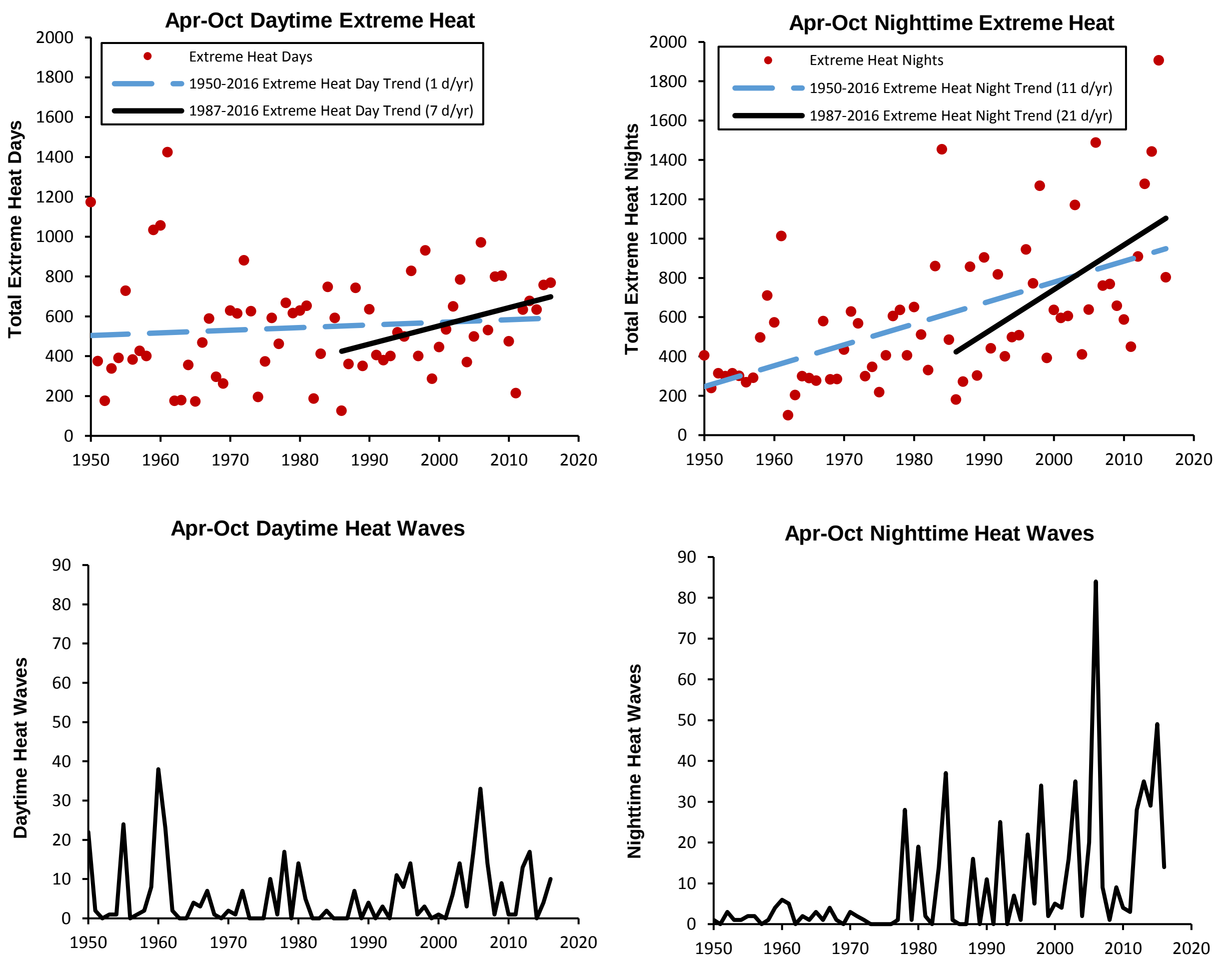
EXTREME HEAT EVENTS

Extreme heat days and nights have become more frequent since 1950. Heat waves have been variable each year, but nighttime heat waves have shown a marked increase since the mid-1970s.

Figure 1. Statewide trends in extreme heat and heat waves



Source: WRCC, 2017

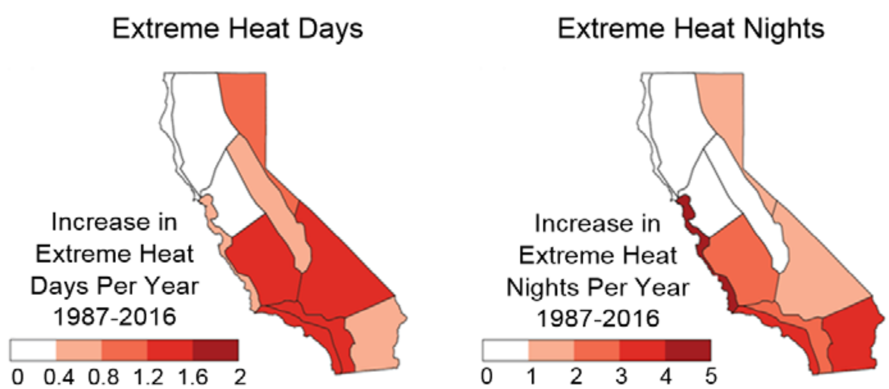
This analysis uses CalAdapt's definitions of "extreme heat" or "heat wave" (Cal-Adapt, 2017). For a given location, an extreme heat day occurs during the period from April through October when the maximum temperature exceeds the 98th percentile (or is among the highest two percent) of historical daily maximum temperatures during the reference period of 1961 to 1990. Similarly, an extreme heat night occurs when the minimum temperature exceeds the 98th percentile of the historical daily minimum temperatures between 1961 and 1990 at that location. The total number of extreme heat days (or extreme heat nights) is calculated individually for each of the 146 weather stations in California, and then summed across weather stations to derive the statewide value for each year. (Hence, the annual value can exceed 365 days.) Five or more consecutive extreme heat days or nights at a given location are defined as a heat wave.

What does the indicator show?

The two top graphs in Figure 1 show statewide trends in the number of extreme heat days and nights from April through October. The dashed blue lines show the linear trend for the period from 1950 to 2016. The solid line shows the trend for the last 30 years (1987-2016). Since 1950, the number of extreme heat days has increased slightly statewide, at a rate of about one day per year. In contrast, the rate of increase in the occurrence of extreme heat nights for the same period is over 10 times higher, at 11 days per year. For both extreme heat days and nights, the rate of change has been greater over the most recent 30 years. From 1987 to 2016, extreme heat days and nights increased by 7 and 21 days per year, respectively.

Statewide heat waves are shown in the two bottom graphs in Figure 1. The number of daytime heat waves shows considerable year-to-year variability, without a clear trend. Nighttime heat waves, which occurred infrequently until the mid-1970s, have increased in frequency over the past 40 years.

Figure 2. Regional trends in extreme heat days and nights



Source: WRCC, 2017

Regional trends in the number of extreme heat days and nights over the 30-year period from 1987 to 2016 are illustrated in the maps in Figure 2. For most regions, the rate of increase in the number of extreme heat nights was twice that of the rate of increase in extreme heat days. The greatest increase in the total number of daytime and nighttime extreme heat events occurred in Southern California. Nighttime heat increased the most in the Central Coast region.

Why is this indicator important?

Periods of extremely high temperatures have significant public health, ecological, and economic impacts. Among these are heat-related illnesses and deaths, livestock deaths, increased water demand, increased air pollution, and strains on the power supply. Heat causes the most weather-related deaths in the United States (NOAA, 2017).

Heat events are projected to become more frequent and last longer (USGCRP, 2016). Taking action to mitigate the impacts of extreme heat is critical, particularly given the largely preventable adverse effects on public health. Anticipating the effects of unusually high temperatures on wildfires, agriculture, and energy demand will also help inform planning and resource allocation.

A recent study found a changing pattern of heat waves in California. Since the 1980s, heat waves have become more humid, in part due to ocean warming (Gershunov et al., 2009). Humidity prevents surfaces from cooling down at night, leading to higher nighttime temperatures. Warmer nighttime temperatures have a significant biological impact. People, animals, and plants that are adapted to California's traditionally dry daytime heat and nighttime cooling are unable to recover from extreme heat, especially when humidity is high at night. The increase in nighttime heat waves presents an additional risk factor for vulnerable populations.

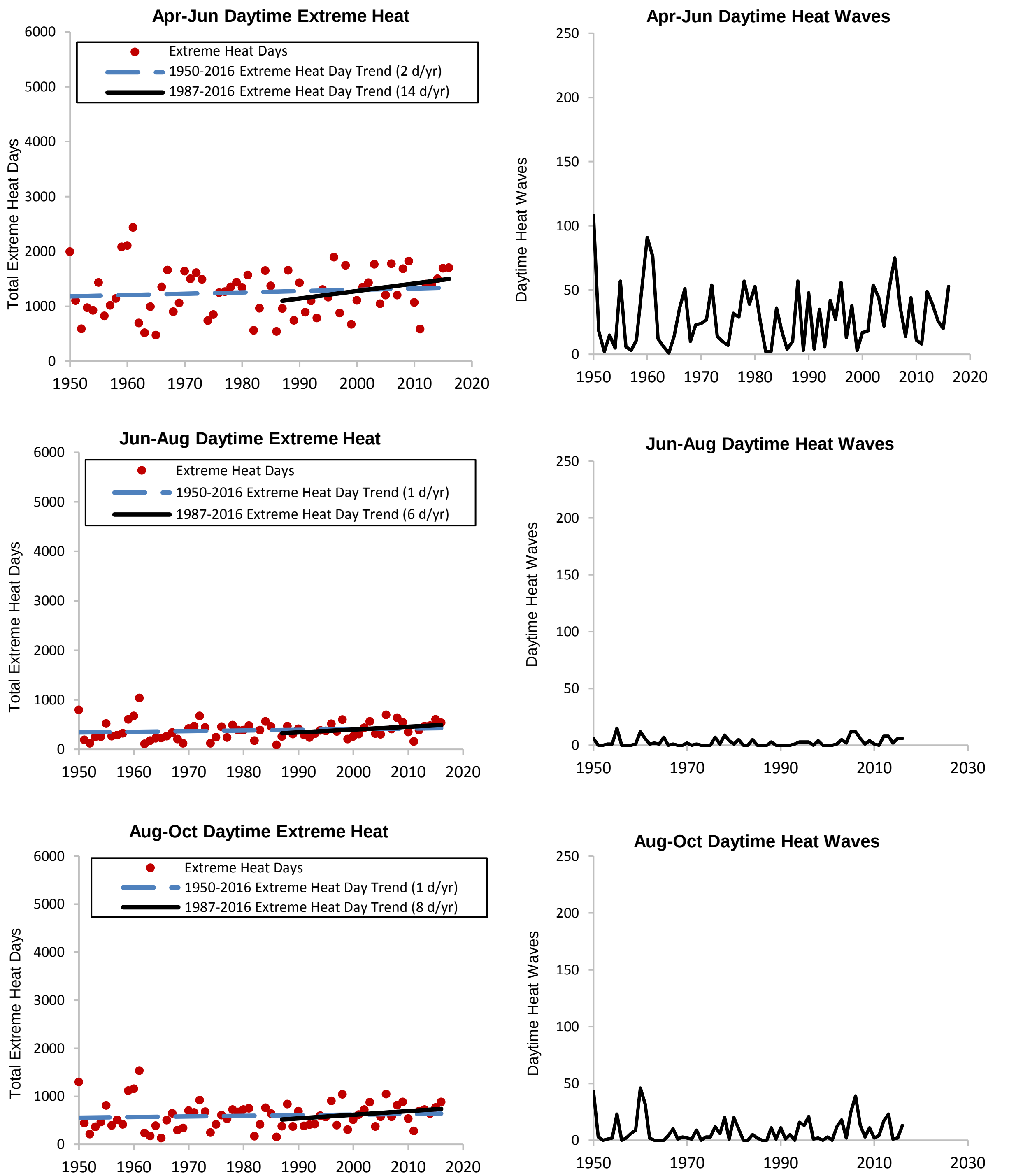
What factors influence the indicators?

Air temperature varies according to the time of day, the season of the year, and geographic location. Temperatures in urban areas can also be affected by the urban heat island effect due to land surface modification and other human activities. However, rural locations see comparable increases in extreme heat days and nights and all regions of California are affected by regional climate change. This suggests that urbanization and land use does not explain the changes observed in California. The asymmetric increase in nighttime California heat wave activity and extreme heat nights compared to daytime heat extremes is consistent with impacts expected under global climate change.

As noted above, heat waves are becoming more humid. Although concern over greenhouse gas emissions tends to focus on carbon dioxide, water vapor is the most abundant greenhouse gas in the atmosphere, and the largest contributor to warming (Myhre et al, 2013). Human activities have little direct influence on the amount of atmospheric water vapor (Forster et al., 2007). As air temperatures rise due to anthropogenic emissions of other greenhouse gases, the water vapor content of the atmosphere increases. Water vapor absorbs outgoing longwave terrestrial radiation and re-radiates energy back to the surface, thus impeding radiative cooling. Therefore, there is less nighttime respite from heat when specific humidity is high. Moreover, humid heat waves tend to last longer due to the stronger coupling of maximum and minimum temperatures during humid heat waves (Gershunov et al., 2009).

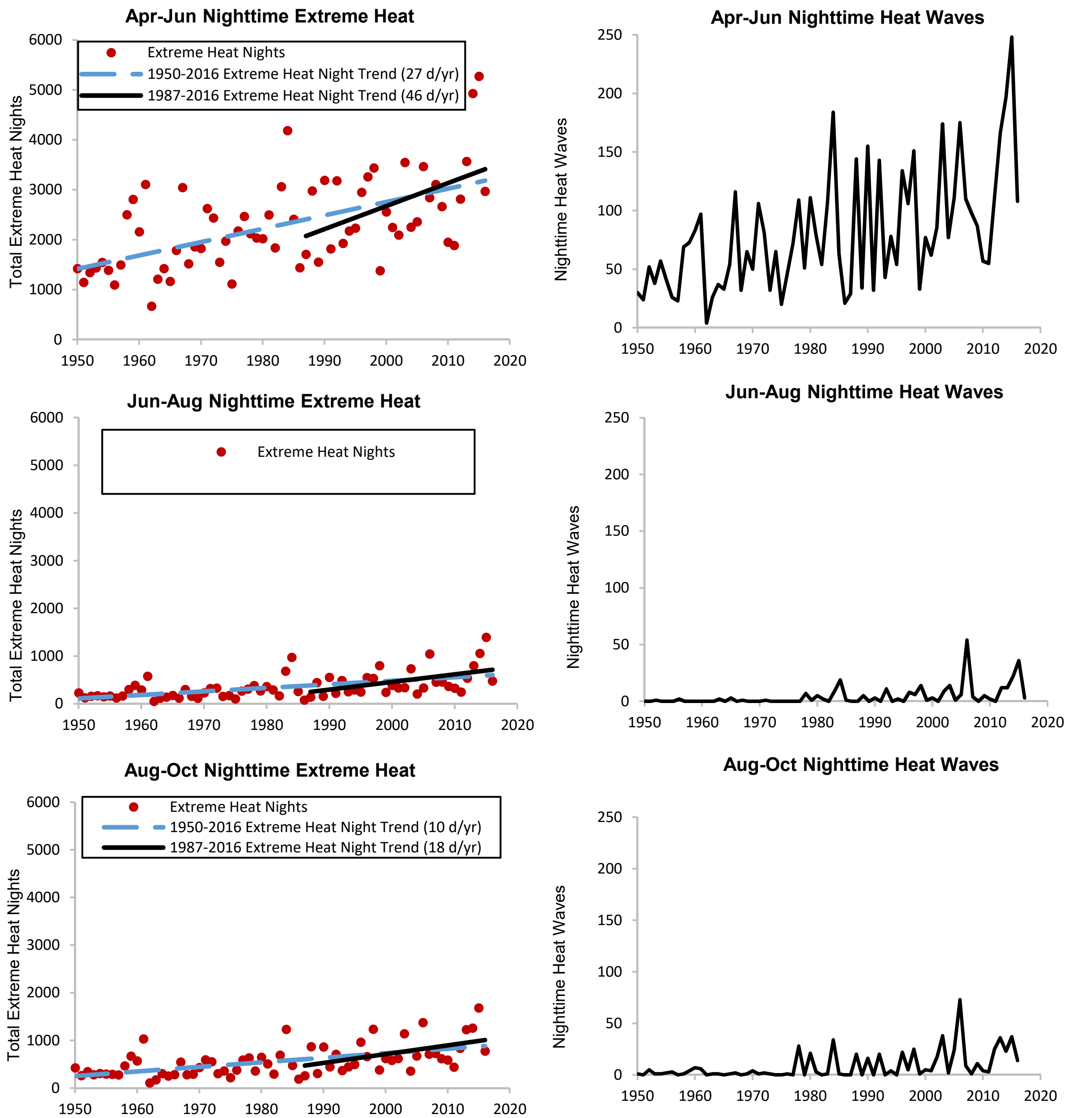
The influence of the time of year (or season) is evident in the extreme heat trends presented in the graphs (Figures 3 and 4) and Table 1. The period from April to June showed the greatest increase in the number of extreme heat days and nights (see Figure 3, 4 and 5). This suggests that these months are warming at a faster rate than other months of the year. Further, the increase in extreme heat occurred at a faster rate during the past 30 years (1987-2016) than the past 67 years (1950-2016), suggesting that warming has increased during the recent decades.

Figure 3. Statewide trends in daytime heat waves and extreme heat days



Source: WRCC, 2017

Figure 4. Statewide trends in nighttime heat waves and extreme heat nights

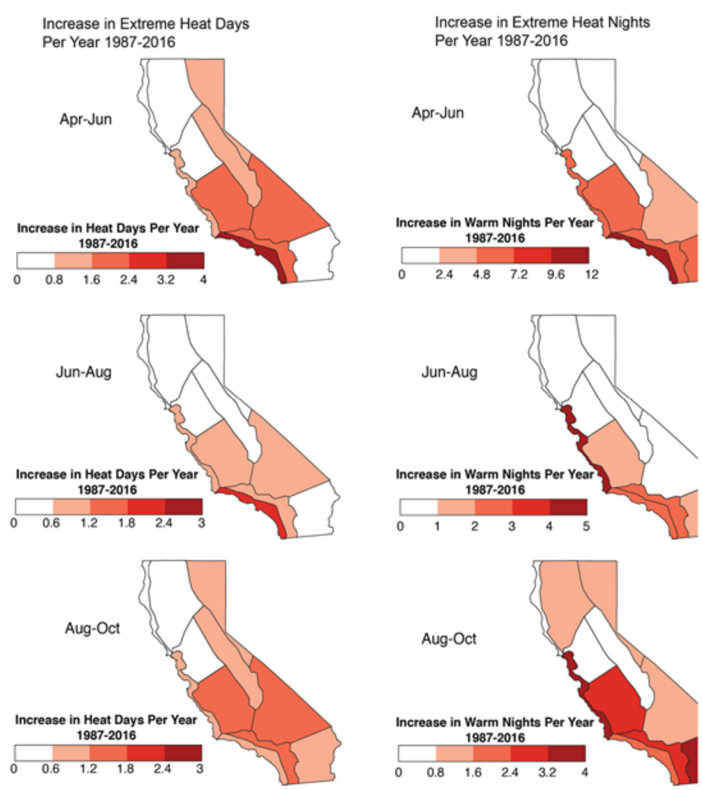


Source: WRCC, 2017

Table 1. Summary of extreme heat trends Rate of increase in the number of extreme heat days or nights per year for different periods during the warm months at 146 CA weather stations				
Period	Daytime extreme heat trend (days/year)		Nighttime extreme heat trend (days/year)	
	1950-2016	1987-2016	1950-2016	1987-2016
April-October	1	7	11	21
April-June	2	14	27	46
June-August	1	6	7	16
August-October	1	8	10	18

Nighttime trends are at least two times greater than daytime trends in extreme heat. The greatest increases are found in Southern California. The South Coast has experienced the greatest increases in both daytime and nighttime heat extremes during late spring (April-June). Note that the spring season nighttime extreme heat increases are on the order of two to four times greater than other seasons. Summer (June-August) increases in nighttime heat extremes are most pronounced along the Central Coast followed by the South Coast and South Interior regions. Early fall (August-October) increases in nighttime extreme heat is more widespread throughout southern California with the Central Coast and Mojave Desert regions experiencing the greatest increases, followed by the South Interior and San Joaquin Valley regions.

Figure 5. Regional trends in extreme heat days and nights for different months



See Figure 6 for more info about the regions as defined by WRCC.

Source: WRCC, 2017

Technical Considerations

Data Characteristics

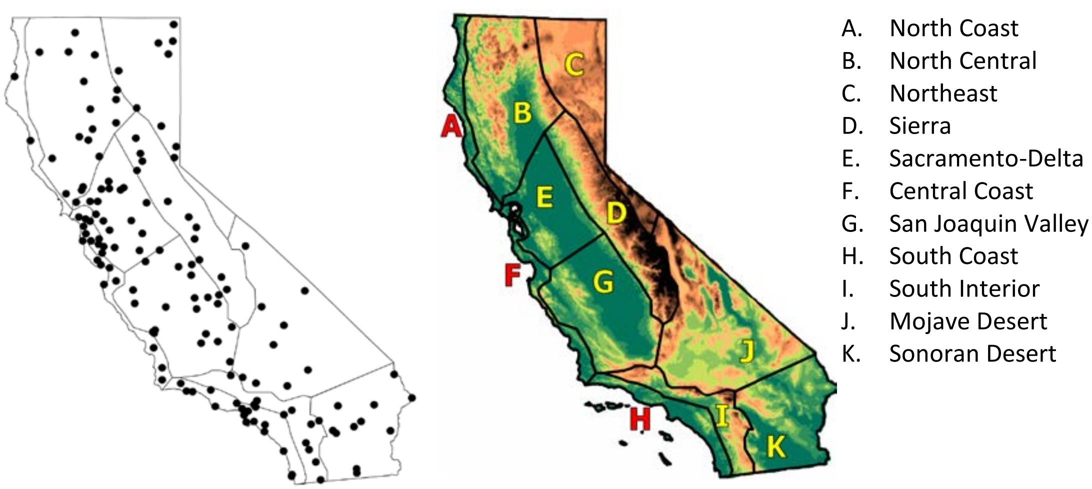
This indicator uses station data from the National Weather Service (NWS) cooperative observation network acquired from the Applied Climate Information System (via https://wrcc.dri.edu/csc/scenic/). The vast majority of the observers are trained volunteers, and the network also includes the NWS principal climatological stations. The observing equipment used at all of the stations, whether at volunteer sites or federal installations, are calibrated and maintained by NWS field representatives, Cooperative Program Managers, and Hydro-Meteorological Technicians. Only stations with at least 90 percent complete records were used in the analysis for a total of 146 stations. These stations are shown in Figure 6.

Regional trends are presented according the California's climate regions, as defined by the Western Regional Climate Center (see Figure 6 for region boundaries).

Figure 6. California's Climate Regions

A. Location of monitors used in the analysis

B. Boundaries of the eleven climate regions



Source: WRCC, 2017

Strengths and Limitations of the Data

The station data have received a high measure of quality control through computer and manual edits, and are subjected to internal consistency checks, compared against climatological limits, checked serially, and evaluated against surrounding stations. Station coverage is not uniformly distributed geographically and coverage can be quite sparse in mountainous areas such as the Sierra Nevada and Klamath Mountain regions, therefore there is a bias towards populated areas and lower elevations. Recorded temperatures in urban areas can also be affected by the urban heat island effect due to land surface modification and other human activities. The majority of California's population resides in urban areas, implying that the heat impacts from urban-induced warming on health are non-negligible. The statewide and climate region-based estimates should be interpreted as maximum estimates of changes in heat extremes due to the contribution of urban warming. Quantification of the specific magnitudes of station-based urban heat contributions and its influence on regional and statewide trends in heat extremes are beyond the scope of the present study but are the subject of ongoing research. The stations used in this analysis have undergone a homogenization technique applied by the National Center for Environmental Information to reduce urban heat-related biases (Hausfather et al., 2013).

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