CNAP

California-Nevada Climate Applications Program

— A NOAA RISA —

CALIFORNIA HEAT WAVES

JULY 2015

A New Type of Heat Wave

Heat waves in California and Nevada are traditionally dry and tolerable. The temperature warms up during the day and normally cools off greatly at night allowing plants and animals to recuperate and get ready for another day of scorching heat. However, this traditional type of heat wave, natural for our semi-arid Mediterranean climate, has increasingly tended to be more humid and more often accentuated at night since the 1980s (Figure 1). Humidity, that is water vapor in the air, absorbs infrared radiation emitted by the earth's surface hampering the ability of the surface to cool off. In short, humidity leads to higher night time temperatures. Humidity makes the difference between cool desert and sultry bayou nights. Increased humidity also makes extreme heat much more difficult for humans as it reduces our bodies' ability to cool off by evaporating water – sweating. Humid heat waves start off with higher temperatures in the morning and tend to reach higher temperatures during the day, lasting longer than their dry counterparts. The observed trend towards more humid, more intense and longer-lasting heat waves in California[1] has so far culminated in the July 2006 heat wave, an event of unprecedented impact on human health in the state (see box). Californian plants and animals are not acclimated to persistent humid heat, making them more likely to succumb.

Great heat waves are rare. Heat waves impacting California are caused by a specific weather pattern characterized by high atmospheric pressure in the Great Plains and low pressure off California's coast which together draw warm moist air from the south. Coastal waters west of Baja California are an important source for this humid air; these waters have become unusually warm in recent decades as part of a global warming pattern. This ocean warming has been partially responsible for the fact that the rare weather patterns associated with great California heat waves have tended to bring warmer, more humid air.

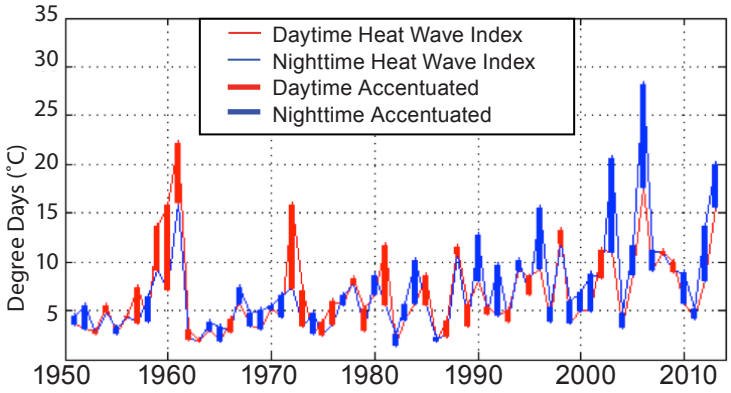

Figure 1. The graph shows heat wave activity since 1950. The red line is based on maximum temperatures and the blue line is based on minimum temperatures. Degree days are the sum of degrees that exceed the 95th percentile of daily temperatures during June, July and August. The bold parts of the graph indicate when the heat wave activity is accentuated in minimum or nighttime temperatures (blue) or during the day (red), predominantly humid or dry days respectively.

In California, occasional great heat waves punctuate an increasing trend in heat wave activity observed since around 1980 (Figure 1). These heat waves have changed from the traditional dry daytime-accentuated heat waves in the summers of 1959, '60, '61, '72, '81 to the humid nighttime-accentuated heat waves of 1990, '96, 2003, and '06. The trend towards nighttime-accentuated humid heat waves has continued in summers 2012 and '13, although we have not seen a heat wave of 2006 magnitude since.

2006 HEAT WAVE &HEALTH

The 2006 California heat wave killed more than 600 people[2], 147 directly by hyperthermia[3], and resulted in over 1,200 hospitalizations and 16,000 emergency-department visits[4,5]. Most of the deaths from hyperthermia occurred in inland counties, which were the hottest, while the highest morbidity (illness) was along the highly vulnerable coast[5] (discussed on back). The 2006 heat wave also had grave effects on ranching and agriculture, ecosystems and the energy sector. In severe drought years, like this one, a great heat wave could additionally exert significant stress on water resources.

1. Gershunov et al., *Journal of Climate*, 2009.
2. Ostro et al., *Environmental Resarch*, 2009.
3. Trent, R. B., 2007: Review of July 2006 heat wave related fatalities in California. CA Dept. of Health Services Report.
4. Knowlton et al., *Environ. Health Perspectives*, 2009.
5. Guirguis et al., *Journal of Applied Meteorology and Climatology*, 2014.
6. Cayan et al., California Climate Change Center CEC-500-2009-014-D, 2009.
7. Gershunov and Guirguis, *Geophysical Research Letters*, 2012.

CONTACTS: **Alexander Gershunov – sasha@ucsd.edu**
Kristen Guirguis - kguirguis@ucsd.edu

Southwest Climate Science Center

NATIONAL WEATHER SERVICE

CW3E

Climate Education Partners SAN DIEGO REGION

Heat Waves, Climate Change & Coast

In future climate projections, heat wave activity increases throughout California as the climate warms. The number of heat waves, relative to present day thresholds, would increase 4-8 fold in their daytime and 5-10 fold in their nighttime temperature expressions by end of century (Figure 2), depending on how much greenhouse gas is emitted into the atmosphere. Heat waves will not only occur more frequently, but they will be more intense and longer-lasting[6]. Climate change will also bring a disproportionate increase in humid heat waves in California expressed more strongly in minimum or nighttime temperatures. When using temperature thresholds that evolve along with the warming climate, heat waves are expected to become more extreme along the coast relative to other parts of the state (Figure 3)[7]. This is supported by observations along the coast where heat wave activity has already outpaced summertime warming and resulted in disproportionate health impacts of recent heat waves [5].

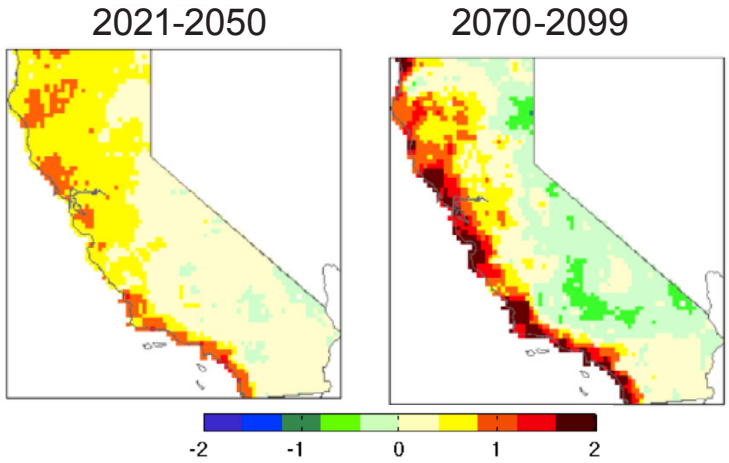

Figure 3. The maps above show the projected increase in heat wave temperatures relative to seasonal warming at mid century and end of the century. This means that along the coasts, by the end of the century, the differences between heat wave temperatures and median summer temperatures will increase by up to 2˚C. By contrast, heat waves inland are expected to become relatively less hot compared to much warmer seasonal temperatures.

Most Californians reside in coastal counties where they are least acclimated to extreme heat and many lack air conditioning. Marine influence, in particular via marine layer clouds, typically cools the coast during the peak of summer. During some heat waves (e.g. July 2006), marine layer clouds are absent, leading to the strongest temperature spikes and the strongest health impacts along the coast [5].

The summer of 2014 was the warmest summer in California's history, though no major heat wave occurred. Continued warming, particularly of the coastal ocean near Baja, is priming the region for a major humid event of 2006 magnitude raising the odds for record-breaking heat, especially if the requisite weather pattern occurs at the peak of summer in late July – early August. The weather pattern responsible for large-scale California heat waves is challenging to predict at lead times longer than about a week leaving uncertainty as to what might occur this summer.

FREQUENCY OF HEAT WAVES PROJECTED IN THE FUTURE

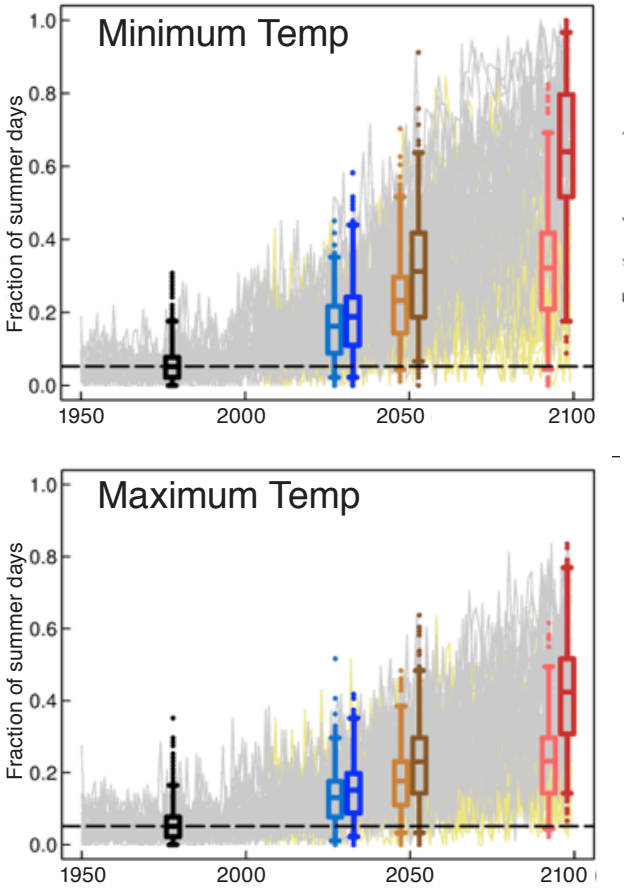

Figure 2. The two figures show the projected increase in the frequency of heat waves in Sacramento during June, July and August using minimum (top) and maximum (bottom) temperatures. The color symbols highlight the projected changes at 2030, 2050 and 2100. The lighter colors represent greenhouse gas emissions that level off by the end of the century (RCP 4.5) whereas the darker colors show the projections under greenhouse gas emissions that accelerate throughout the century (RCP 8.5), the business as usual scenario.

- **CNAP**, the California Nevada Applications Program, is a NOAA RISA team conducting applied climate research that is inspired by and useful to decision makers in the region. ***cnap.ucsd.edu***
- **NWS**, the National Weather Service, provides real-time forecasts and notification of heat waves and collects observation data used by decision makers and researchers. ***www.weather.gov***
- **Climate Education Partners**, an NSF-CCEP-II funded alliance providing locally relevant climate science so regional leaders can make informed decisions about San Diego's future. ***www.sandiego.edu/climate***
- The **SWCSC**, Southwest Climate Science Center, sponsored by the US Depart. of the Interior, provides scientific information, tools, and techniques to anticipate, monitor, and adapt to climate change. ***www.swcsc.arizona.edu***
- **CW3E**, Center for Western Weather and Water Extremes, provides science to support effective policy on extreme weather and water events. ***cw3e.ucsd.edu***