HEALTH & AIR QUALITY

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Neighborhood-Scale Extreme Humid Heat Health Impacts

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Project Summary

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Neighborhood-Scale Extreme Humid Heat Health Impacts

Short title: Extreme Humid Heat Impacts

Project PI: Peter Kalmus

ROSES 2021 A.37: Earth Science Applications: Health and Air Quality

Project Summary: The objective is to produce high-quality, validated projections of extreme humid heat at unprecedented spatial resolution, and to resolve the morbidity and mortality impacts geographically and population-wise. The applications stakeholders are the Red Cross Red Crescent, and the Los Angeles County Chief Sustainability Office. The primary decision-making context is urban heat planning and mitigation, in Los Angeles and global cities.

Geographic Scope: Global

Project Partners/Collaborators

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Role	Name	Affiliation	Org. Type
Co-I: High-resolution T data	Glynn Hulley	JPL	NASA
Data scientist	Tinh La		
Co-I: AC data and analysis	Kelly Sanders	USC	University
Student	McKenna Peplinski		
Co-I: Health data and analysis	Howard Chang	Emory	University
Student	Xiaping Zheng		
Co-I: Statistical methods	Emily Kang	U Cincinnati	University
Student	Ayesha Ekanayaka		
Collaborator: Physiological model	David Romps	UC Berkeley	University
Student	Yi-Chuan Lu		
Collaborator: Humid heat	Luke Parsons	Duke	University
Collaborator: Humid heat	Drew Shindell	Duke	University
Collaborator: Thermophysiology	Ollie Jay	Sidney	University

Project objectives

Objective 1: Create neighborhood-scale projections of extreme humid heat health impacts in global urban centers.

Objective 2: Guide decision-making activities on extreme humid heat preparedness and mitigation in global urban centers.

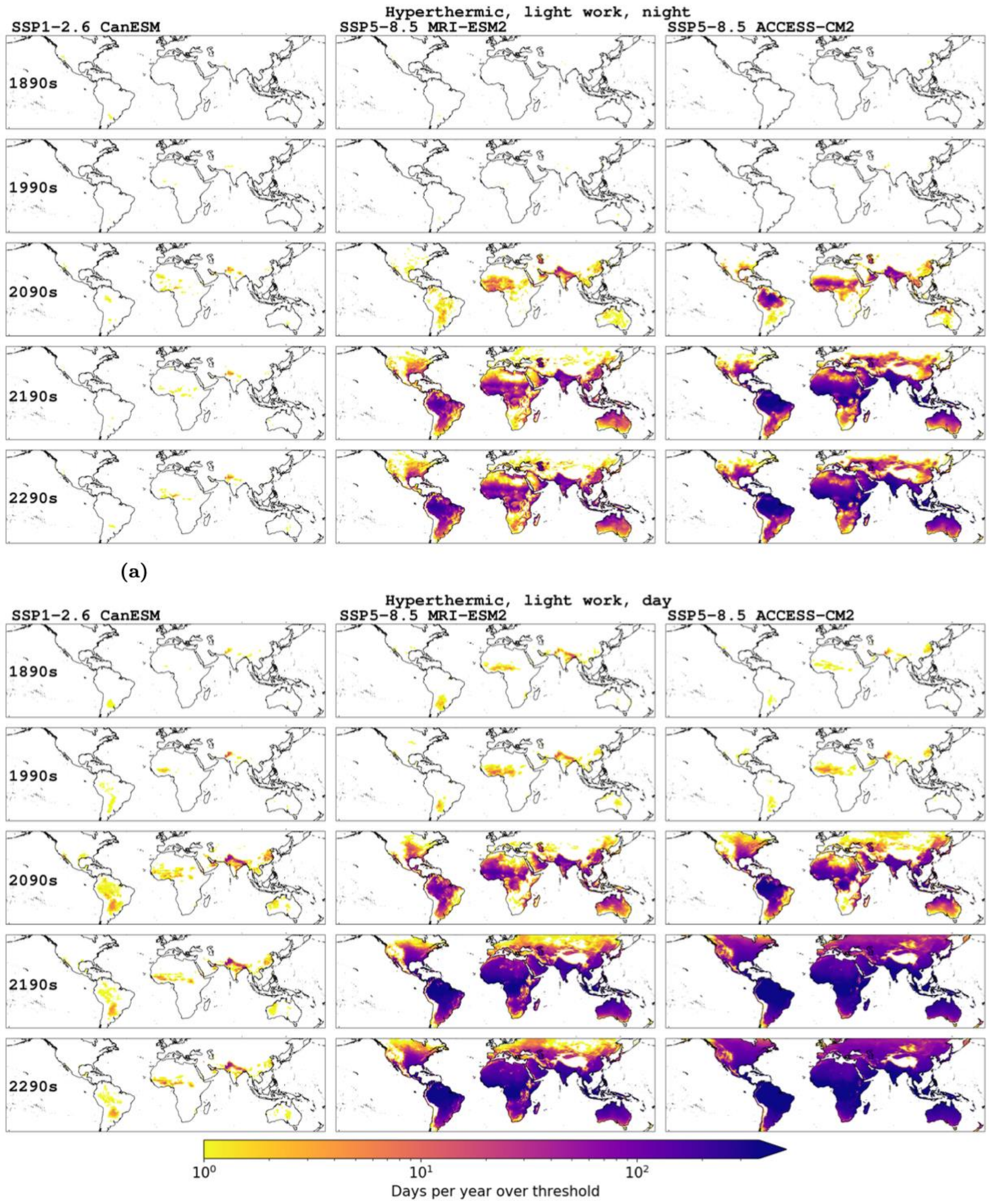
Key project results

- Projections of humid heat health impacts, global 10 km, to 2300
  - Kalmus, P., Parsons, L., Jay, O., Ekanayaka, A., Lu, Y., Romps, D., 2024. Fatal humid heat conditions to 2300. In revisions.
  - Kalmus, P., Ekanayaka, A., Shreevastava, A., Goodman, A., Hulley, G., Kang, E., Lu, Y., Parsons, L., Romps, D., Shindell, D., 2024. Global projections of uncompensable and fatal humid heat. In revisions.
- 2m air temperatures at 375 m over LA County and Delhi
- Modeling AC penetration rates in LA County (led by USC team)
  - Peplinski, M., Kalmus, P., Sanders, K.T. 2023: Investigating whether the inclusion of humid heat metrics improves estimates of AC penetration rates: A case study of Southern California. *Environmental Research Letters* 18. https://doi.org/10.1088/1748-9326/acfb96
- New methodology to better characterize AC penetration rates using hourly electricity data (led by USC team)
  - Can inform demand side management programs and strategies designed to reduce energy insecurity.
- Preliminary analysis of heat, emergency department visits and air conditioning penetration for Los Angeles (led by Emory team)

10 km humid heat impact projections

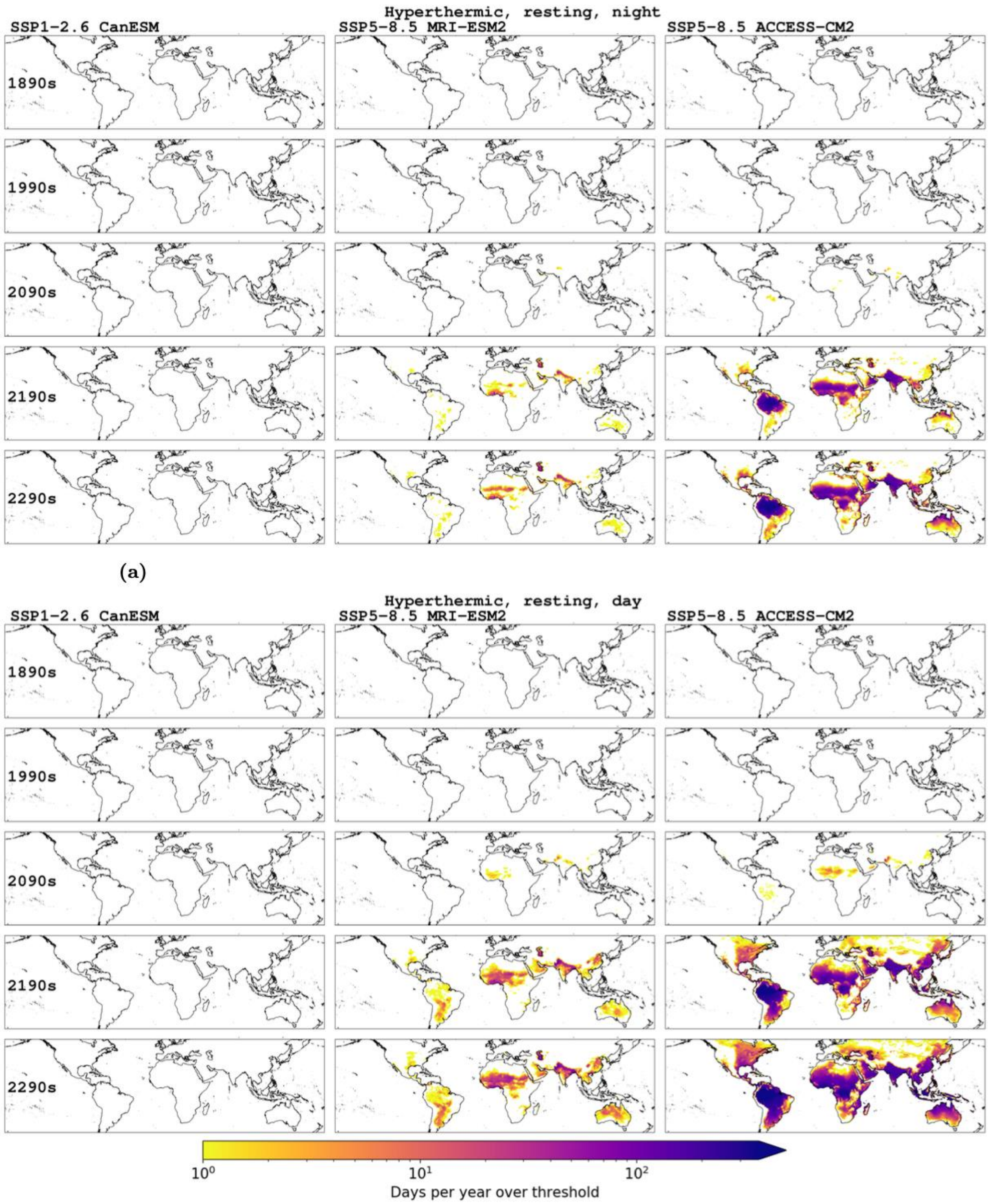
- Statistically downscale CMIP6 global projections of T and RH
  - using ERA5-Land
- Use model of human core temperature given T, RH, wind speed, metabolic work rate
  - For an ideally healthy perfectly acclimated person
  - Steady-state model: Lu & Romps 2022: Extending the Heat Index.
  - Indoor wind speed
  - Resting and light work (e.g. walking) metabolic work rates
  - Shade, unlimited water, minimal clothing

310 K (37°C, 98.6°F)



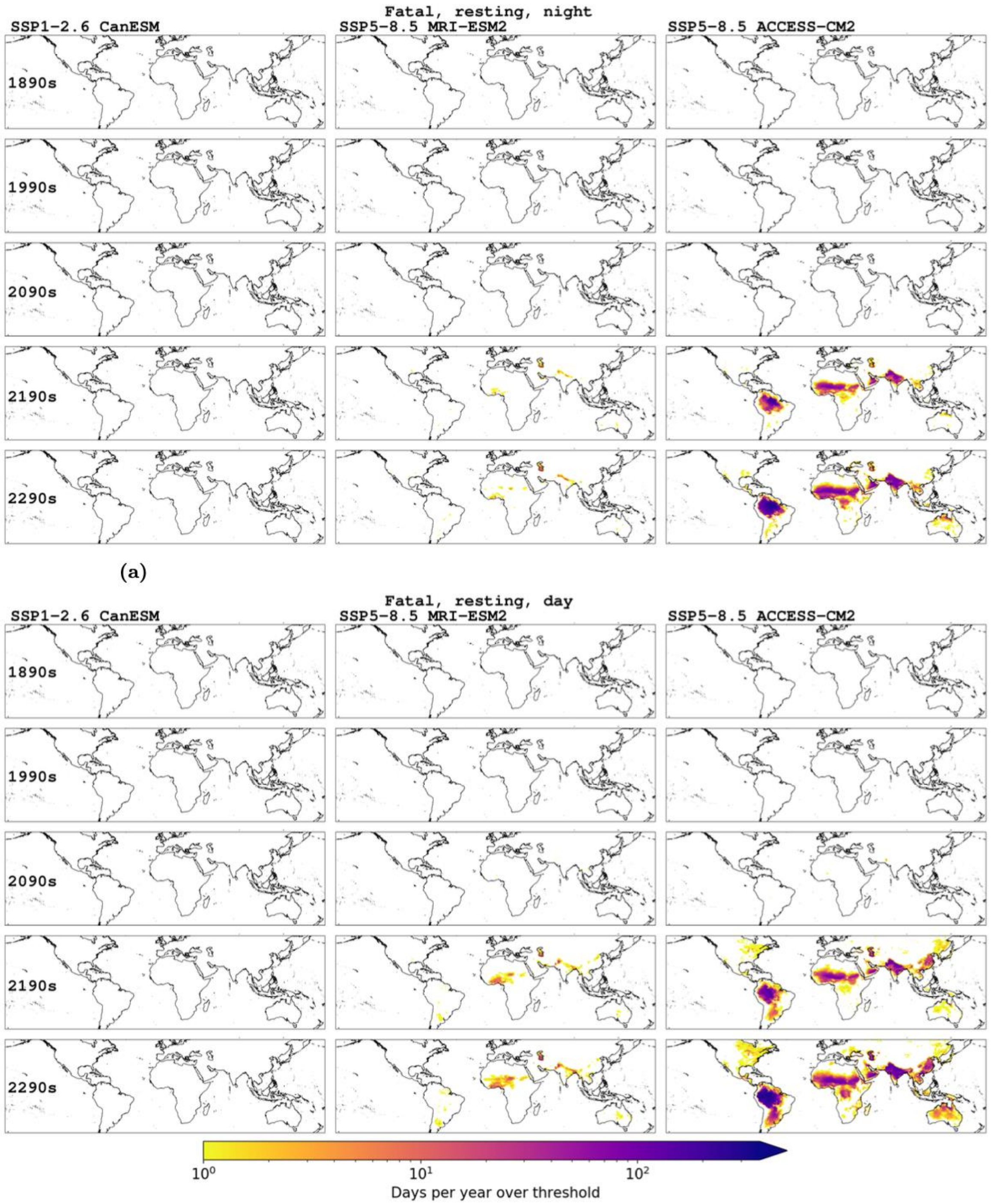
Extreme humi

312.5K (39.5°C, 103°F)

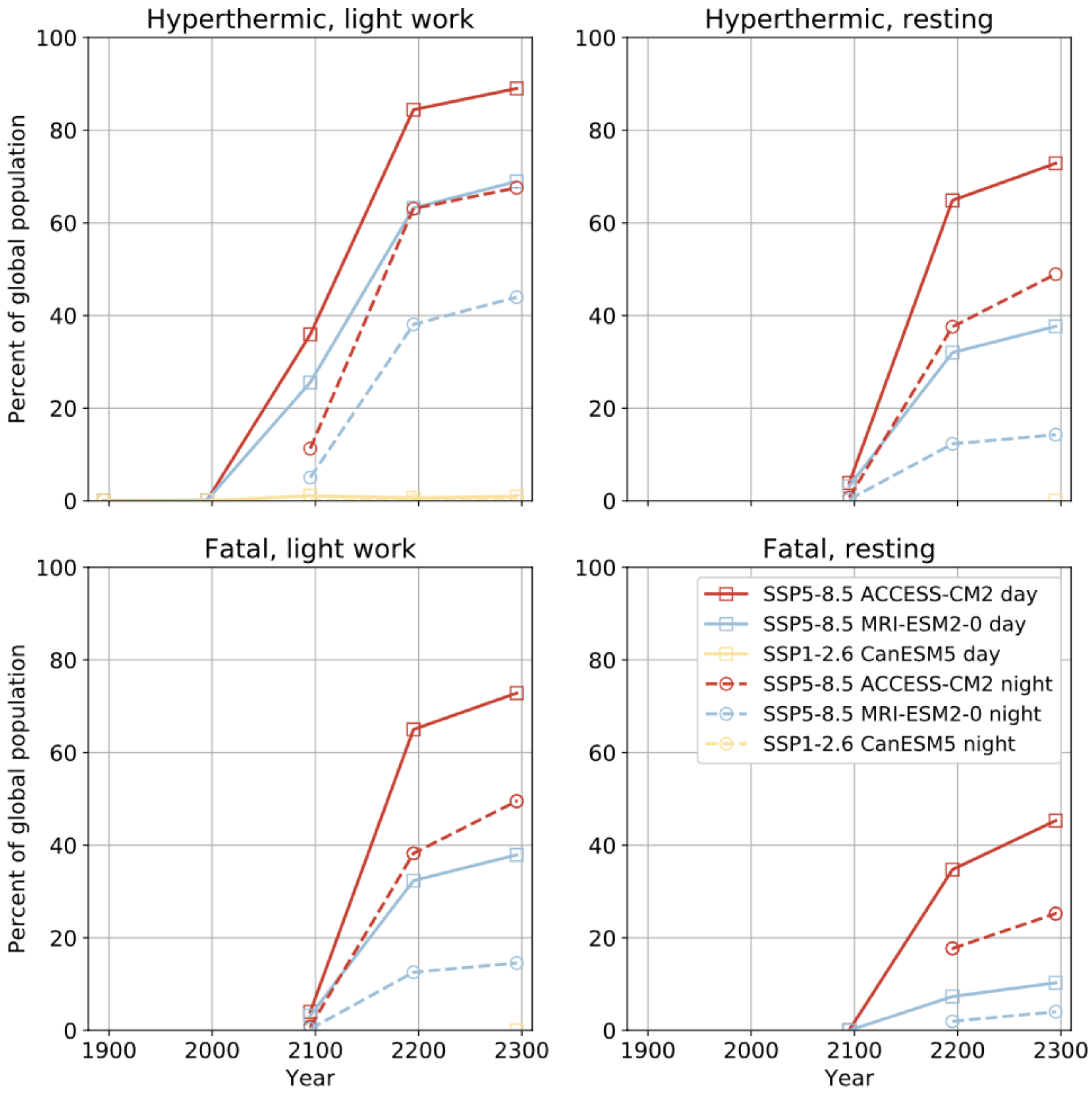


Extreme humid

315K (42°C, 108°F)



Extreme humid



Hyperthermic, light work
Hyperthermic, resting
Fatal, light work
Fatal, resting
Percent of global population
Year
0
20
40
60
80
100
1900
2000
2100
2200
2300
SSP5-8.5 ACCESS-CM2 day
SSP5-8.5 MRI-ESM2-0 day
SSP1-2.6 CanESM5 day
SSP5-8.5 ACCESS-CM2 night
SSP5-8.5 MRI-ESM2-0 night
SSP1-2.6 CanESM5 night

High-resolution Tair product

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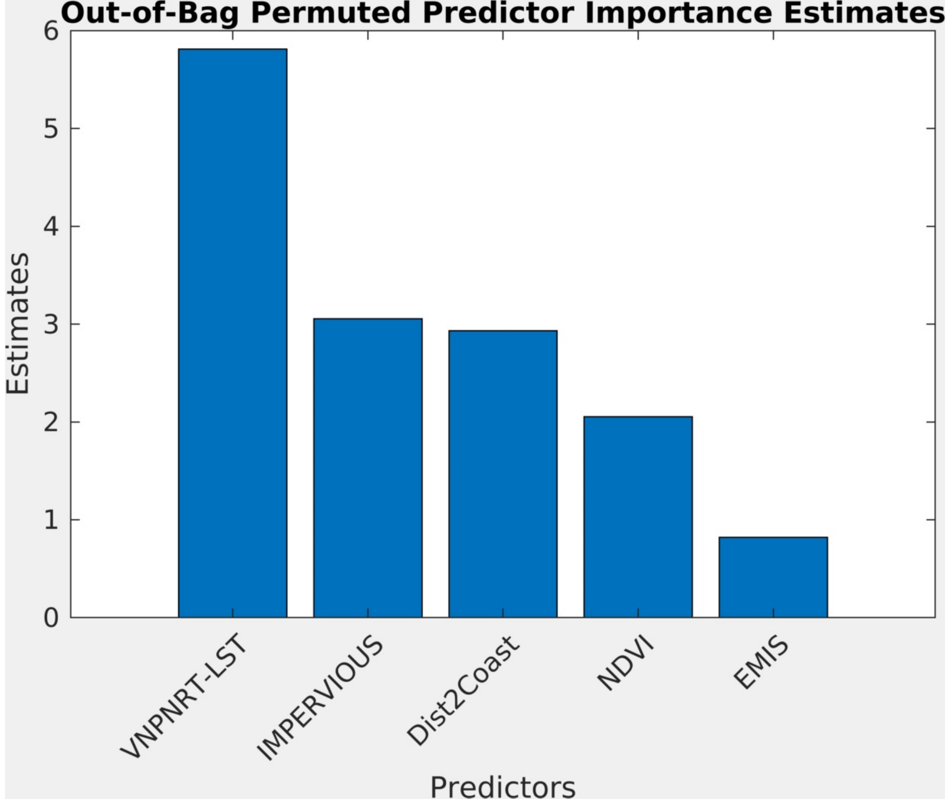
- Creation and validation of the 375 m Tair product over Delhi and LA County.
- Inputs:
  - NOAA NCDC Ground Stations measuring Daily min/max Air Temperature
  - VIIRS 375-m land surface temperature (day and night, 1:30 am/pm)
  - Random Forest machine learning model (100 trees)
- July, August September; 2018-2020

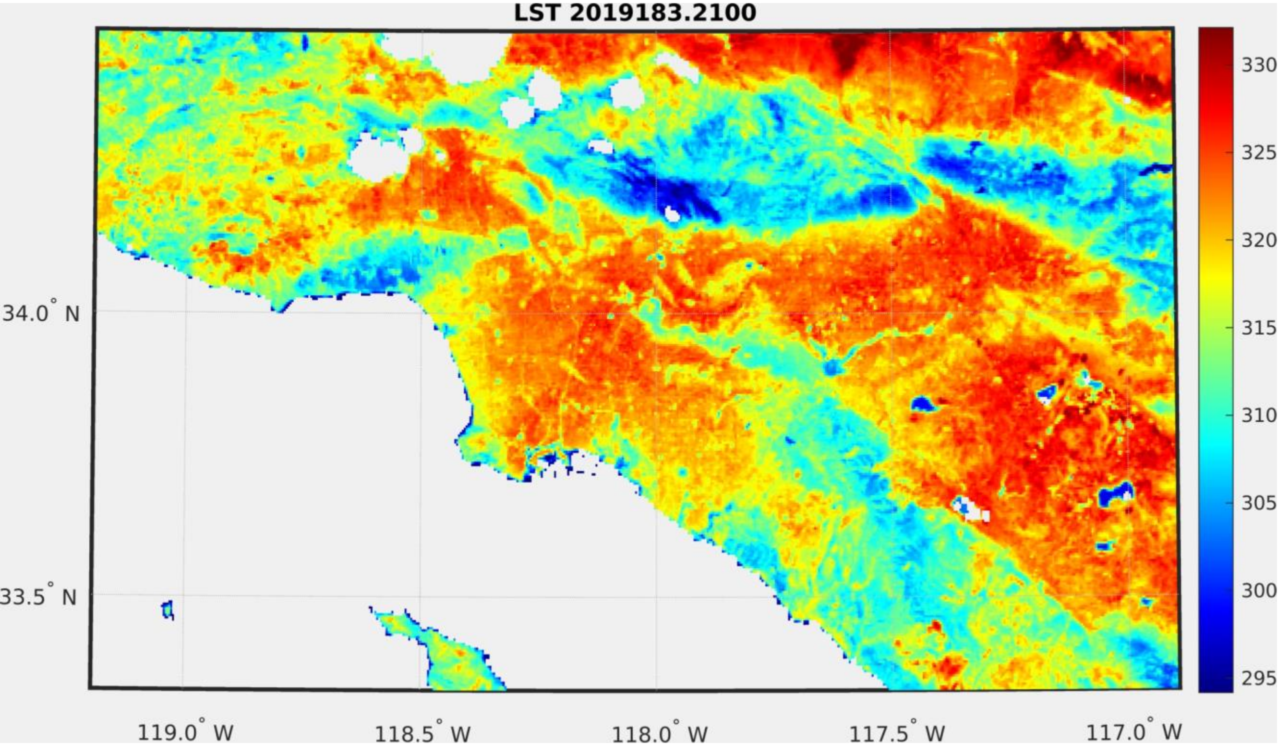
Predictors for model

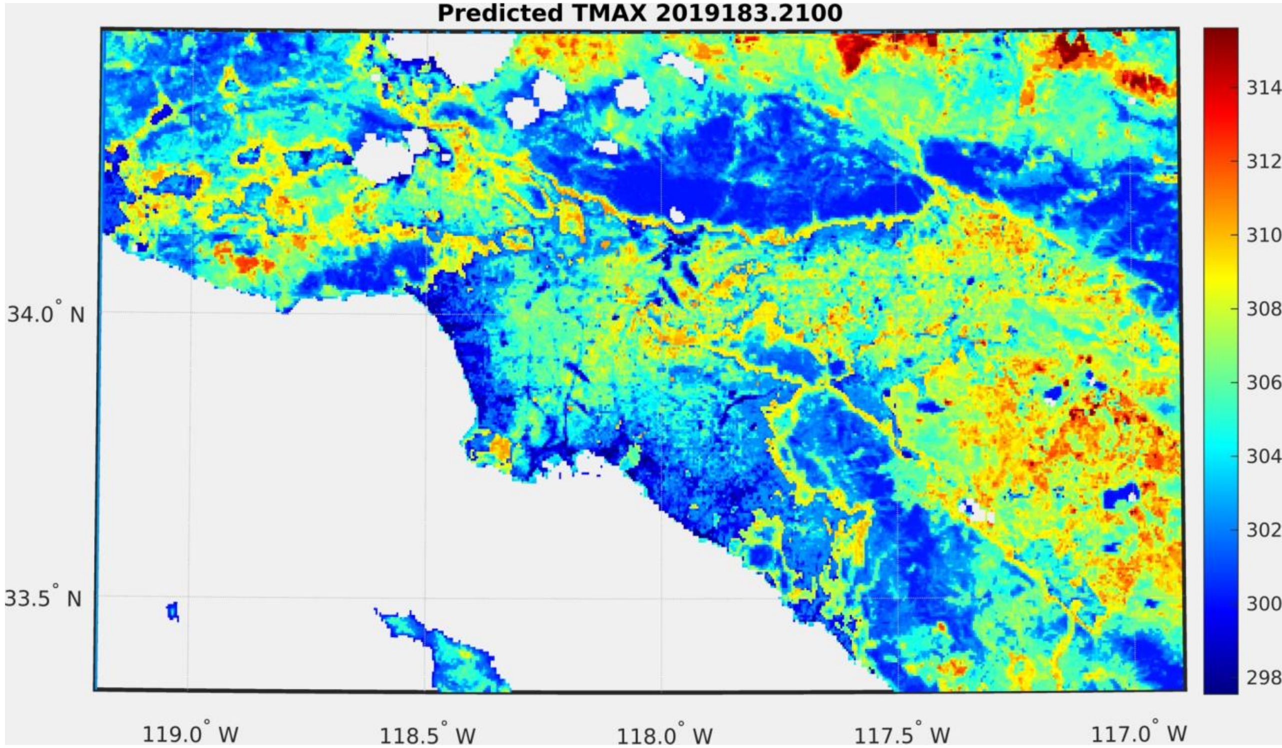
- Five predictors were used in total:
  1. Land Surface Temperature (LST)
  2. Emissivity (EMIS)
  3. Normalized Vegetation Index (NDVI)
  4. Impervious fraction
  5. Distance To Coast



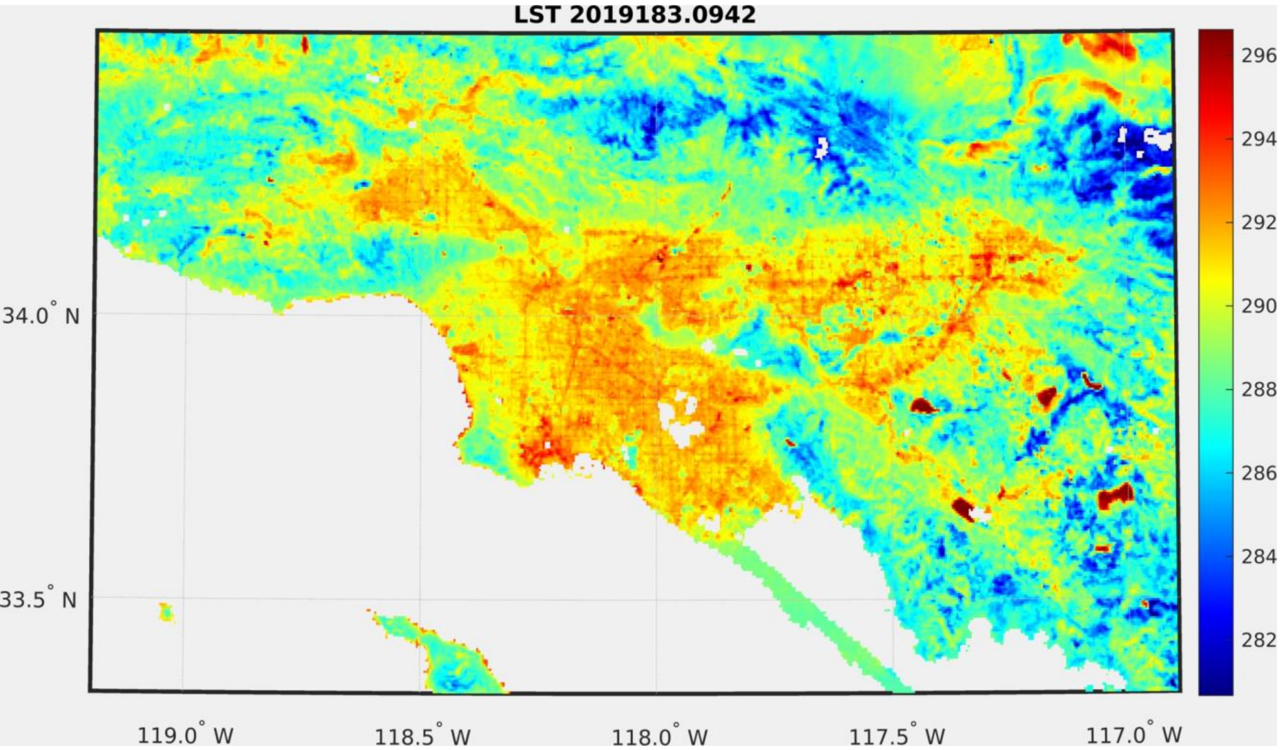
- LST and EMIS are from the Visible Infrared Imaging Radiometer Suite (VIIRS) Land Surface Temperature Product (VNP21IMG)
  - Scenes with >50% cloudy were excluded
- NDVI calculated from two surface reflectance bands: the first band (SRI1) and the second (SRI2) of the VIIRS Surface Reflectance Product (VNP09)
- 2010 Impervious data is from Landsat
  - sedac.ciesin.columbia.edu/data/set/ulandsat-gmis-v1/

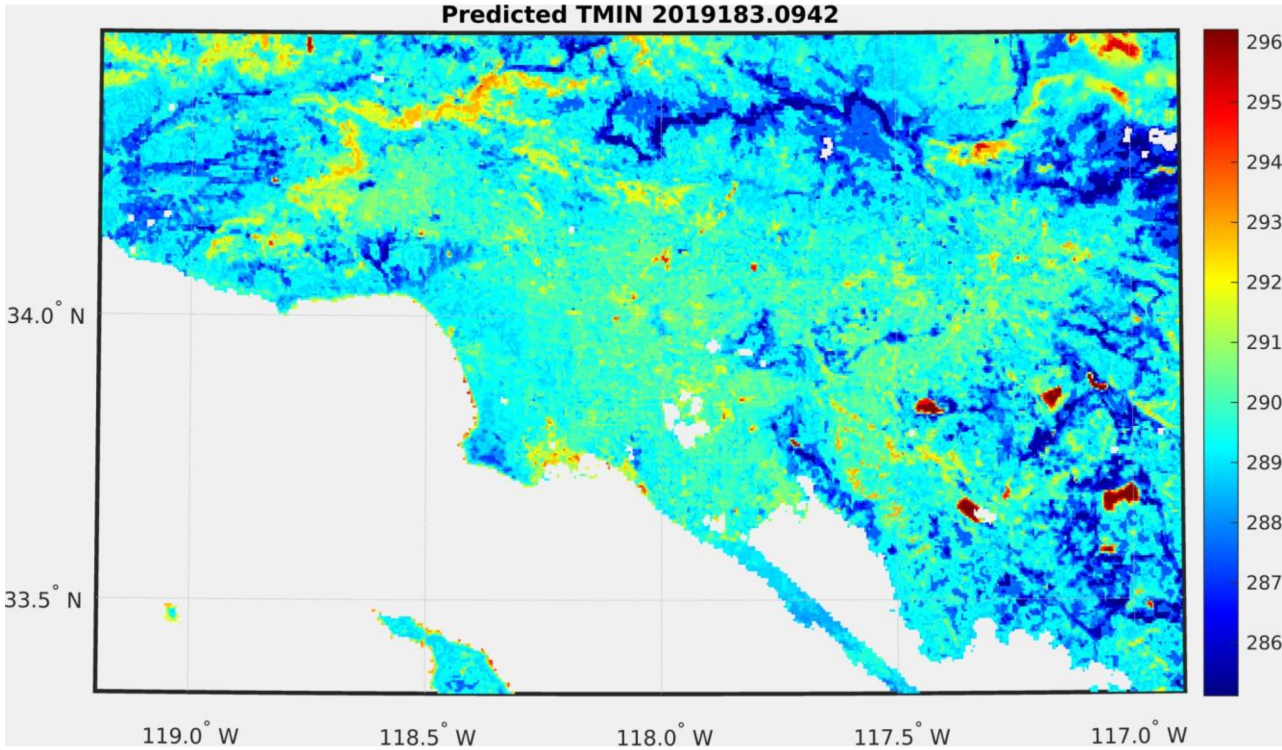
July 2, 2019, 2:00 pm local time



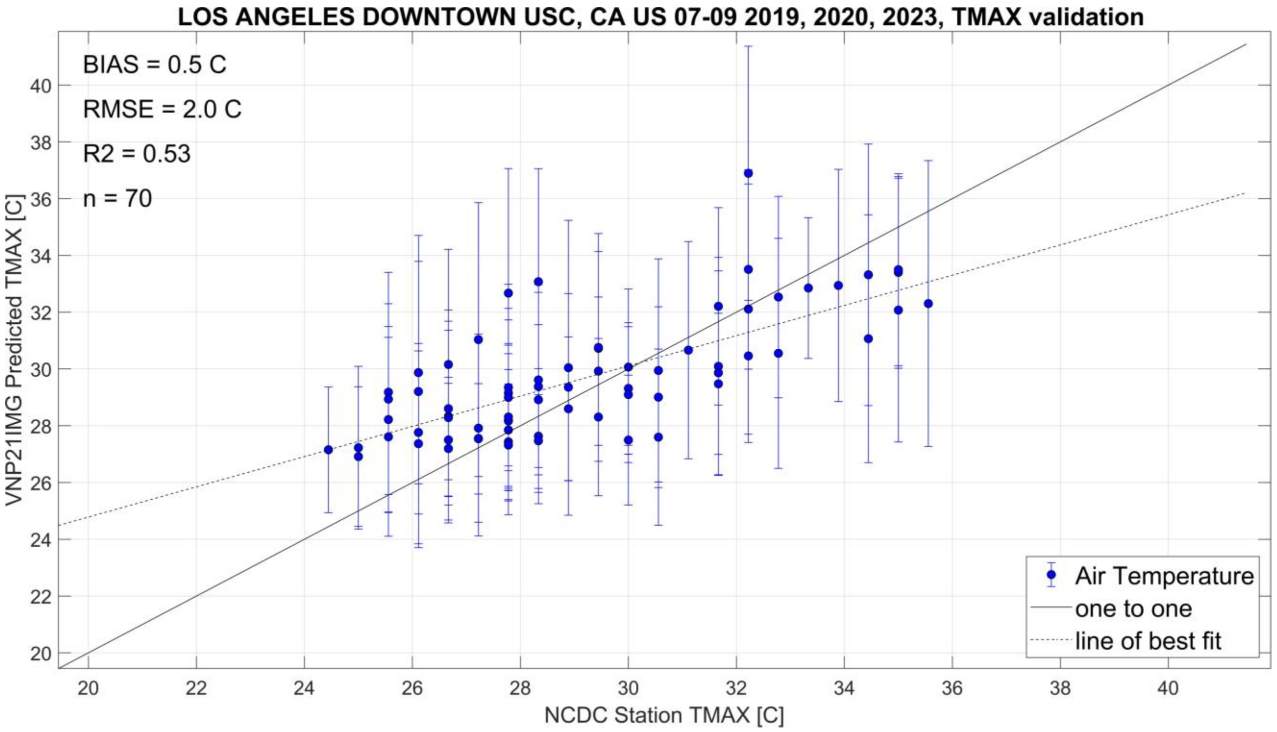


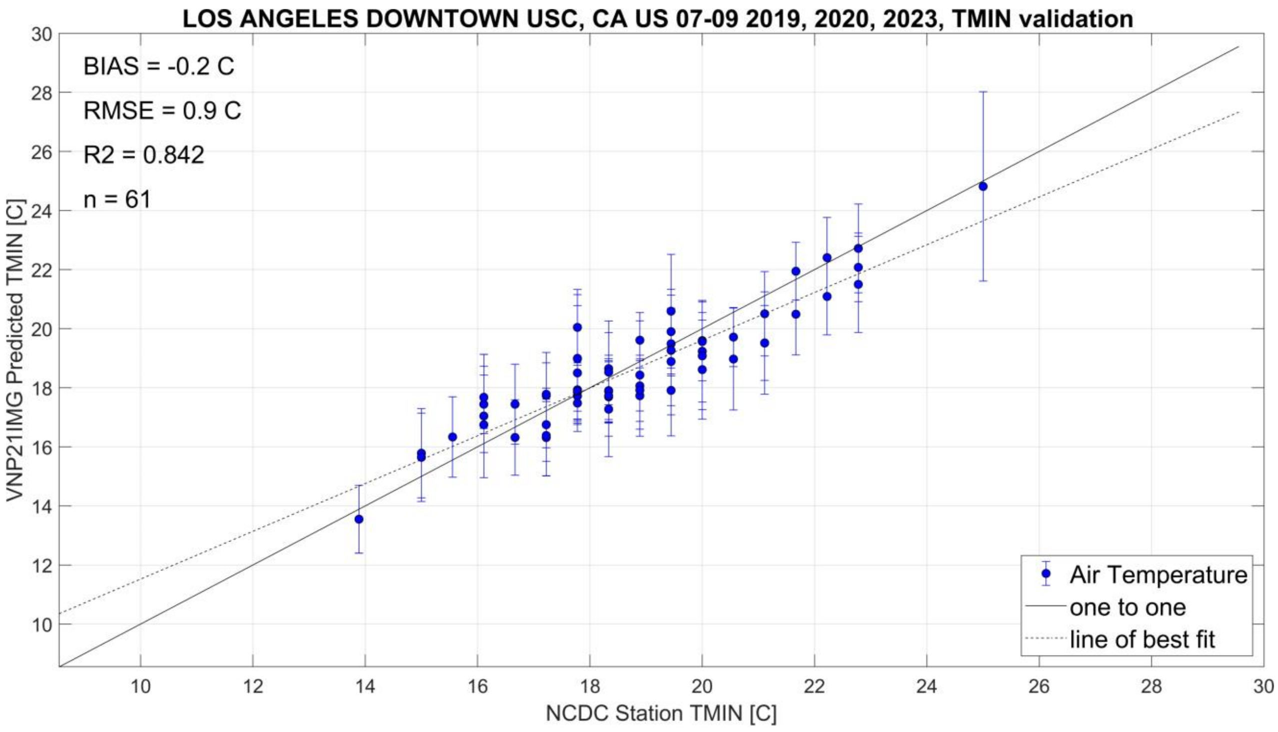
July 2, 2019, 2:42 am local time





	TMAX Stats				TMIN Stats			
Site (2019, 2020, 2023)	BIAS (C)	RMSE (C)	R2	N	BIAS (C)	RMSE (C)	R2	N
BEVERLY HILLS, CA, US	0.1	1.5	0.80	77	-0.1	1.3	0.80	60
BURBANK GLENDALE PASADENA AIRPORT, CA US	0.6	2.4	0.61	77	0.4	1.0	0.86	71
BURBANK VALLEY PUMP PLANT, CA US	0.4	1.9	0.75	71	0.4	1.0	0.82	73
CHILAO CALIFORNIA, CA US	0.4	1.9	0.66	60	-0.1	1.7	0.77	73
CLEAR CREEK CALIFORNIA, CA US	-0.2	1.6	0.72	67	0.1	1.3	0.89	83
CULVER CITY, CA US	-0.1	1.4	0.75	62	0.3	0.7	0.88	41
FULLERTON MUNICIPAL AIRPORT, CA US	0.2	2.6	0.43	78	0.0	0.6	0.93	50
HAWTHORNE MUNICIPAL AIRPORT, CA US	0.2	1.7	0.72	73	-0.4	1.2	0.68	54
LITTLE TUJUNGA CALIFORNIA, CA US	0.2	1.6	0.82	74	0.1	0.9	0.92	76
LONG BEACH DAUGHERTY AIRPORT, CA US	0.8	2.6	0.50	80	0.1	0.8	0.87	50
LOS ANGELES DOWNTOWN USC, CA US	0.5	2.0	0.53	70	-0.2	0.9	0.84	61
LOS ANGELES INTERNATIONAL AIRPORT, CA US	0.4	1.7	0.67	67	0.1	1.0	0.75	39
PASADENA, CA US	-0.4	2.3	0.62	70	0.2	1.0	0.85	28
REDONDO BEACH, CA US	0.5	1.2	0.66	64	-0.2	0.9	0.87	14
SANTA ANA FIRE STATION, CA US	0.3	2.1	0.55	75	0.1	0.6	0.93	45
SANTA MONICA MUNICIPAL AIRPORT, CA US	0.8	1.9	0.65	65	0.2	0.8	0.87	48
TORRANCE AIRPORT, CA US	0.2	1.5	0.74	64	-0.1	0.7	0.89	46
U C L A, CA US	0.2	2.1	0.61	72	0.1	0.8	0.84	49
VAN NUYS AIRPORT, CA US	0.6	2.5	0.60	75	-0.1	0.8	0.92	77


LOS ANGELES DOWNTOWN USC, CA US 07-09 2019, 2020, 2023, TMAX validation
BIAS = 0.5 C
RMSE = 2.0 C
R2 = 0.53
n = 70
Air Temperature
one to one
line of best fit
VNP21IMG Predicted TMAX [C]
NCDC Station TMAX [C]


LOS ANGELES DOWNTOWN USC, CA US 07-09 2019, 2020, 2023, TMIN validation
BIAS = -0.2 C
RMSE = 0.9 C
R2 = 0.842
n = 61
Air Temperature
one to one
line of best fit
VNP21IMG Predicted TMIN [C]
NCDC Station TMIN [C]

Schedule & Milestones

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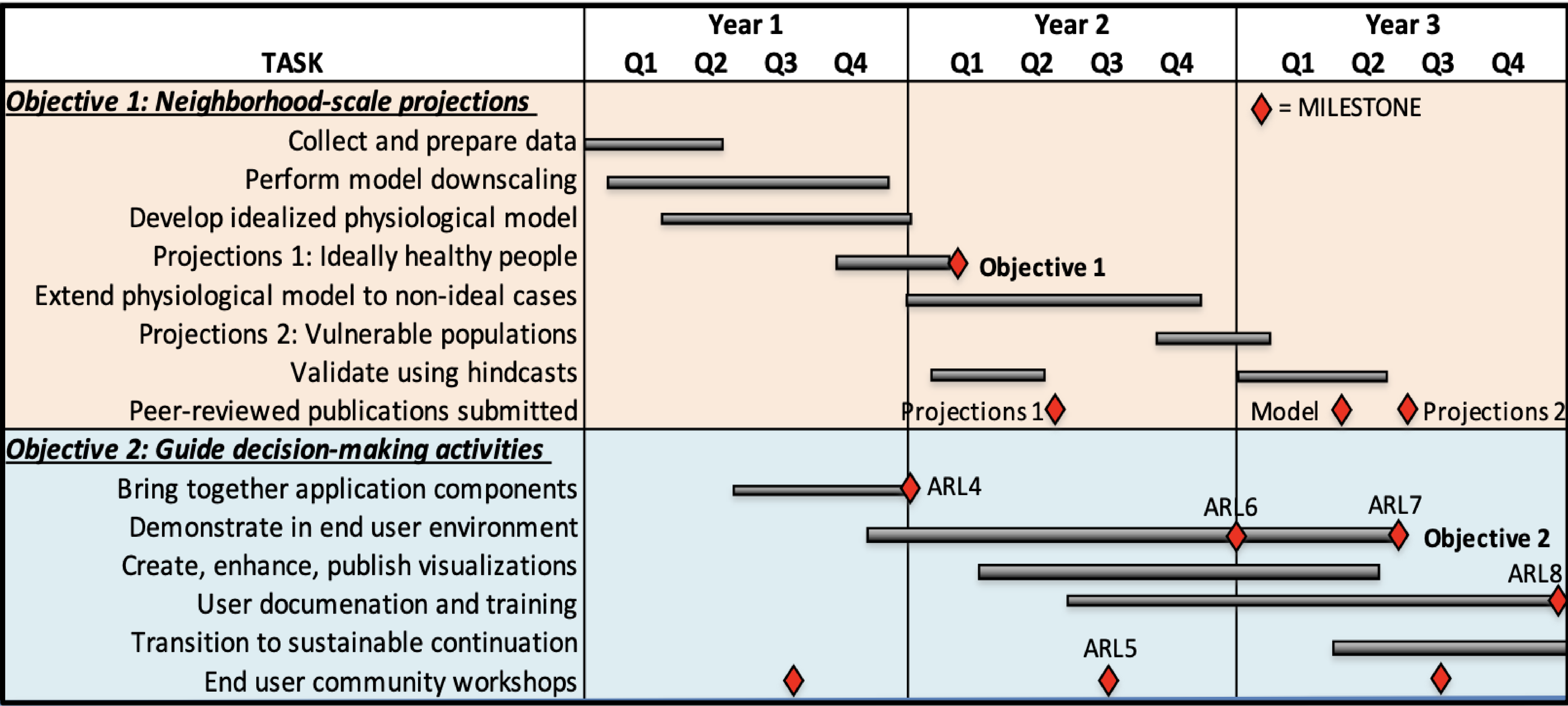
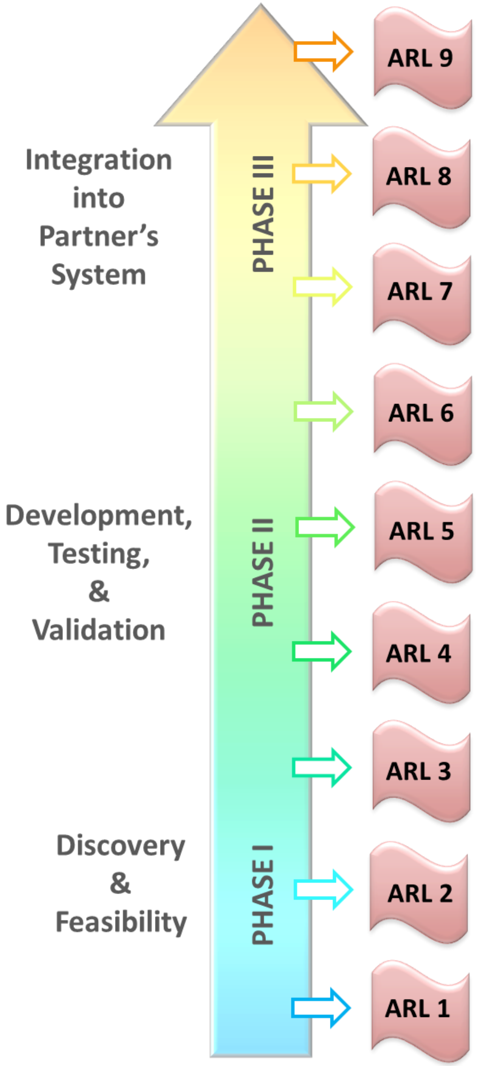


ARL Performance



- Start-of-Project ARL = 3 *(July 2022)*
  - All project components needed for obtaining Objective 1 have been created and validated independently, and decision-making activity has been characterized.
- Goal ARL = 7
- Current ARL = 5 *(September 2023)*

ARL 5 Supporting Evidence

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Application components have been integrated into a functioning prototype application system with realistic supporting elements.

- We have prototyped the 375m 2m air temperature (Tair) model using a random forest machine learning model, which has produced plausible results from the VIIRS land surface temperature product. We use LST, NDVI, emissivity, and impervious fraction as input data sets.
- We have done a preliminary validation of these data against data from the gridded 1-km resolution Tair data from the Spatially Varying Coefficient Models with Sign Preservation (SVCM-SP) algorithm.
- This validation shows good agreement: daytime Tair (Tmax) with a RMSE of 1.9 K, while nighttime Tair (Tmdin) could be predicted with a RMSE of 1.0 K.

ARL 5 Supporting Evidence

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The application systems potential to improve the decision-making activity has been determined and articulated (e.g., projected impacts on cost, functionality, delivery time, etc.)

- These are the first-ever 2m air temperature regional maps at this level of resolution ("neighborhood" resolution). Our LA County stakeholder has communicated to us that this product has the potential to improve decision making, with new functionality. They just submitted a report to the LA County Board of Supervisors on a proposed framework and next steps for developing a Heat Action Plan.

Progress toward ARL 6

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We have demonstrated the new products to the LA County stakeholder and begun discussing the projected improvement in decision-making activities.

We are beginning to plan our second workshop, which will focus on LA County.

Stakeholder quote:

"This innovative research gives the County much better insight on our residents' potential exposure to heat as they go about their day-to-day lives. It will inform the development of our County Heat Action Plan and help us more precisely identify where to implement heat resilience strategies for maximum impact, which is incredibly important for effective deployment of our limited resources."