Consortium for the Study of Rapidly Urbanizing Regions

CSRUR

Research Vignette No.2 September 2003

FUTURE CLIMATE IN CENTRAL ARIZONA: Heat and the Role of Urbanization

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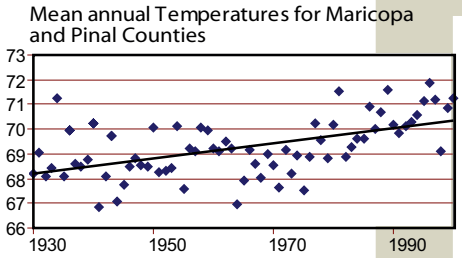
Urban regions are among the most rapidly changing environments on earth. As cities grow, they impact local and regional climates, including temperature averages and extremes. Urban areas are known to alter mean annual air temperatures by 2-5^{0}F per 100 years and up to 20^{0}F at night (1). Temperature changes affect urban dwellers in many ways, influencing their health and comfort, energy costs, air quality and visibility levels, water availability and quality, ecological services, recreation, and overall quality of life (2).

How Have Temperatures Changed Over the Last 100 Years?

FIG 1

From National Climate Data Center (NOAA) monthly temperature records. Before 1930, samples were too small for regional averages.



Over the 20th century, average annual temperatures have increased 3.1^{0}F in Maricopa and Pinal counties (Figure 1). In urban areas of the counties, however, temperatures rose over three times higher (increase of 7.6^{0}F) than in rural areas (increase of 2.3^{0}F). This warming rate for Phoenix is one of the greatest urban-warming rates in the world for its population (3). For example, Los Angeles' rate was 0.8^{0}F/decade; San Francisco, 0.2^{0}F/decade; Tucson, 0.6^{0}F/decade (4); Baltimore, 0.2^{0}F/decade; Washington, 0.5^{0}F/decade; Shanghai, 0.2^{0}F/decade; and Tokyo, 0.6^{0}F/decade. Phoenix's warming trend was very evident this year, when the region experienced its highest July monthly average temperature on record.

What accounts for the difference between Phoenix and other large cities? The growth rate is about 5% per year compared to other urban places (~2%) (8). This population explosion, combined with clear, calm weather, a low latitude with intense sun, and heat-absorbing surfaces may explain our greater-than-normal urban warming.

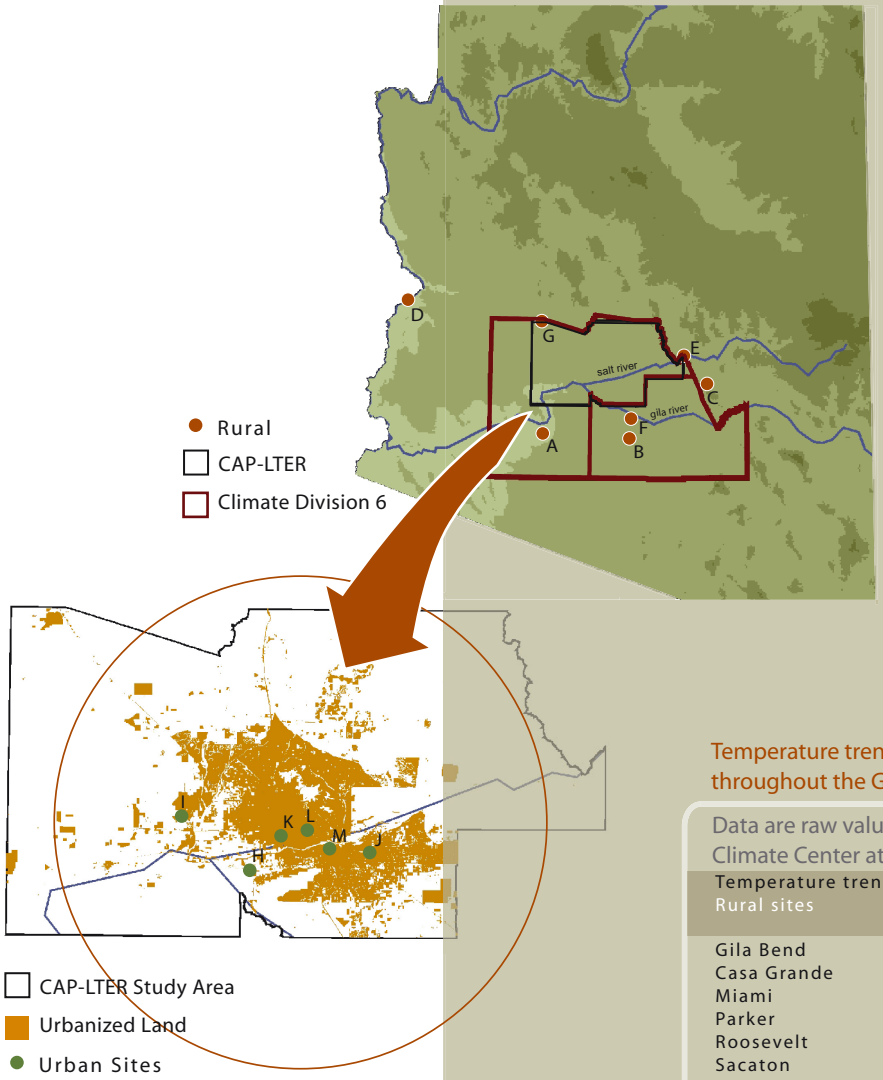


FIG 2

Map of AZ showing Maricopa and Pinal counties, bounded within Climate Division 6.

TABLE 1

Temperature trend rates (°F/decade) at monitoring sites throughout the Greater Phoenix region.

Data are raw values obtained from Western Regional Climate Center at www.wrcc.dri.edu.

Temperature trend rates (°F/decade) Rural sites	(annual mean temperature)	(Map Locus)
Gila Bend	.31	A
Casa Grande	.31	B
Miami	.13	C
Parker	.31	D
Roosevelt	.07	E
Sacaton	.24	F
Wickenburg	.21	G
Urban sites		
Laveen	.39	H
Litchfield Park	.46	I
Mesa	.64	J
Phoenix Downtown	.82	K
Sky Harbor Airport	1.12	L
Tempe	1.13	M
Rural Mean	0.23	
Urban Mean	0.76	

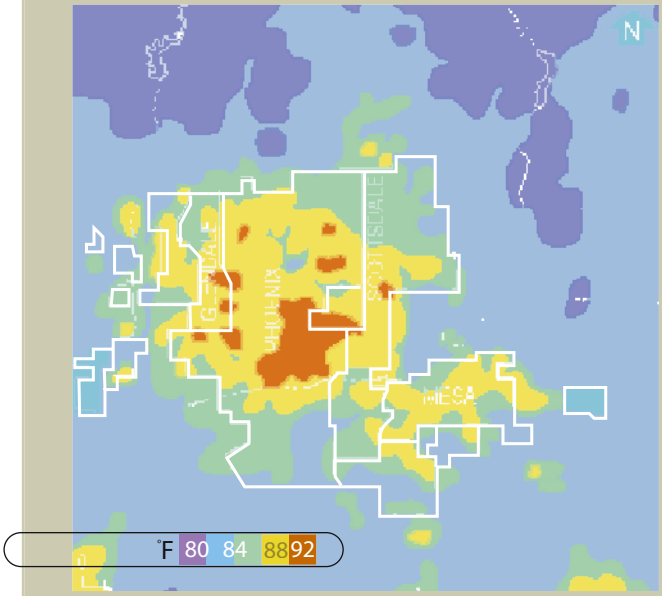


FIG 3

Nighttime (2 am) temperatures from several clear, calm periods in summer illustrating the urban heat island (after Balling and Brazel, 1989).

The Changing Climate

- Average temperatures are increasing.
- Nighttime temperatures are much hotter than 100 years ago.
- These increased nighttime temperatures have resulted in the urban heat island effect.
- Urban areas are increasingly warmer than the surrounding rural areas.
- Temperatures in rural areas are increasing, but not at the urban rate.
- Temperatures in Phoenix have increased more than comparably populated cities around the world.

Urban Heat Island

The resulting "urban heat island" typically occurs after sundown as large heat absorption by cement, asphalt and other elements of the built environment during the daytime is slowly released back to the atmosphere during the night (Fig. 3, references 4, 5, 6). High evening temperatures caused by urbanization account for most of the differences in the urban versus rural warming rates.

What is the Future of Heat in Central AZ?

The US Climate Assessment (2) conservatively projects that the Southwest will see a 5.4°F increase in mean annual temperatures by 2100. This increase is much higher than the 3.1°F increase experienced in the last 70 years. Urban heat increases are likely to be much higher in the coming decades than in the past.

The annual mean temperature for Central Arizona's rural areas may warm slightly more than 1°F by 2050 and 2.3°F by 2100. This scenario uses the same rates experienced in the 20th century and is conservative, given the expectations of a 5.4°F increase in the Southwest by 2100. The entire region (both urban and rural) may heat by 1.7°F by 2050 and 4.5°F by 2100 under the mid-range growth projection. Exactly where and how local temperatures would increase depends upon climate-system trends, urbanization rates, building materials, and landscaping.

Presently, the region's urban areas experience nighttime temperatures that are 12°F warmer than the rural areas. Even with moderate population growth, this temperature gap is expected to widen, with potential for a 15°F nighttime increase by 2030 in our urban area; 60 years from now, a 20°F increase; and by 2100, a 25°F increase (based on equation after [7] and population estimates from [8]).

Conclusions

Although temperatures are likely to increase in the future, the degree of this warming trend is uncertain, depending upon the vagaries of natural forces and human factors. At the local scale, it is undoubtedly clear that rapid urbanization is compounding the human impacts upon our arid ecosystem. If we are to turn back the clock on these warming trends, we will need to alter our building strategies, land-use patterns, landscape practices, and more.

CSRUR addresses one of the globe's greatest challenges: the human, political, economic, and environmental impacts of Earth's rapidly urbanizing environments. This consortium brings together academic, government, and community groups that use interdisciplinary perspectives to analyze patterns and dynamics of human-environment interactions across multiple scales of time, space, and social organization.

Editing
Nancy Jones, Lauren Kuby

Vignette Design
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Special thanks
Russel S. Vose, Chief
Climate Analysis Branch
National Climate Data Center

Map credits
Radha Kunda

Center for Environmental Studies

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References

1. Oke, T.R. 1997. Urban environments. In *The Surface Climates of Canada*. Eds. W.G. Bailey, T.R. Oke, and W.R. Rouse, McGill-Queen's University Press, Montreal. 303-327.

2. Sprigg, W.A., and T. Hinkley. 2000. *Preparing for a changing climate - The potential consequences of climate variability and change - Southwest.* Report for the Southwest Regional Assessment Group, US Global Change Research Program. Institute for the Study of Planet Earth. University of Arizona, 60 pp.

3. Hansen, J, R. Ruedy, J. Glascoe, and M. Sato. 1999. GISS analysis of surface temperature change. *J. Geophysical Research.* 104(D24-D30): 997-31,022.

4. Comrie, A.C. 2000. Mapping a wind-modified urban heart island in Tucson, Arizona (with comments on integrating research and undergraduate learning). *Bulletin of the American Meteorological Society.* 81(10): 2417-2431.

5. Balling, R.C., Jr., and S.W. Brazel. 1989. High-resolution nighttime temperature patterns in Phoenix, J. *Arizona-Nevada Academy of Science.* (23): 49-53.

6. Brazel, A.J., N. Selover, R. Vose, and G. Heisler. 2000. The tale of two climates - Baltimore and Phoenix urban LTER sites. *Climate Research. (*15): 123-135.

7. Oke, T. R. 1987. *Boundary Layer Climates.* Methuen, 435pp.

8. *Greater Phoenix Regional Atlas, A Preview of the Region's 50 Year Future.* 2003. Greater Phoenix 2100. Arizona State University, 70 pp.