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Research Interest:

- Regional Climate Modeling
- Climate Downscaling
- Urban Climate
- Climate Change Assessment

Urban Heat in the Kansas City Metropolitan Area and Cool Roofs' Mitigation Potential: An Integrated Regional Modeling and Heat Mapping Campaign Study

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INTRODUCTION

Individuals that live in metropolitan areas are in a unique position to experience greater temperatures compared to those living in more rural areas due to the urban heat island (UHI) effect. An UHI is a type of local climate that causes the temperature within cities to become significantly warmer than that of the surrounding rural areas due to human activities and infrastructure. One method that has shown promise in mitigating the UHI effect is cool roofs.

The goal of this study is to provide evidence for the effectiveness of widespread deployment of cool roofs in mitigating the UHI effect in the Kansas City metropolitan area during a July 2012 heatwave.

METHODS

- Climate simulations were performed using the Weather Research and Forecasting (WRF) model.
- The three simulations were focused over the Kansas City metro area
  - 1) Control with normal albedo (0.3)
  - 2) Cool Roofs with an albedo of 0.5 and an albedo of 0.8
- The Cool Roof cases represent widespread installation of cool roofs throughout the metro area.
- Simulations consisted of 3 domains with resolutions of 9, 3, and 1 km
- Observation data from five local stations are used for model validation
- NOAA funded Kansas City Urban Heat Mapping Campaign led by UMKC

MODELING RESULTS

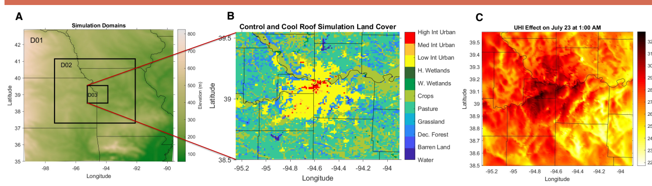


Fig 1. A) Three study domains with elevation of the coarsest domain shown. **B)** 1-km domain shown with land use categories. **C)** Example of the UHI effect in the Kansas City metropolitan area (1-km domain)

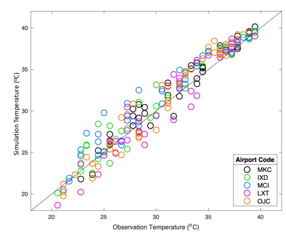


Fig 2. Comparison of observation data from five local airports to the Control simulation. Note: observation temperatures are of integer precision

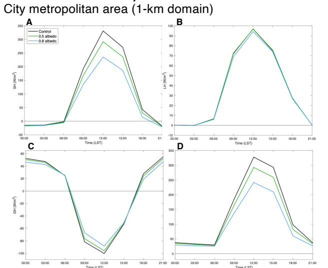


Fig 3. Diurnal cycles of the **A)** sensible, **B)** latent, **C)** ground storage, and **D)** net radiation fluxes during the simulations

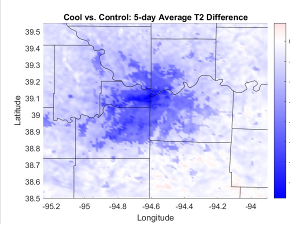


Fig 4. Impact of 0.8-albedo cool roofs on 2-m air temperature in the Kansas City metro area. Low-intensity urban land cover: -0.5ºC; med and high urban categories: -0.6ºC

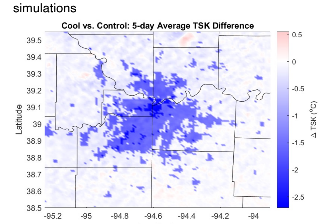
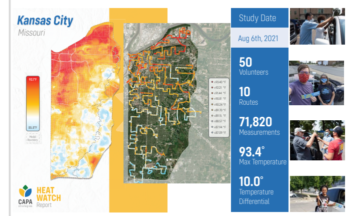


Fig 5. Change in ground surface temperature over the entire heat wave with 0.8-albedo cool roofs. Low-intensity urban land cover: -1.6ºC; med and high: -2.5ºC and -2.6ºC, respectfully

KC URBAN HEAT MAPPING



MODELING PAPER & CAMPAIGN REPORT

Reed and Sun 2023 Climate Dynamics

Kansas City Urban Heat Mapping Campaign Report

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  The Kansas City Missouri Office of Environmental Quality
  The Mid-America Regional Council
  The Missouri Local Science Engagement Network
  Missouri Office of the Public Counsel
  Evergy, Inc.
  Bridging the Gap Inc.
  Kansas City Teen Summit

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Investigating End-of-Century Climate Changes in Missouri

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Introduction

- Climate change is a significant threat to Missouri because it can increase the number of extreme weather and climate events, which will impact agriculture production and infrastructure.
- Many studies have utilized general circulation models to study climate change impacts on a global scale. However, there is a lack of regional-scale analysis.
- Regional-scale analysis is critical because the impact of climate change is not uniform. Different areas may experience very different hazards and intensities from climate change.

Aim and Objectives

This study aimed to examine the potential changes in temperature, precipitation, and wind speed for the Missouri region at the end of the century by utilizing Atmosphere-Ocean General Circulation Models from the Coupled Model Intercomparison Project's sixth phase (CMIP6) under an SSP5-8.5 emissions scenario.

The study had two objectives to achieve this aim.

- To investigate the annual and seasonal mean changes in surface air temperature, precipitation, and wind speed.
- To evaluate the frequency of extreme temperature, precipitation, and wind speed events during the winter and summer seasons.

Results and Discussion

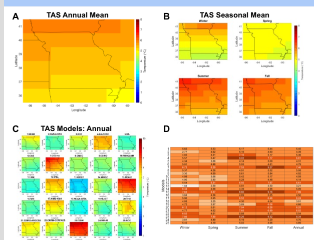

Fig 1. A) Annual ensemble mean temperature change. B) Seasonal ensemble mean temperature change. C) Annual mean temperature change. D) Heatmap of area averaged mean temperature change for all models and seasons.

Mean Temperature Change

- A high model agreement that temperatures are going to increase across all seasons at the end of the century.
- Most models have the greatest temperature increase in the northern areas of Missouri.
- Summer and fall seasons are at the most risk for temperature increases.

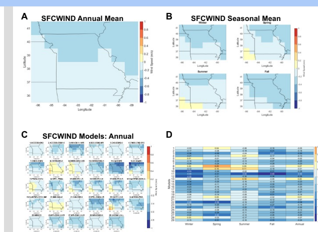

Fig 3. A) Annual ensemble mean wind speed change. B) Seasonal ensemble mean wind speed change. C) Annual mean wind speed change. D) Heatmap of area averaged mean wind speed change for all models and seasons.

Mean Wind Speed Change

- Spring has the greatest increase in wind speed while fall has the greatest decrease in wind speed.
- Largest wind speed decrease in the northern areas of Missouri.
- Wind speeds mean changes are very small compared to temperature and precipitation.

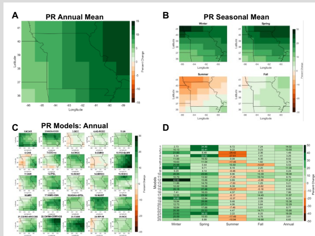

Fig 2. A) Annual ensemble mean precipitation percent change. B) Seasonal ensemble mean precipitation percent change. C) Annual mean precipitation percent change. D) Heatmap of area averaged mean precipitation percent change for all models and seasons.

Mean Precipitation Percent Change

- Strong seasonal differences.
- High model agreement that precipitation will increase during winter and spring, while summer and fall may have precipitation deficits.
- Winter has the greatest increase in precipitation, while the summer has the most risk for precipitation decrease.

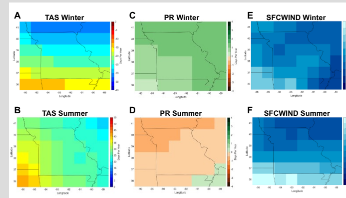

***Fig 4.** Ensemble mean extreme event frequency difference between Historical and SSP5-8.5 number of days with extreme events. **A)** Cold winter temperature events. **B)** Hot summer temperature events. **C)** Heavy Winter precipitation events. **D)** Heavy Summer precipitation events. **E)** Fast winter wind speed events. **F)** Fast summer wind speed events.*

Frequency Change of Extreme Events

Fig 4 indicates that the number of:

- Winter cold events will decrease greatly, while summer hot events will increase by a large margin.
- Heavy winter precipitation events will increase, while heavy summer precipitation will decrease.
- Winter and summer extreme wind speed events are expected to decrease slightly.

Data and Methods

CMIP6 data collected:

- Baseline Scenario: Historical (1984 to 2014)
- Future Scenario: SSP5-8.5 (2070 to 2100)
- Variables: Air Temperature (tas), Precipitation Flux (pr), and Near Surface Wind Speed (sfcWind).
- Frequency: Monthly and Daily

The data was processed and analyzed by:

- Regridded to 1° to 1° grid cell size.
- Mean change was evaluated by calculating the difference between the mean future and baseline scenario values.
- Extreme tas events were investigated using a 0°C threshold for the winter season and a 35°C threshold for the summer season.
- Extreme pr and sfcWind events were both explored using 95th percentile thresholds for the winter and summer seasons.

Table 1. Models used for temperature and precipitation analysis.

Number	Institution	Model	Grid (lat x lon)	Monthly Available	Daily Available
1	NCAR	CESM2-WACCM	192x288	✓	✓
2	NASA-GISS	GISS-E2-1-G	90x144	✓	
3	BCC	BCC-CSM2-MR	160x320	✓	✓
4	AS-RCEC	TaiESM1	192x288	✓	✓
5	UA	MCM-UA-1-0	80x96	✓	
6	CAS	FGOALS-f3-L	180x288	✓	
7	CCCma	CanESM5	64x128	✓	✓
8	CMCC	CMCC-CM2-SR5	192x288	✓	✓
9	CSIRO	ACCESS-ESM1-5	145x192	✓	✓
10	FIO-QLNM	FIO-ESM-2-0	192x288	✓	
11	INM	INM-CM4-8	120x180	✓	✓
12	IPSL	IPSL-CM6A-LR	143x144	✓	✓
13	KIOST	KIOST-ESM	96x192	✓	✓
14	MIROC	MIROC6	128x256	✓	✓
15	MOHC	UKESM1-0-LL	144x192	✓	✓
16	MRI	MRI-ESM2-0	160x320	✓	✓
17	NIMS-KMA	KACE-1-0-G	144x192	✓	✓
18	NOAA-GFDL	GFDL-ESM4	180x288	✓	✓
19	NUIST	NESM3	96x192	✓	✓
20	THU	CIESM	192x288	✓	
21	CSIRO-ARCCSS	ACCESS-CM2	144x192	✓	✓
22	CNRM-CERFACS	CNRM-ESM2-1	128x256	✓	✓
23	E3SM	E3SM-1-1	180x360	✓	
24	MPI-M	MPI-ESM1-2-LR	96x192	✓	✓
25	NCC	NorESM2-LM	96x144	✓	✓

- Monthly data was used to evaluate mean change, and daily data was used to explore the frequency change of extreme events.

Table 2. Models used for wind speed analysis.

Number	Institution	Model	Grid (lat x lon)	Monthly Available	Daily Available
1	CSIRO-ARCCSS	ACCESS-CM2	144x192	✓	✓
2	CSIRO	ACCESS-ESM1-5	145x192	✓	✓
3	AWI	AWI-CM-1-1-MR	192x384	✓	
4	BCC	BCC-CSM2-MR	160x320	✓	
5	CAS	CAS-ESM2-0	128x256	✓	
6	CMCC	CMCC-CM2-SR5	192x288	✓	✓
7	CMCC	CMCC-ESM2	192x288	✓	✓
8	CNRM-CERFACS	CNRM-CM6-1	128x256	✓	
9	CNRM-CERFACS	CNRM-CM6-1-HR	360x720	✓	
10	CNRM-CERFACS	CNRM-ESM2-1	128x256	✓	
11	CCCma	CanESM5	64x128	✓	✓
12	EC-Earth-Consortium	EC-Earth3	256x512	✓	✓
13	CAS	FGOALS-f3-L	180x288	✓	
14	NOAA-GFDL	GFDL-ESM4	180x288	✓	✓
15	NASA-GISS	GISS-E2-1-G	90x144	✓	
16	NASA-GISS	GISS-E2-1-H	90x144	✓	
17	NASA-GISS	GISS-E2-2-G	90x144	✓	
18	MOHC	HadGEM3-GC31-LL	144x192	✓	✓
19	MOHC	HadGEM3-GC31-MM	324x432	✓	✓
20	INM	INM-CM4-8	120x180	✓	✓
21	INM	INM-CM5-0	120x180	✓	✓
22	IPSL	IPSL-CM6A-LR	143x144	✓	✓
23	NIMS-KMA	KACE-1-0-G	144x192	✓	
24	MIROC	MIROC-ES2L	64x128	✓	✓
25	MIROC	MIROC6	128x256	✓	✓
26	MPI-M	MPI-ESM1-2-HR	192x384	✓	✓
27	MPI-M	MPI-ESM1-2-LR	96x192	✓	✓
28	MRI	MRI-ESM2-0	160x320	✓	✓
29	MOHC	UKESM1-0-LL	144x192	✓	✓

Conclusions

- At the end of the century, Missouri is likely to have mean temperature increases all year round, precipitation increases all year round except for summer, and wind speeds decrease all year round.
- In addition, extreme cold temperature events will decrease in winter, while extreme hot temperature events will increase during the summer. Extreme precipitation events are going to increase during the winter and decrease in the summer. Lastly, extreme wind speed events will decrease in the winter and summer.
- These results indicate that Missouri is at greatest risk of increased flooding during the winter and drought during the summer.

Acknowledgements

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