Analysis of Extreme Heat Events and Illness in San Francisco, CA

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Overview

Data on temperature, hospitalizations and emergency department (ED) visits in San Francisco were acquired and analyzed to understand the relationship between extreme heat events and illness. Hospitalization and ED visit data include total visits and visits identified as heat-related. The analysis informs San Francisco's extreme heat emergency preparedness efforts.

Extreme heat events cause heat-related illnesses (e.g. heat stroke, heat exhaustion, dehydration), and exacerbate many chronic illnesses, such as heart disease and asthma. During extreme heat events there could be an increase in patients presenting with a variety of illnesses associated with the heat event. Since extreme heat events exacerbate many chronic illnesses that may not be recorded as a heat-related illness, total hospitalizations and ED visits were analyzed in addition to heat-related hospitalizations and ED visits. This analysis helps inform the temperature at which the city declares a heat emergency.

Extreme heat events may have health impacts for days after extreme heat events occur, even if temperature subsides, known as the "bathtub effect." To assess this effect, hospitalization and ED visit data following the most extreme heat events were analyzed to understand if hospitalizations and ED visit increases persist beyond the extreme heat event, indicating that the bathtub effect is occurring. This analysis informs the length of extreme heat emergency efforts.

Methods

To understand recent temperature trends in San Francisco, temperature data from two San Francisco weather stations were downloaded from the National Climatic Data Center (ncdc.noaa.gov), Global Historical Climatology Network (GHCN)-Daily database. Daily temperature data were acquired for Oceanside and Downtown San Francisco stations from January 1, 2000 to December 31, 2012, with the exception of a few dates where temperature data at the Oceanside location were randomly missing over the twelve-year period. The 95th and 98th percentiles, and the number of days that exceeded 25 degrees Celsius was reported by month and year from 2002-2012 were calculated and reported separately for each station.

Daily heat-related and total hospitalization data were acquired from January 1, 2000 to December 31, 2010, and daily heat-related and total emergency department (ED) visit data were acquired from January 1, 2005 to December 31, 2010. These data are aggregated at the city level, unlike the temperature data, which includes two geographic locations. Downtown and Oceanside data are graphed separately as averaging the temperatures would not necessarily provide an accurate estimate of the citywide temperature. Additionally, since temperatures are regularly monitored at these two locations, this study's analysis of the relationship between illness and temperature at two locations directly informs the City's future heat preparedness efforts.

To further understand the relationship between heat and illness in San Francisco, total and heat-related hospitalizations/ED visit data were compared by degree Celsius. The number of respective illnesses were averaged by degree and graphed. When fewer than 20 days throughout the 10-year period were recorded for a specific degree Celsius (e.g., extreme highs and lows, like 10 or 35 degrees Celsius), hospitalizations, ED visits and temperature data of multiple degrees were merged and averaged such that the data point represented at least 20 values, and the average temperature of those values.

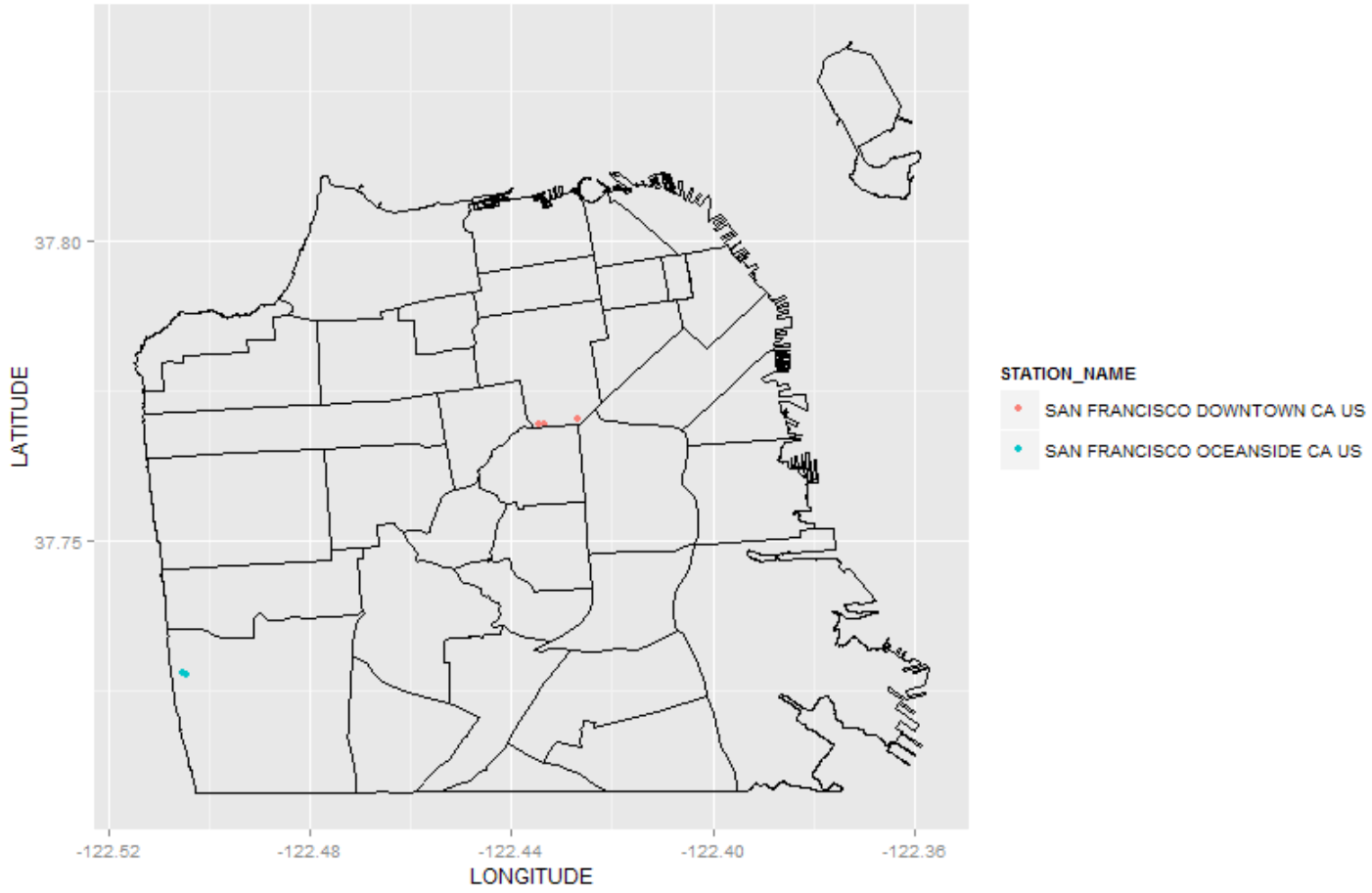
The Oceanside and Downtown temperature data and the resulting hospitalizations/ED visits are displayed separately in order to analyze potentially different heat thresholds across the city. This is intended to answer the questions, at what temperature in Downtown, San Francisco should a heat emergency be declared? At what temperature in Oceanside, San Francisco should a heat emergency be declared? Polynomial trend lines were used to better visualize the impact of temperature on illness.

To assess the bathtub effect, the number of total hospitalizations and ED visits during hottest days over the 10-year (hospitalizations) and 5-year (ED visits) study period were analyzed. The days following the extreme heat events were graphed to understand if a bathtub effect was observed. In order to better visualize the impact of total hospitalizations and ED visits, heat-related hospitalizations and ED visits are analyzed separately.

Analysis

Analysis by Temperature

Figure 1: San Francisco Weather Stations



To identify temperature patterns and how they differ across the city, maximum and minimum daily temperature data were accessed from two weather stations. Figure 1 shows the location of the Oceanside and Downtown weather stations. The Oceanside Station was moved once (2011-04-25) and the Downtown Station was moved twice (2003-02-12, 2007-01-26). Distances were short and assumed not to affect temperature readings.

Analysis

Figure 2: Maximum Daily Temperature (2000 – 2012)

Table 1: Maximum Temperature at the 95th and 98th Percentile (Degrees Celsius)

Station Name	95th Percentile	98th Percentile
Downtown, San Francisco	25.6	29.4
Oceanside, San Francisco	21.1	25.6
Combined	24.4	27.8

Table 1 shows the maximum temperature at the 95th and 98th percentile for each station and combined, and Figure 2 shows maximum daily temperatures for each weather station from 2000 through 2012. The maximum daily temperatures in Oceanside were generally cooler than those in Downtown.

Analysis

Figure 3: Extreme Heat Days by Month (2002 to 2012)

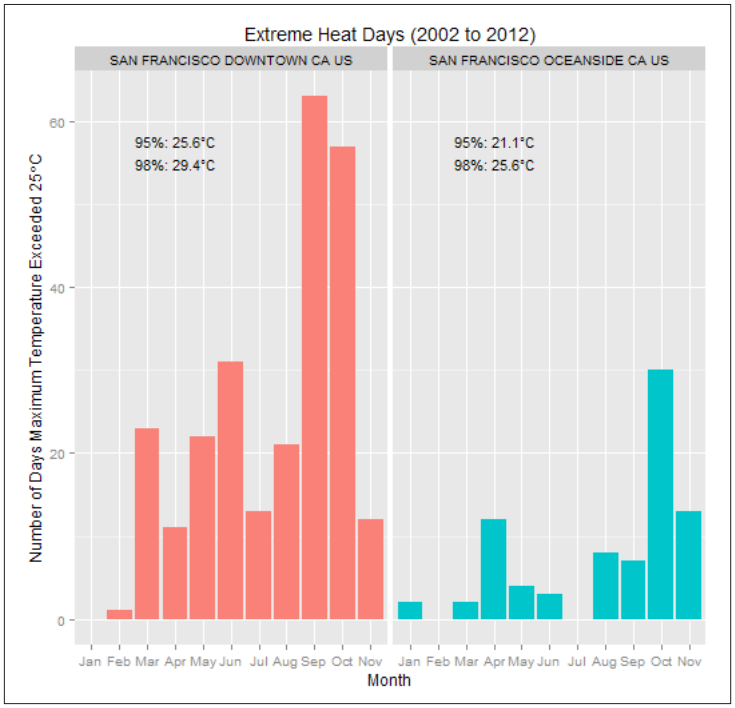


Figure 3 shows the number of extreme heat days in each month over a ten-year period, defined by the number of days where the maximum temperature exceeded 25 degrees Celsius. Downtown and Oceanside are displayed separately, demonstrating that Downtown experiences a greater number of extreme heat days than Oceanside. Extreme heat events most commonly occur in September and October, however, extreme heat events historically occur with some frequency in the spring and summer months, with the exception of July, when extreme heat events are less common.

Figure 4: Extreme Heat Days by Year (2001 – 2012)

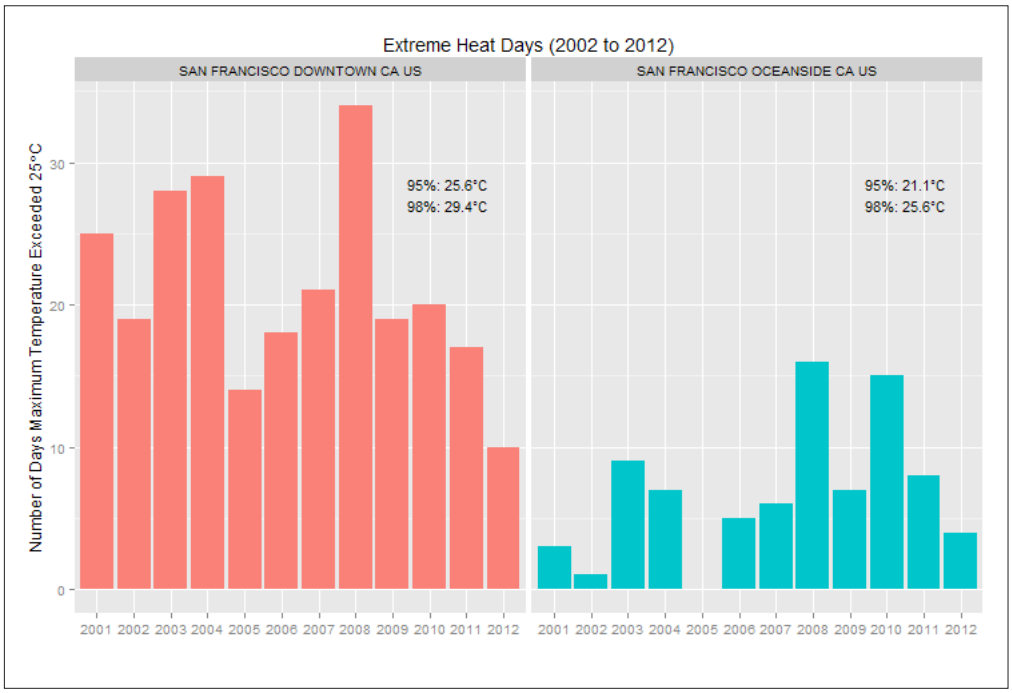


Figure 4 shows the number of extreme heat days by year. The greatest number of extreme heat days in both Downtown and Oceanside occurred in 2008, however extreme heat days occur every year in Downtown San Francisco.

Analysis of Extreme Heat Events and Illness

Overall, hospitalizations and ED visits increase as temperature increases, demonstrating a correlation between heat and illness (see figures 5-8 below). Downtown and Oceanside data are presented separately since averaging the temperatures would not necessarily provide an accurate estimate of the citywide temperature. Since Oceanside temperatures are generally lower than Downtown temperatures, and the number of people hospitalized or visiting the emergency department is an aggregate for the city, the degree at which illnesses increase is generally lower in Oceanside than that of Downtown.

The average temperature (based on Downtown temperatures) and the average number of hospitalizations and ED visits over the ten- and five-year periods, respectively, were plotted (labeled "Average") on each figure in order to facilitate analysis.

Figure 5: Total Hospitalizations by Temperature

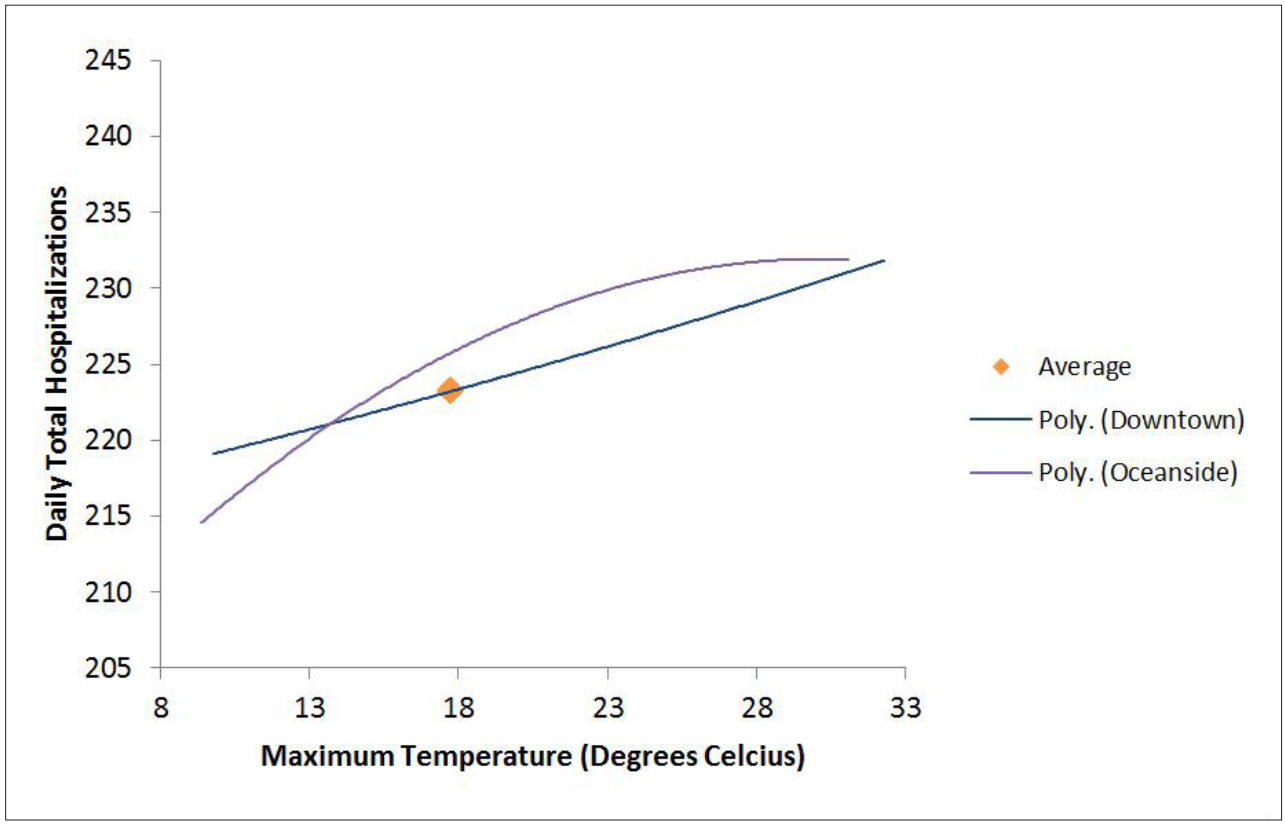
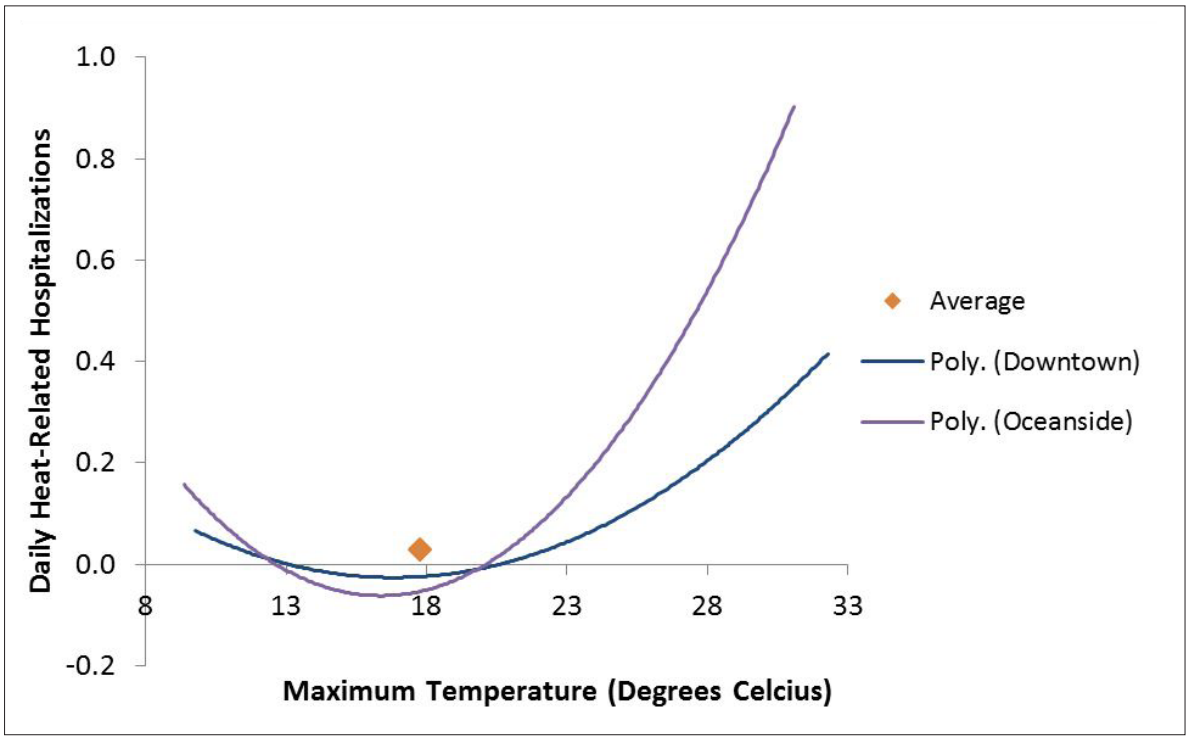


Figure 5 demonstrates that heat-related hospitalizations increase significantly when temperatures increase in Downtown and Oceanside, San Francisco. Heat related illnesses generally increase at a lower temperature in Oceanside than in Downtown. The average number of heat related illnesses is exceeded at approximately 18 degrees Celsius in Downtown San Francisco.

Analysis

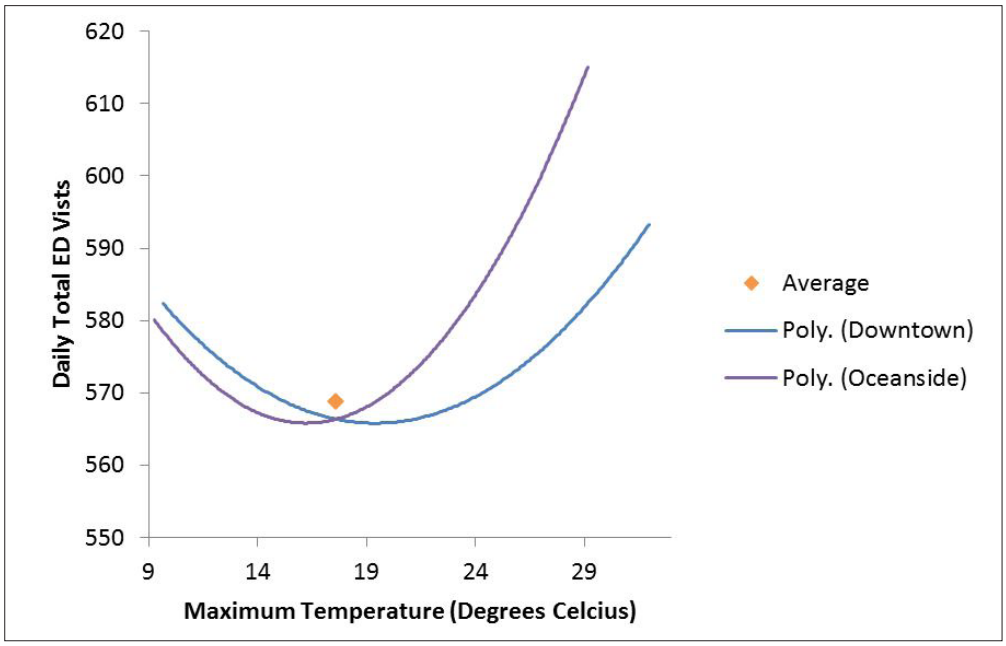
Figure 6: Heat-Related Hospitalizations by Temperature



Hospitalizations attributed to heat increase sharply as temperature increases. Hospitalizations increase rapidly when temperatures exceed 22 degrees Celsius. The average number of heat-related hospitalizations per degree is relatively low, even when temperatures are high. The increasing total hospitalizations observed when temperature increases, however, suggests a relationship between illness and heat. This suggests that heat-related hospitalizations may be undercounted, or may not be attributed to heat.

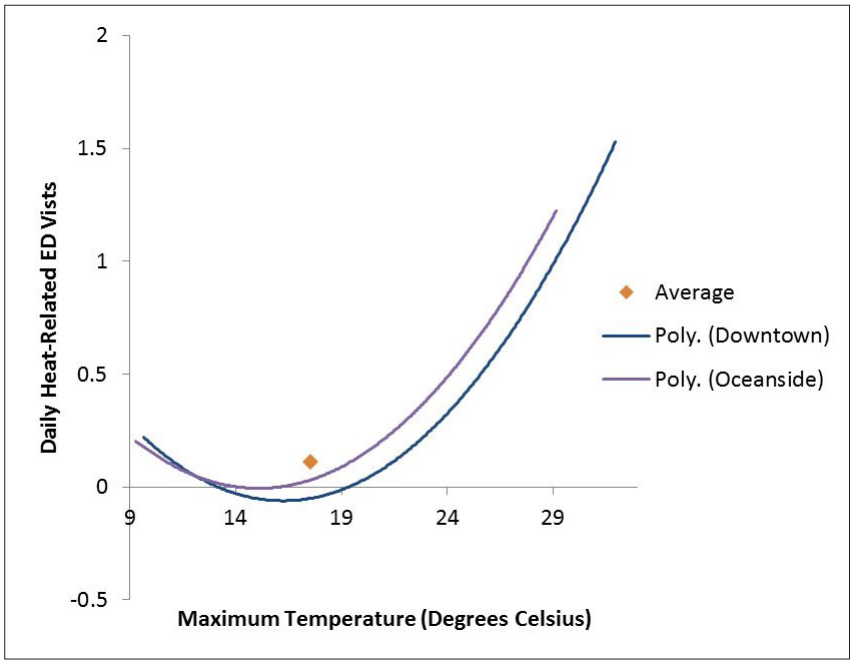
Analysis of Extreme Heat Events and Illness

Figure 7:
Total Emergency Department Visits by Temperature



Total emergency department visits follow a pattern similar to total hospitalizations; as temperatures increase, ED visits increase and the average number of ED visits is approximately 18 degrees Celsius. ED visits increase drastically when temperatures are approximately 24 degrees in Downtown San Francisco.

Figure 8:
Heat-Related Emergency Department Visits by Temperature



Heat related emergency visits follow a pattern similar to heat-related hospitalizations. When temperatures in both Oceanside and Downtown San Francisco reach approximately 24 degrees, the number of ED visits per degree increases drastically.

Analysis

Figure 9: Time Series of Total Hospitalizations During and After an Extreme Heat Event (Downtown)

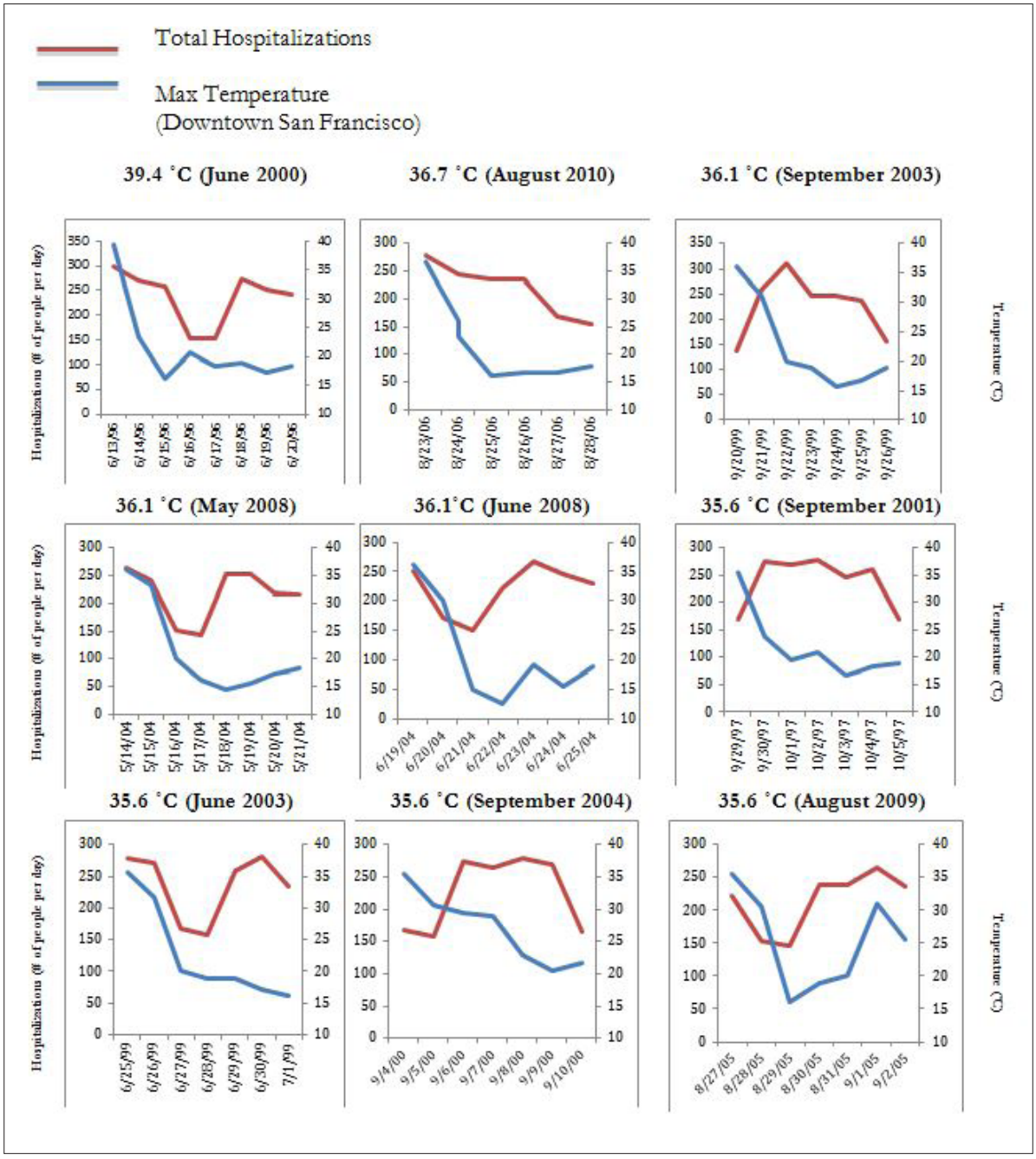
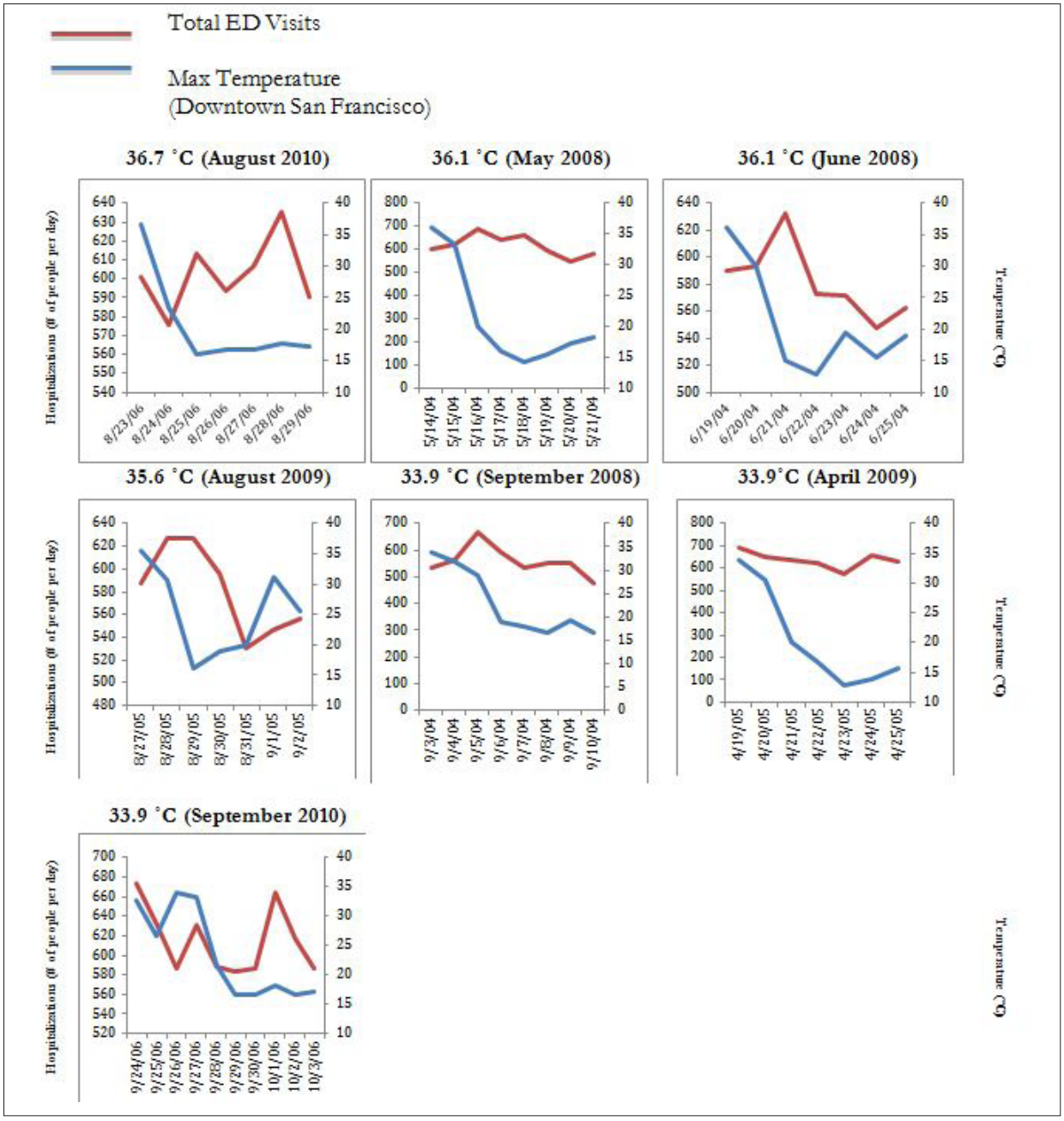


Figure 10:
Time Series of Total Emergency Department Visits During and After an Extreme Heat Event (Downtown)



Analysis of Extreme Heat Events and Illness

Table 2: Time Series of Heat-Related Hospitalizations and Emergency Department Visits

Date	Max Downtown Temp (°C)	Total Hospital-izations	Heat-related Hospital-izations
6/14/00	39.4	299	15
6/15/00	23.3	272	9
6/16/00	16.1	259	0
6/17/00	20.6	152	0
6/18/00	18.3	155	0
6/19/00	18.9	274	0
6/20/00	17.2	251	0
6/21/00	18.3	241	1
8/24/10	36.7	279	3
8/25/10	26.1	245	1
8/25/10	23.3	245	1
8/26/10	16.1	235	0
8/27/10	16.7	236	0
8/28/10	16.7	169	0
8/29/10	17.8	155	0
5/15/08	36.1	265	1
5/16/08	33.3	241	0
5/17/08	20	152	1
5/18/08	16.1	144	1
5/19/08	14.4	252	0
5/20/08	15.6	254	0
5/21/08	17.2	219	0

Date	Max Downtown Temp (°C)	Total ED visits	Heat-related ED visits
5/15/08	36.1	603	6
5/16/08	33.3	622	1
5/17/08	20	691	3
5/18/08	16.1	639	1
5/19/08	14.4	664	1
5/20/08	15.6	596	0
5/21/08	17.2	547	0
6/20/08	36.1	590	3
6/21/08	30	594	3
6/22/08	15	632	0
6/23/08	12.8	573	0
6/24/08	19.4	572	1
6/25/08	15.6	548	0
6/26/08	18.9	563	0
8/24/10	36.7	601	4
8/25/10	23.3	576	2
8/26/10	16.1	613	0
8/27/10	16.7	594	0
8/28/10	16.7	607	0
8/29/10	17.8	635	0
8/30/10	17.2	590	0

Data on heat-related hospitalizations and emergency department visits also indicate a bathtub effect. Table 2 displays the heat-related hospitalizations and ED visits during the week following the three warmest days over the 10- and 5-year periods, respectively. The warmest day occurred on June 14, 2000 and resulted in 15 heat-related hospitalizations. The following day resulted in nine hospitalizations, even though temperatures declined. Eight days following the extreme heat event, an additional heat-hospitalization was recorded, although temperatures returned to average for almost a week. Similar trends can be seen following other extreme heat events, although the bathtub effect appears to last approximately three to five days, perhaps due to the slightly lower temperature.

Discussion

The data demonstrate that as heat increases, total illnesses, measured by hospitalizations and emergency department visits. The data does not provide a clear degree at which illnesses peak, as illnesses increase moderately over the 10-year hospitalization data and more drastically over the 5-year emergency department data, with a spike in illness beginning at approximately 24 degrees Celsius.

While the clear association between heat and illness suggests that some illnesses can be exacerbated by heat, the lack of hospitalization data makes it difficult to assess the impacts of extreme heat events on health. Heat-related illnesses may be undercounted, as the number of heat-related hospitalizations and ED visits is extremely low despite the large number of hospitalizations and ED visits that increase as temperatures increase. Additionally, heat might not be identified as the cause of an illness, especially because heat often exacerbates existing illnesses, such as cardiovascular disease, respiratory disease, and other chronic diseases. Patients may appear with chronic illnesses that are exacerbated by heat, and hospitals may not associate these illnesses with extreme heat. Improving hospital data collection can help strengthen our understanding of how heat impacts illness, and the degree at which that happens.

Extreme heat events are predicted to become more frequent and extreme by the end of the century.[i] Data demonstrates that while most extreme heat events occur in September and October, a significant number of heat events occur throughout the year, and that the number of annual extreme heat events can vary drastically from year to year. Preparedness is ever more important, as heat events can occur with little warning, and result in serious health impacts, especially among San Francisco's most vulnerable populations.

Next Steps

In order to further develop the San Francisco Department of Public Health's extreme heat preparedness efforts, next steps include projecting the number of extreme heat days through the end of the century, and the impact of extreme heat days on hospitalizations and emergency department visits. This analysis will inform the magnitude and frequency of extreme heat events, and prepare efforts to identify and treat illness related to heat-related climactic changes.

[i] Cal-Adapt web-based tool. California Energy Commission, 2013. Available at: www.Cal-Adapt.org