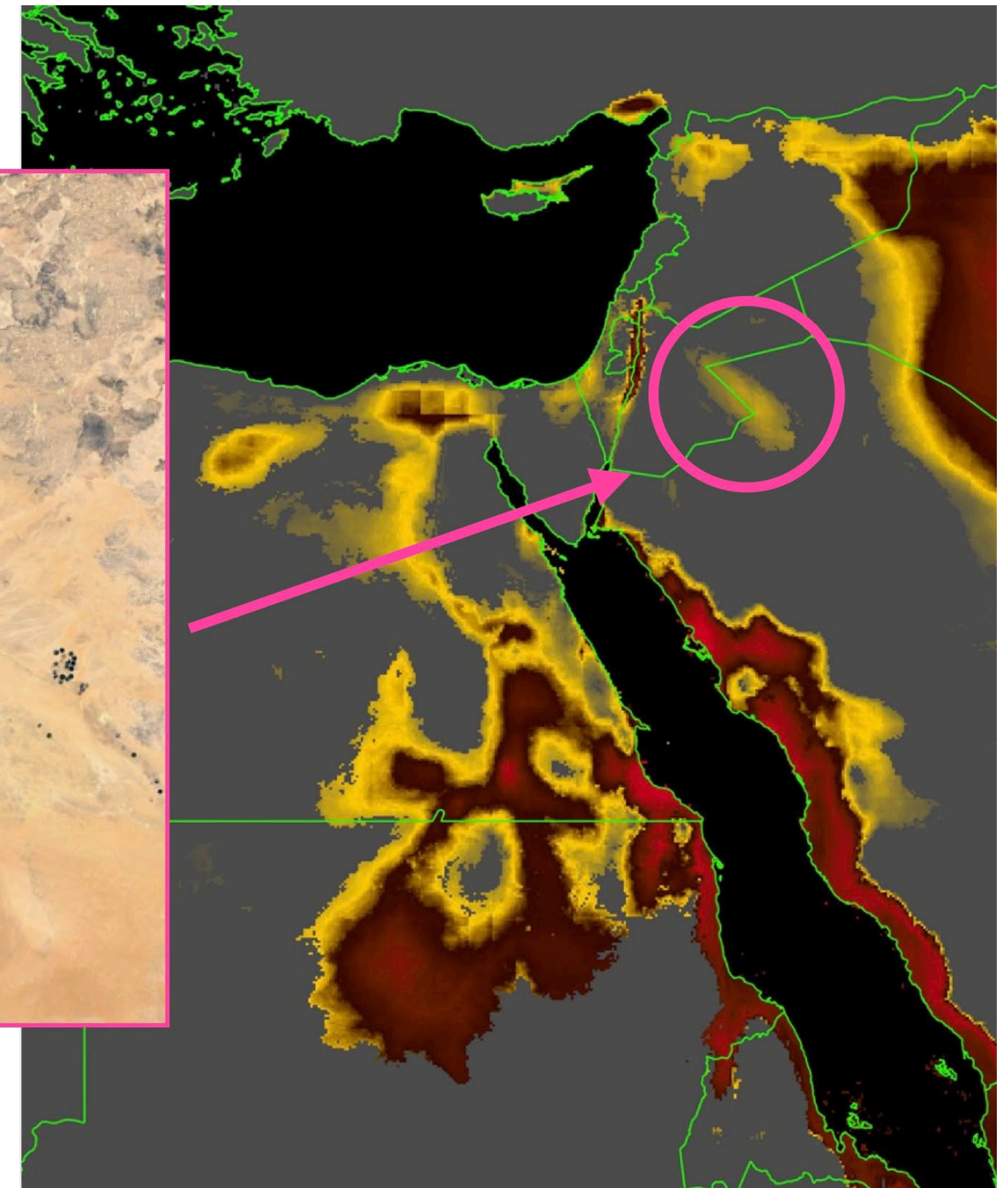
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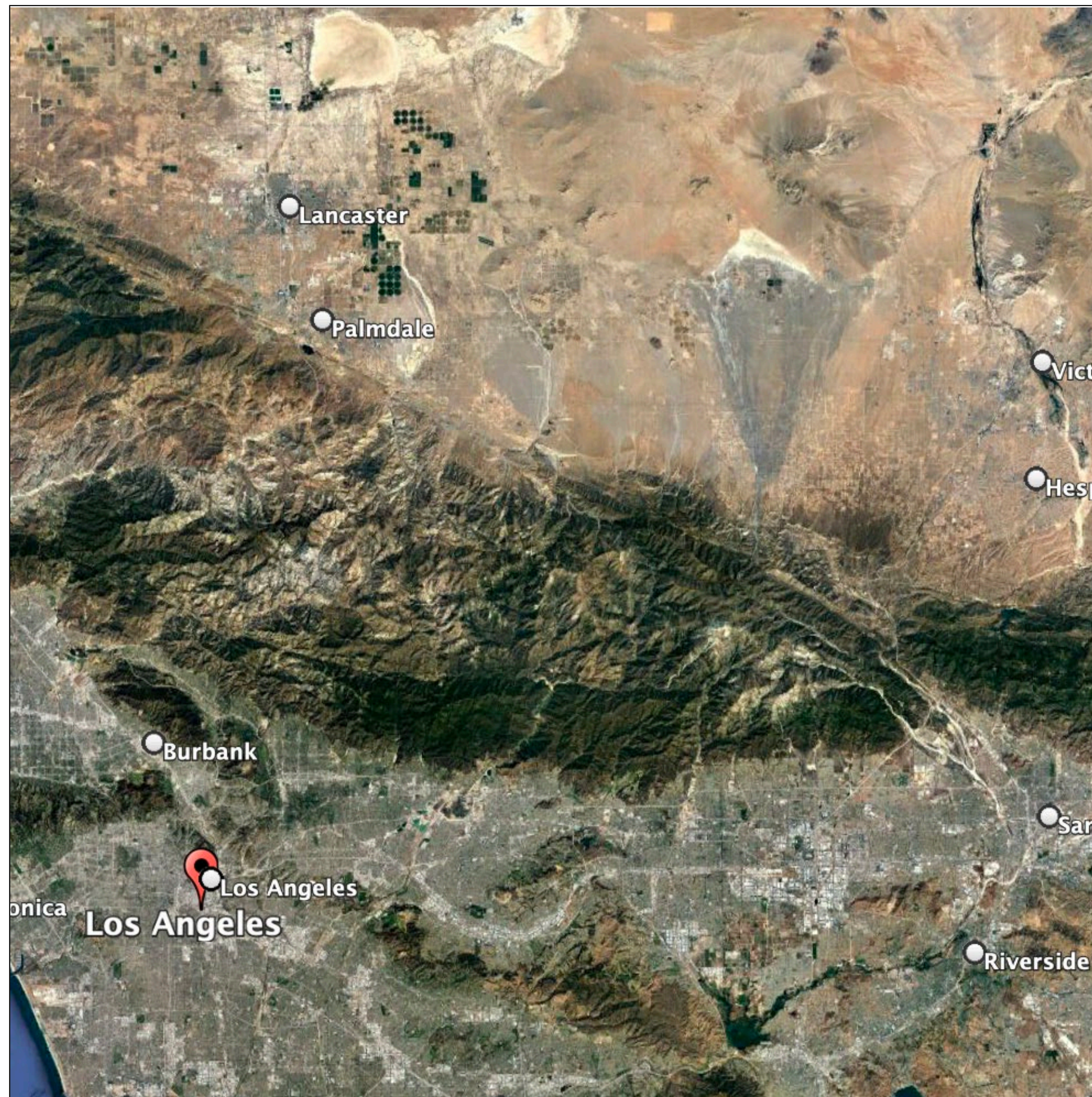


Progress: Humid-Heat Dynamics

- Evidence of “agriculture humid-heat islands”
- Next step: how does land cover modulate heat waves with WRF model?



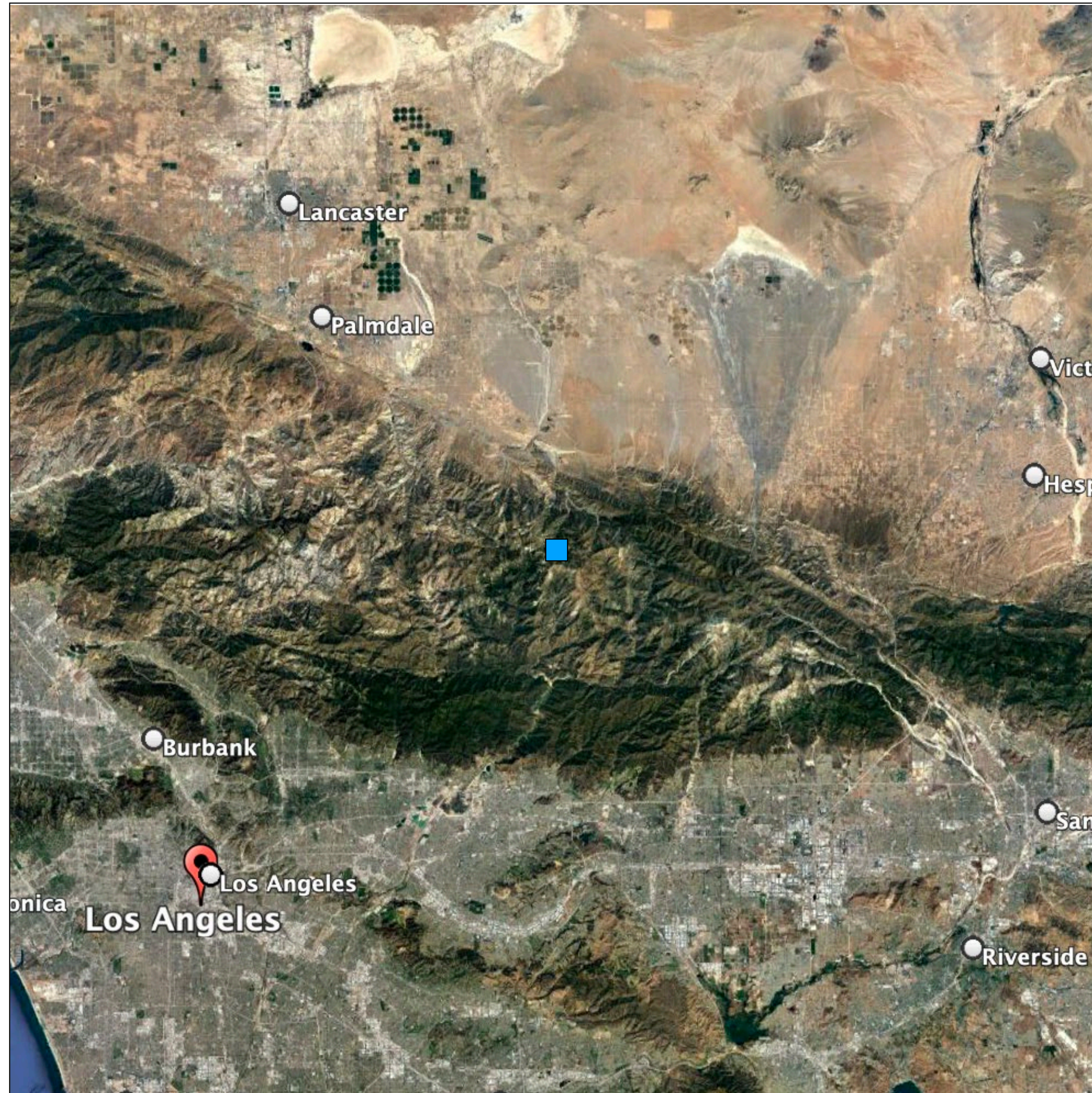
CMIP-6
Climate Projection
100 x 100 km



CMIP6 Projections

Williams *et al.* 2024.
Scientific Data

CHC-CMIP6 Projections



CMIP-6
Climate Projection
100 x 100 km

■ New
CHC-CMIP6
Projections
5 x 5 km

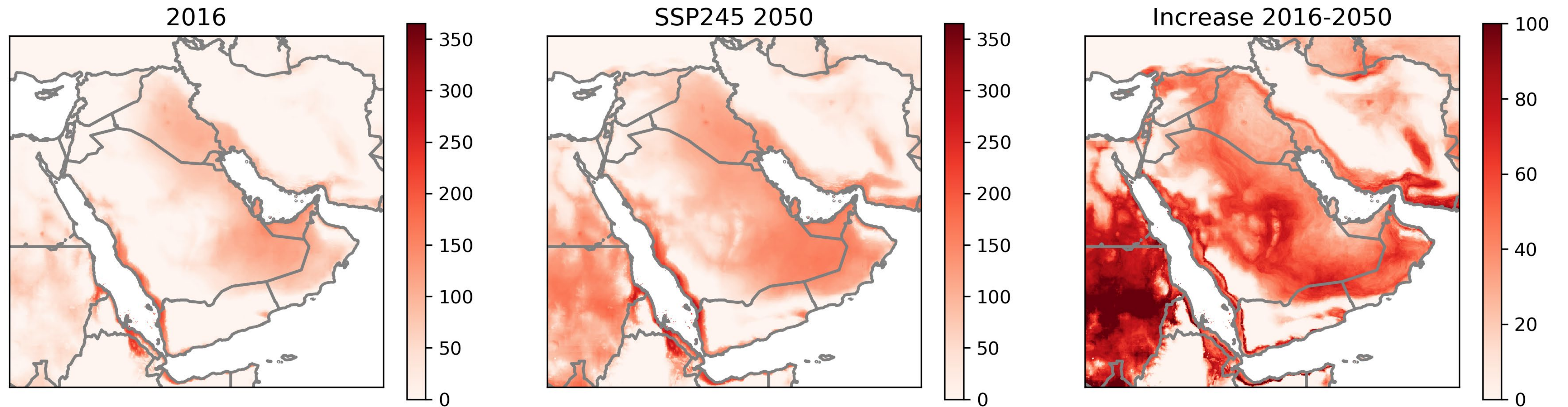
Daily Projections
5-km projections of
precipitation vapor
pressure deficit, heat
index and indoor wet bulb
globe temperature

Data available for SSP245
and SSP585 for 2030 and
2050 ensembles.

Williams *et al.* 2024.
Scientific Data.

Ghana CHC-CMIP6 Heat Index Projections

Increase in Number of Days Per Year $H_{max} > 41^{\circ}\text{C}$ for Arabia 2016 - 2050 (SSP245)



Data from Williams *et al.* 2024. Scientific Data.

Scoping Review by Jenn Bailey and Anais Teyton (UCSD): Heat-Related Health Impacts in the Arabian Peninsula

Databases

Scopus

Pubmed

Web of Science

Years of interest

2010-2023

Search terms (Exposure, Outcome, Region):

("heat wave*" OR heatwave* OR heat OR temperature* OR humidex OR "heat ind*" OR "warm spell*")

AND

(Morbidity OR mortality OR hospital* OR "emergency department" OR "emergency service*" OR death OR emergenc* OR health)

AND

("Arabian Peninsula" OR "Arabian Desert" OR Arabia OR "Saudi Arabia" OR Yemen OR Oman OR Kuwait OR Qatar OR Bahrain OR "United Arab Emirates" OR Jordan OR Iraq)

Of the 654 aggregated articles, **10** articles assessed the relationship between temperature exposure and direct health outcome(s) and were located within the Arabian Peninsula.

Preliminary Findings (n=10)

Extraction Variables	Categories	Totals
Type of Analysis	Quantitative	9
	Qualitative	0
	Mixed Methods	1
Type of Temperature Exposure	Average wet-bulb globe temperature	1
	Maximum wet-bulb globe temperature	1
	Average temperature	7
	Maximum temperature	2
Duration of Temperature Exposure	Daily	7
	Weekly	1
	Monthly	2

Extraction Variables	Categories	Totals
Exposure measurement	Sensor-based	1
	Meteorological station(s)	8
	Combination of data sources (e.g., ERA global reanalysis)	1
Outcome measurement	All-cause mortality	4
	Mortality classifications (including cardiovascular-related)	2
	Cardiovascular-related morbidity	1
	Occupational health injuries	1
	Thermal comfort	1
	Glycemic control	1

In The News in 2023 ...

WIRED

Heat Waves Aren't Just Getting Hotter—They're Stickier Too

If you're in a desert and suffering days of 110-plus-degree heat, you can at least look forward to those temperatures coming down at night, as the landscape sheds built-up heat. But when it's humid, the atmosphere stubbornly holds onto that heat. "With more and more humidity, more people will be impacted during the night. And I don't think we're ready at all for that," says [Tarik Benmarhnia](#), an environmental epidemiologist at the UC San Diego. "There's basically no break, no pause in the stress that heat is going to cause to humans."

The Washington Post

The heat index reached 152 degrees in the Middle East – nearly at the limit for human survival

"We know these extreme temperatures are killing people right now," said [Cascade Tuholske](#), an assistant professor at Montana State University.



'Lose, lose, lose': Oil-producing Persian Gulf faces extreme heat



"The challenge that the Persian Gulf countries face is that they are situated at the boundary between a very hot desert in the Arabian Peninsula ... and the extremely warm, bathtub-like water of the Persian Gulf," said [Colin Raymond](#), who [led a 2020 study](#) that found extreme heat and humidity are occurring more than twice as often as they did just a few decades ago.

Thank you! Questions?

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