Rural to Urban Temperature Gradients:
CAP-LTER in Context of the Recent Trends in the Mojave & Sonora Desert Region

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Abstract:

Phoenix is home to well-observed heat island effect (UHI) (Brazel, et al. 2000; Balling & Brazel 1987). To better understand Phoenix as a UHI, and to put its observed effects into context within the region, we analyzed the temperature records for urban and rurally located weather stations throughout the desert southwest. Each urban station was paired with one or more rural stations located between 25 and 100 kilometers from the urban locale. We studied eight pairs with the following urban cities: Phoenix, Las Vegas, Tucson, Yuma, St. George, Lake Havasu City, Blythe, and Bishop. For each pair, temperature records, trends, and rates of change were examined to determine the presence or lack of an urban heat island. Phoenix (as part of the CAP-LTER [Central Arizona Phoenix Long Term Ecological Research] study area) was then compared to the remaining 7 sites to determine differences and/or similarities in urban heating throughout the region.

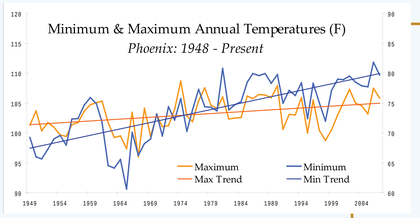
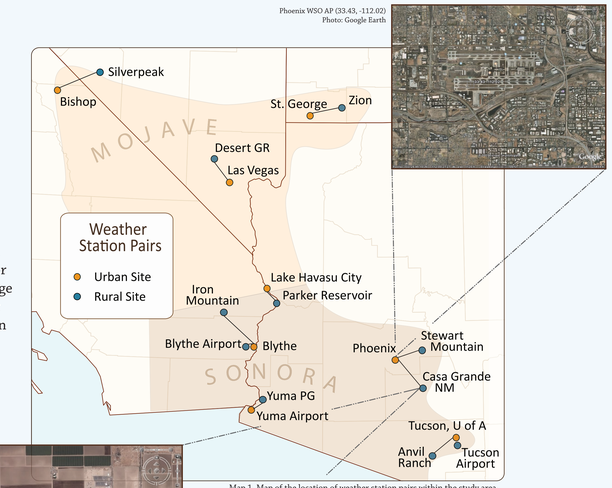


Figure 1*. Graph of the annual maximum and minimum temperatures,and there trends regressed against time (p< 0.05) in Phoenix, AZ at Sky Harbor International Airport.*

CAP-LTER (Phoenix):

This study centers on the largest city in the region, Phoenix. Earlier studies of the UHI in Phoenix indicate a significant decrease in the diurnal temperature range in urban Phoenix (in this study, measured to Sky Harbor Airport, Fig. 1) with minimum temperatures comprising most of the change (Brazel 2000). By observing the temperatures of nearby rural stations over the same time period, a increasing 'gradient' can be seen between the urban center and a "rural" site in an undeveloped setting. Distances in this study were established from Karl, et. al. (1984) at 25 – 100 km separation between rural and urban sites. Rural sites are defined as having less than 2000 people and little asphalt/concrete development. Population is used as a general measure of urbanity (Karl, et. al 1988).



Map 1. Map of the location of weather station pairs within the study area. Desert interpretation based on Weiss & Overpeck (2005) and USGS study of desert ecosystems, including the Mojave at geology.usgs.gov.

As seen in Fig. 1, minimum temperatures (axis on right) have increased an average of over 10 degrees Fahrenheit since 1950 In the last 10 years, as development around the airport slows, the temperature can be seen stabalizing.

In Fig. 2, the increase in not only urban but also rural minimum temperatures is seen, a clear illustration of regional drivers affecting the climate in addition to urbanization.

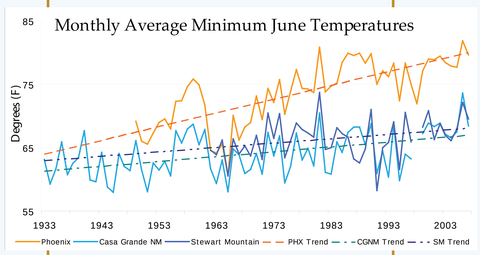


Figure 2*. Graph of the annual maximum and minimum temperatures, and there trends in Phoenix, AZ at Sky Harbor International Airport.*

Results & Discussion:

All stations in the study have at least 90% of data present for the analysis period 1948 – 2007. Minimum temperatures in June were chosen to observe the greatest differences in urban – rural temperatures, clarity of their record and to avoid most of the damping affects from the Mexican monsoon in later summer months (Brazel 2000). An analysis of the June temperatures at all 19 stations indicated that maximum temperatures varied only a small amount over 59 years with minimal differences between urban and rural stations. The differences between minimum temperatures over this same period indicated an increasing gradient between most urban and rural sites as minimum temperatures increased more quickly in the larger urban sites with rates from ~ 1.5 - 2° F per decade. (Fig. 3). Minimum temperatures also increased with a significant trend in 5 of 11 rural stations (Fig. 4) though only at ~ 0.5° F per decade.

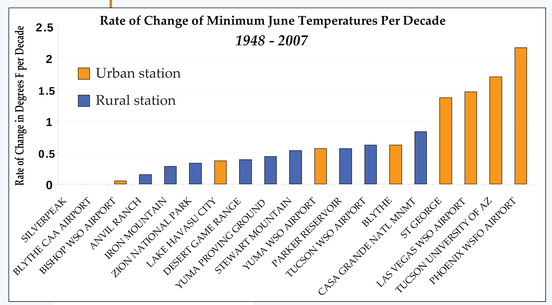


Figure 3*. Graph of the rate of change (primarily increasing) temperatures by decate in degrees Fahrenheit per 10 years.*

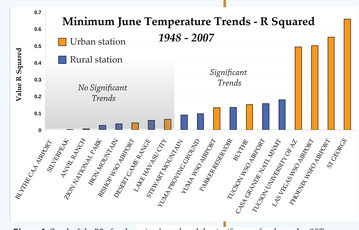


Figure 4*. Graph of the R2 of each stations' trend, and the significance of each trend at 95% .*

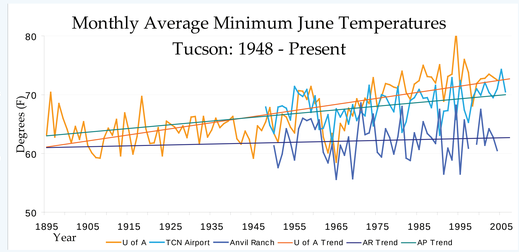
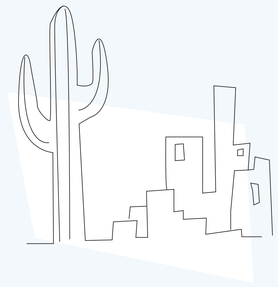


Figure 5*. Graph of the minimum June temperatures in and around Tucson regressed against time, 1895 to the present. The light aquamarine line of the airport indicates an 'edge' station. It is outside the main urban center and is a transition between urban and rural, but shows interesting growth as development and a larger population begin to encroach the station.*

Station Pairs	2006 Population	Avg. Annual Precipitation	Rate of Change Rank	Rate of Change (°F/decade)	R^2	Significant
PHOENIX WSFO AIRPORT	1,777,539	6.29	Urban	2.16	0.549	Yes
CASA GRANDE NATL MNMT	< 2,000	7.6	Rural	0.83	0.178	Yes
STEWART MOUNTAIN	< 2,000	10.48	Rural	0.53	0.088	Yes
LAS VEGAS WSO AIRPORT	1,512,986	4.48	Urban	1.46	0.499	Yes
DESERT GAME RANGE	< 2,000	5.12	Rural	0.39	0.057	No
TUCSON UNIVERSITY OF AZ	518,956	11.14	Urban	1.7	0.492	Yes
TUCSON WSO AIRPORT	< 2,000	9.93	Edge	0.62	0.155	Yes
ANVIL RANCH	< 2,000	17.33	Rural	0.15	0.006	No
YUMA WSO AIRPORT	96,000	2.96	Urban	0.56	0.131	Yes
YUMA PROVING GROUND	< 2,000	3.28	Rural	0.44	0.095	Yes
ST GEORGE	67,614	7.21	Urban	1.37	0.657	Yes
ZION NATIONAL PARK	< 2,000	14.47	Rural	0.33	0.026	No
LAKE HAVASU CITY	56,355	2.84	Urban	0.37	0.062	No
PARKER RESERVOIR	< 2,000	5.7	Rural	0.56	0.134	Yes
BLYTHE	22,427	3.26	Urban	0.62	0.151	Yes
BLYTHE CAA AIRPORT	< 2,000	3.6	Edge	0	0	No
IRON MOUNTAIN	< 2,000	3.57	Rural	0.28	0.035	No
BISHOP WSO AIRPORT	3,566	4.51	Urban	0.05	0.041	No
SILVERPEAK	< 2,000	39.41	Rural	-0.06	0.002	No

Figure 5. Statistics for all urban-rural pairs. Sites on gray lines indicate the urban station, followed by corresponding rural station(s). Data collected from the WRCC and US Census Bureau.



Results & Discussion continued:

Cities with higher populations, like Phoenix, Tucson & Las Vegas, had the highest decadal rates of increase. Phoenix, with a population in the metropolitan area of over 4 million people, had the highest rate at 2.16° F per decade, 62% and 76% faster than its' rural pairs, Casa Grande NM & Stewart Mountain, only 66 km & 48 km away, respectively. While it has the greatest increase in temperature in the last 59 years, Phoenix does not appear to be an anomaly as indicated by the smaller but similar temperature increases of other cities within the region (and the US, Karl, *et. al* 1984). The warming trend in urban Phoenix (at the airport) in fact is slowing down as buildout reaches maximum in the area, and it is likely that faster temperature increases will be observed in the near future in areas of rapid urbanization like St. George, Yuma & Tucson.

Urbanization can not be the only driver increasing minimum temperatures in the Southwest, because of temperature increases with significant trends observed at 5 of 11 rural stations (Weiss & Overpeck 2005). Additional drivers at a regional level, or even global level, must then be considered.

An emphasis on the impact of urbanization on local climate is observed in Fig. 5, where the ochre line indicates Tucson minimum temperatures noticeably increasing after the early 1950's, when the population jumped from 120,000 to 220,000 in 10 years, and brought with it major development that has been growing ever since.

Selected Sources:

Brazel AJ, Selover N, Vose R, Heisler G (2000) The tale of two climates – Baltimore and Phoenix urban LTER sites. Clim Res 15, 123 – 125.

Cayay DR, Douglas AV (1984) Urban Influences on Surface Temperatures in the Southwestern United States during Recent Decades. Jor of Clim & App Met vol. 23, 1520 – 1530.

Karl TR, Kukla G, Gavin J (1984) Decreasing Diurnal Temperature Range in the United States and Canada from 1941 through 1980. Journal of Clim & App Meteorology 23, no. 11

Karl TR, Diaz HF, Kukla G (1988) Urbanization: Its Detection and Effect in the United States Climate Record. Journal of Climate, vol. 1, 1099 – 1123.

Weiss JL, Overpeck JT (2005) Is the Sonoran Desert losing its cool? Global Change Biology 11, 1 – 13.

All temperature data came from the National Climatic Data Center through the Western Regional Climate Center (WRCC) in Reno, NV USA.

Population information used to estimate urbanity obtained from the United States Census Bureau at www.census.gov.