Overview

The goal of the ClimaWATCH (Climate and Weather Analytics, Trends, and Community Health) prototype is to facilitate exploration of the association between climate event and health outcomes, including where they concentrate geographically, how they change over time, and affected populations. The prototype summarizes extreme weather events and related health issues and enable the end-user to see the geographic and temporal spread of extreme weather events, assess who is most vulnerable to health-related issues, and examine estimated spending to address such health issues. The visualizations programmed show climate exposure and health outcome for a given year as well as trends in metrics over time. The current prototype focuses on a single type of extreme weather event – heatwaves – and heat-related health outcomes. In the future, we plan to expand the tool to summarize other types of extreme weather events, such as wildfires and hurricanes, and related health issues.

Data and Methods

Environmental exposure data

We obtained daily temperature and dew point data from the PRISM Climate Group (2020) for the 48 contiguous U.S. states and from the National Centers for Environmental Information (2021) for Alaska and Hawaii. For the contiguous U.S., we applied a population-weighted approach to 4 km² grid-level data to calculate daily county-level temperature estimates during the warm season of May 1 to September 30 between 1981 and 2019 (Anderson et al. 2013; Gronlund et al. 2014). For Alaska and Hawaii, we averaged data from individual weather stations within a county to calculate county-level estimates. We chose apparent temperature (AT) as the primary heat exposure metric to account for the joint effects of temperature and humidity on human health. We calculated AT (in °C), as follows, based on the methods of Kalkstein and Valimon (1986):

\[
AT = -2.653 + (0.994 \times \text{mean temperature}) + 0.0153 \times (\text{dew point})^2
\]

Using this measure, we identified heatwaves for each county and year. Note that a heatwave can be defined based on consecutive days with temperatures above a physiologically based absolute threshold or above a location based relative threshold (Robinson 2001). Taking into account both of these thresholds, we defined as a heatwave as two or more consecutive days when the daily mean AT exceeded either 90 degrees Fahrenheit (32.2 °C) or the 95th percentile of the daily average AT during the warm seasons of 1981-2019, whichever was greater.

Health outcomes data

As a first step to estimating heat-related health service use and spending, we reviewed the literature to identify acute conditions that are caused by or exacerbated by excessive heat. We identified four relevant diagnosis categories: heat-related illnesses, electrolyte imbalance, acute renal failure, and acute myocardial infarction. Table 1 displays International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) codes for these diagnosis categories. We also aggregated these codes into a broad acute composite diagnosis category.

Medicaid data. We obtained Medicaid program data on health service use and spending from the Transformed Medicaid Statistical Information System Analytic Files (TAF) Research Identifiable Files. For the years 2016 through 2019, we retained claims in the Inpatient or Other Services files that had a

1 The diagnosis categories are modified versions of categories used by Knowlton et al. (2009).
primary diagnosis code for any of the diagnoses shown in Table 1 (Morano and Watkins 2017) and a service date within one month of the warm season (that is, from April 1 through October 31).

ClimaWATCH displays the number of unique beneficiaries enrolled in Medicaid during the warm months for the selected geography and year. This number includes those with a heat-related claim as well as beneficiaries who were enrolled but did not have any claims for heat-related health service use during the warm season. The information is based on the TAF Annual Demographic and Eligibility file.

We calculated two key outcomes of interest using the Medicaid data:

(1) **Health service use**, based on the number of Medicaid beneficiaries with a claim for the diagnoses of interest during the months of interest;

(2) **Health care spending** based on the expenditures reflected in such claims. Because the Medicaid data included fee-for-service (FFS) expenditures only, with no data available on managed care expenditures, we extrapolated FFS spending to estimate managed care spending (and thus total spending) based on the percent of all claims that were FFS claims.\(^2\)

**CDC data.** To obtain a more complete national picture of heat-related health issues, we analyzed data from the Center for Disease Control and Prevention’s Environmental Public Health Tracking Network on emergency department visits for heat stress, hospitalizations for heat stress, and heat-related deaths. For each of these measures, we downloaded crude rates (that is, the number of events per 100,000 people) from 2000-2019 (though heat-related mortality data were only available through 2018). We merged this data with state-level summary measures on the number and duration of heatwaves per state per year to examine how health-related outcomes increased as the number or length of heatwaves increased.

**County-level case-crossover design to attribute health issues to heatwave exposures**

To estimate health service use and spending attributable to excessive heat, we adopted a case-crossover study design applied at the county level. This design enables adjustment for known and unknown time-stable confounders and is therefore ideally suited to estimate health service use and spending due to heatwave exposure. Within this framework, we analyzed health outcomes during three periods of time: days during which a heatwave (HW) occurred, days within a 7-day buffer period after each heatwave (BF), and days during a reference period (RF) during which there were no heatwaves. To account for any

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\(^2\) For instance, if we observed $100 in FFS expenditures, and that 30% of all claims were FFS claims, we estimated that managed care expenditures would amount to $233.33 using the following formula:

\[
\text{Total expenditure} = \text{FFS expenditure} \times \left(1 - \% \text{ of claims that are FFS}\right) / \% \text{ of claims that are FFS}
\]

Because we did not know the “true” managed care expenditures, and because capitated payment arrangements make it challenging to assign an expenditure amount to a given service, we assumed that the managed care distribution of services matched the FFS claims, and that costs for each service were identical under both payment models.
natural time trend effects, we identified two reference periods for each heatwave – one before the heatwave and one after. Both reference periods were chosen to be as close in time to the heatwave as possible and were always within the same year and heat season as the heatwave.

- To identify pre-heatwave RF periods, we developed a sequential matching algorithm to identify a period that had the same length and a similar number of weekends and holidays (+/- 1 day) as the heatwave period, was free of excessive heat, and was not within a 14-day washout period of another heatwave.

- To identify post-heatwave RF periods, we adjusted the matching algorithm such that, when the algorithm failed to identify a matching period for a given heatwave, we lightened the matching requirements. Specifically, we allowed the reference period to be shorter than the heatwave (for heatwaves that were longer than ten days), we removed the requirement to include a similar number of weekend/holiday days as the heatwave, and we allowed a given reference period to be “reused” for another heatwave, if necessary.

For each of these three periods, we summed daily health service use and spending for all beneficiaries within a county (for reference period days, we averaged outcomes during the pre-heatwave and post-heatwave reference periods). Because these periods may have varied in length, we standardized our outcome metrics by calculating service use and spending per day.

Lastly, to determine the excesses health service use and spending attributable to heatwave exposure (that is, to parse out background, expected levels of health service use and spending from the whole), we compared outcomes that occurred during a heatwave or within a 7-day buffer period after the heatwave with outcomes that occurred during the non-heatwave reference period, as follows:

$$Excess = (\text{weighted average use/spending per day during } [(\text{HW} + \text{BF}) - RF] \times \text{number of heatwave days})$$

We reported this excess as both an absolute difference (in the units of total beneficiaries with excess health service use or total dollars spent on this excess health service use) and a percent change from the background reference period (which is undefined if there was no service use or spending during the reference period).

To calculate state-level outcome and excess measures, we summed county-level daily health service use and spending for all counties across the state during each day of the three periods of interest. We also broke out summaries of Medicaid health service use and spending by:

- **Geography.** U.S., state, or county
- **Year.** 2016 through 2019
- **Demographic group.** Adults (including expansion Adults), Children (Medicaid and Children’s Health Insurance Program), Blind and Disabled, Aged, and Pregnant, defined using the Medicaid eligibility group categories (*Note: We excluded the newly eligible COVID group because the data we analyzed precede the pandemic*).
- **Care setting.** Emergency department, in-patient hospital, and other (which includes care provided in any other facility or non-facility setting other than a long-term care facility).
- **Diagnosis category.** Acute composite, acute myocardial infarction, acute renal failure, electrolyte imbalance, or heat related illnesses.
Limitations

- Results may be somewhat sensitive to our definition of a heatwave and could vary with alternate characterizations (based on max, mean, and min temperature; relative threshold; etc.)

- We were unable to report health information for some geographies or months because a large proportion of records were masked (which occurred when more than zero but fewer than 11 beneficiaries had a heat-related claim). As a result of this masking, our tool likely underestimates total health service use and spending. To address this issue, we imputed masked values by:
  1. Setting masked health service utilization to a midpoint of 5 beneficiaries; and
  2. Setting masked per-beneficiary spending to the national average spending for that combination of year, diagnosis, and either beneficiary category or service setting (depending on which the user selects).

- The proportion of Medicaid beneficiaries enrolled in managed care varies from state to state and can range greatly (from 9 to 99 percent). ClimaWATCH displays this proportion (which is based on the Centers for Medicare & Medicaid Services Medicaid Managed Care Enrollment Report) to appropriately contextualize estimated heat-related health care spending.

  o Because the data we analyzed only include expenditures based on FFS claims, estimated spending for states with a large proportion of beneficiaries in managed care may be less reliable than estimates for states that primarily use FFS payment models.

  o Because managed care spending estimates are extrapolated from spending on FFS claims, we may underestimate expenditures when FFS claims within a given category have $0 payment amounts.  

- The quality of the Medicaid TAF data we analyzed can vary by state and year. Users interested in learning more about TAF data quality can consult the DQ Atlas and TAF Data Quality Resources provided by the Centers for Medicare and Medicaid Services.

References


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3 FFS claims can have $0 payment amounts for a valid reason tied to specific state or federal policies, such as when services are provided at a Federally Qualified Health Center. However, we generally expect positive payment amounts in TAF records, and $0 payment amounts may indicate data quality issues.
