

Documentation for

gridMET Weather Data

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Requested Acknowledgment

If you used the Contextual Data Resource data in a written analysis, please include the following acknowledgement:

This analysis uses data or information from the Contextual Data Resource (CDR): gridMET Weather Data, developed by Jennifer Ailshire, Kate Vavra-Musser, Eun Young Choi, and Calley E. Fisk at the USC/UCLA Center on Biodemography and Population Health. With funding from the National Institute on Aging (R21 AG045625, P30 AG017625). For more information, please refer to <https://gero.usc.edu/cbph/cdr/>

Suggested Citations

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CDR also recommends including the citation for the original gridMET data source:

- Abatzoglou, J.T. (2013), Development of gridded surface meteorological data for ecological applications and modelling. *International Journal of Climatology*, 33(1), 121–131.

Data Sources

John T. Abatzoglou Climatology Lab, University of California Merced

<http://www.climatologylab.org/gridmet.html>

Linking CDR Data with HRS Respondent Data

The Contextual Data Resource is designed to be linked with the Health and Retirement Study Cross-Wave Geographic Information (Detail) file, which is available as restricted data. See <https://hrs.isr.umich.edu/data-products/restricted-data> for more information about accessing the HRS restricted data. All geographic identifiers are in string format, and match the geographic identifiers in the HRS Cross-Wave Geographic Information (Detail) file.

- To link census tract level data, merge using the 11-digit LINKCEN2010 geographic identifier, which is [the 2-digit state + 3-digit county + 6-digit census tract FIPS code](#). The LINKCEN2010 geographic identifier has been harmonized to the 2010 census tract boundaries.

Note on HRS Cross-Wave Geographic Information File

Respondent locations are carried forward to the next wave and they appear for waves in which the interview may not have occurred. xIWTYPE in the Tracker file indicates whether someone was actually interviewed in that wave, in which case, the location would have been confirmed.

If users want to limit analyses to waves in which the R was interviewed, keep waves of observations where xIWTYPE = 1. In summary, a location appearing on a given line does not indicate that an interview took place in that wave; it is simply the location that was on record at the time.

Dataset Overview

The CDR weather data provides monthly measures of heat index categories, wind chill index categories, precipitation, and average temperatures. These measures are available from 1979 to 2023. The measures are calculated from gridMET, which provides daily high-resolution meteorological data. CDR interpolated gridMET data to the census tract level and aggregated the data to produce monthly measures.

Data Summary

Dataset Name: gridMET

Data Source: John T. Abatzoglou Climatology Lab, University of California Merced

Data Source URL: <http://www.climatologylab.org/gridmet.html>

Data Collection The underlying data for gridMET is collected from a range of ground-based and satellite monitoring sources, integrated by the PRISM Climate Group and NASA Land Data Assimilation Systems.

- The PRISM Climate Group gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns. For more information see <https://prism.oregonstate.edu/>
- Land Data Assimilation Systems (LDAS) aim to produce high quality fields of land surface states (e.g., soil moisture, temperature) and fluxes (e.g., evapotranspiration, runoff) by integrating satellite- and ground-based observational data products, using advanced land surface modeling and data assimilation techniques. For more information see <https://ldas.gsfc.nasa.gov/nldas/NLDAS2forcing.php#>

Time: gridMET daily measures are available from 1979 onward, updated daily.

Geography: gridMET covers the contiguous US with a 4km by 4km raster grid.

Temporal Aggregation

The CDR team created monthly measures for each set of weather indices. For the heat index and wind chill indices, the measures indicate a count or percent of the total number of days per month within each heat or wind chill level. Precipitation measures include the total amount of precipitation as well as the number of days with precipitation and average number of days with precipitation in a month. Temperature measures include the average minimum and average maximum temperature in a month.

Geographic Interpolation

gridMET data is provided as a roughly 4km by 4km grid across the contiguous US. The CDR team spatially interpolated this gridded data to 2010 census tract boundaries.

CDR Data Files

The CDR provides separate data files for each of the four weather indicators:

- Heat index
- Wind chill
- Precipitation
- Temperature

Each file contains all monthly measures for all data years (1979-2023). Measures for each year and month can be differentiated using the year and month suffix following the variable name. Additionally, each measure includes an indicator of geographic level ('tr' for census tract) in the variable name.

For example, in the heat index data file, the variable for the number of level 0 heat index days in the month aggregated to the census tract for March 2002 is named 'm100tr200203'.

Heat Index

Background

Heat index is calculated using the [National Weather Service \(NWS\) heat index equation](#). This equation uses temperature (ambient) and relative humidity to calculate heat index. However, the gridMet dataset only provides daily minimum and maximum temperature and maximum and minimum relative humidity. Therefore, a modified version of the formula using maximum temperature (T_{\max}) and minimum relative humidity (RH_{\min}) from the gridMet dataset is used to calculate heat index. This modification is based on work by [Dahl et al. 2019](#) who determined that daily T_{\max} and RH_{\min} produced the best approximations of the heat index when using the gridMet dataset – i.e. when only daily minimum and maximum information is available.

The heat index equations are designed for use with temperature in degrees Fahrenheit. Note that the original gridMet temperature files store temperature in degrees Kelvin. The processing script runs the conversion from degrees K to degrees F prior to implementing the heat index formula.

The NWS equation includes a base formula and three formula adjustments for specific temperature and relative humidity ranges. Note that the base formula has [an error of +/- 1.3 F](#). When using the base formula alone, heat index is undefined when temperature is below 80 degrees F. With the adjustments, heat index is defined for all values of temperature and relative humidity.

Note that “[no true equation for the heat index exists](#)” and the NWS equation is one of many possible approximations for heat index. The complete model to calculate heat index uses many additional variables which are not available in the gridMet dataset.

Like temperature (specifically, ambient temperature), heat index is given in units of degrees, but should not be confused with temperature. Note, the term “apparent temperature” is sometimes used interchangeable with the term “heat index” and to differentiate it from “ambient temperature.”

The base equation and adjustments as they are used to calculate heat index using the gridMet data are given below.

Base Equation

$$\begin{aligned}
 HI = & -42.38 + 2.05 T + 10.14 RH - (2.25 \times 10^{-1})T RH - (6.84 \times 10^{-3})T^2 \\
 & - (5.48 \times 10^{-2})RH^2 + (1.23 \times 10^{-3})T^2 RH + (8.53 \times 10^{-4})T RH^2 \\
 & - (1.99 \times 10^{-6})T^2 RH^2
 \end{aligned}$$

Equation Adjustments

The following modifications to the heat index formula are employed in calculating heat index, as per [Dahl et al. 2019](#). Note these adjustments are not employed by NWS and others.

Adjustment 1

When $80 \leq T \leq 112$ and $RH < 13$, **subtract** the following adjustment HI_{adj1} from the calculated HI:

$$HI_{adj1} = \left(\frac{13 - RH}{4} \right) \sqrt{\frac{17 - \text{abs}(T - 95)}{17}}$$

Adjustment 2

When $80 \leq T \leq 87$ and $RH > 85$, **add** the following adjustment HI_{adj2} from the calculated HI:

$$HI_{adj2} = \left(\frac{RH - 85}{10} \right) \left(\frac{87 - T}{5} \right)$$

Adjustment 3

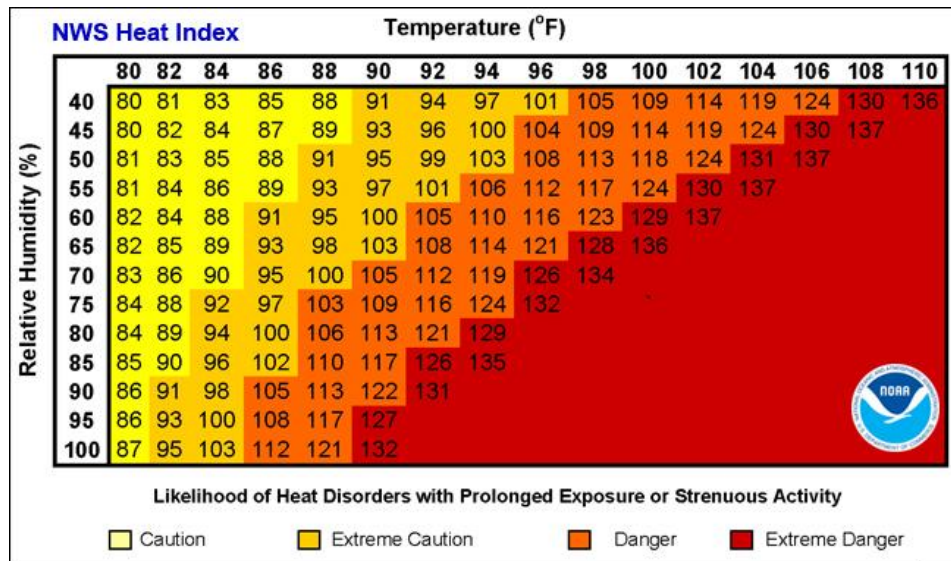
When $HI < 80$, the following equation should be used in lieu of the base formula:

$$HI = 0.5 (61 + T + 1.2 (T - 68) + 0.094 RH)$$

Heat Effect Index

Heat index values can be grouped based on the likelihood of adverse impacts on the human body. Different index designations exist with slightly different cutoff values. Heat index levels are defined using the [NWS heat index level cutoff values](#) given below:

Level	Heat index values	Description
Level 0	Heat index < 80	No hazard
Level 1	Heat index ≥ 80 and < 90	Caution
Level 2	Heat index ≥ 90 and < 103	Extreme caution
Level 3	Heat index ≥ 103 and < 125	Danger
Level 4	Heat index ≥ 125	Extreme danger



Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

Wind Chill

Background

Wind chill is calculated using an equation from the [National Digital Forecast Database \(NDFD\)](#). Further information on wind chill can be found on the [NWS website](#). This equation uses temperature and wind speed to calculate wind chill. However, because the gridMet dataset only provides daily minimum and maximum temperature data, estimated daily average temperature $([T_{\max}+T_{\min}]/2)$ is used in place of temperature for the wind chill calculation. Therefore, the outcome of the script might be interpreted as the minimum possible wind chill for the day.

The wind chill equation is designed for use with temperature in degrees Fahrenheit and wind speed in miles per hour. Note that the gridMet temperature data is in degrees Kelvin and the wind speed data is in meters per second; the processing script runs the temperature conversion from degrees K to degrees F and wind speed conversion from m/s to mph. Wind chill is given in units of degrees, similar to temperature, but should not be confused with ambient temperature.

The equation used to calculate wind chill is technically defined to calculate wind speed at an average height of 5 feet, the typical height of an adult human face, based on readings from the national standard height of 33 feet, which is the typical height of an anemometer. The gridMet data reports wind speed at 10 meters (32.8 ft) so no conversion is necessary.

The wind chill equation is technically only defined for temperatures ranging from -45 to 45 degrees Fahrenheit and wind speeds ranging from 3 to 60 miles per hour. This adjustment is not included in the script calculations; wind chill is calculated for all temperature and wind speed ranges.

The equation used to calculate the wind chill index using the gridMet data is given below.

Equation

$$WC = 35.74 + 0.6215 T - 35.75 VS^{0.16} + 0.4275 T VS^{0.16}$$

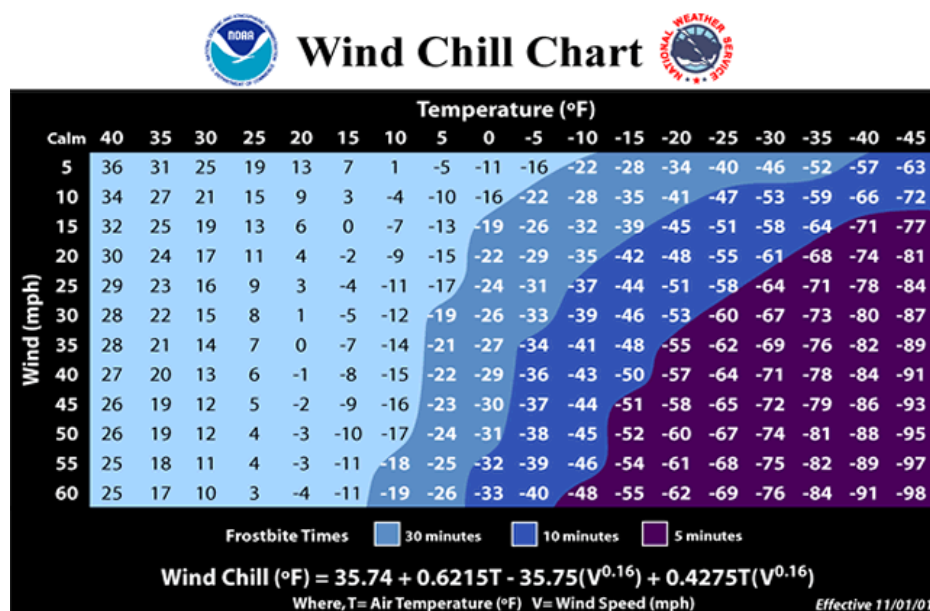
Wind Chill Effect Index / Frostbite Index

Wind chill values can be categorized based on the probability of adverse health impacts, particularly the risk of frostbite. Various wind chill indices exist, each with slightly different threshold definitions. The CDR wind chill categories follow the [Roshan et al. \(2010\)](#) hazard classifications, which define risk levels according to wind chill severity, as summarized in table below. For detailed descriptions, please see the following citation:

- Roshan, G., Mirkatouli, G., Shakoor, A., & Mohammad-Nejad, V. (2010). Studying wind chill index as a climatic index effective on the health of athletes and tourists interested in winter sports. *Asian journal of sports medicine*, 1(2), 108–116. <https://doi.org/10.5812/asjasm.34861>

Table 1: Environment and Climate Change Wind Chill Categories (Roshan et al. 2010).

Level	Wind chill index values	Description
Level 0	Wind chill > 0	No risk
Level 1	Wind chill ≤ 0 and > -10	Conditions for outdoor activities are discomforting
Level 2	Wind chill ≤ -10 and > -15	Body skin gets cold if not covered
Level 3	Wind chill ≤ -15 and > -25	No descriptions
Level 4	Wind chill ≤ -25 and > -45	All body organs should be covered; uncovered body parts might become frostbit
Level 5	Wind chill ≤ -45 and > -60	Very discomforting and outdoor activities should be limited to very short periods of time; there is danger of sudden body temperature fall
Level 6	Wind chill ≤ -60	Outdoor conditions are very dangerous; if body skin is not covered, it will become frostbitten



Precipitation

Precipitation measures include a representative total number of days in a month with any precipitation (precipitation > 0), the percent of days in a month with any precipitation, total precipitation (in mm) per month, and the average amount of precipitation per day (in mm) in a month.

Temperature

Temperature measures include a representative average of minimum and maximum temperature (in degrees Fahrenheit) in a month.

Variable List

Variable names for heat, wind chill, precipitation, and temperature include the initial prefix listed below, plus the geographic level (tr), the four-digit year, and the month as a two-digit code from 01 to 12.

Name	Definition	Type
<u>Geographic Identifier</u>		
LINKCEN2010	2010 Census Tract FIPS code (11 digits: 1-2 state, 3-5 county, 6-11 tract)	string
<u>Heat Index</u>		
m100	Number of level 0 heat index (no hazard) days in month	number
m101	Number of level 1 heat index (caution) days in month	number
m102	Number of level 2 heat index (extreme caution) days in month	number
m103	Number of level 3 heat index (danger) days in month	number
m104	Number of level 4 heat index (extreme danger) days in month	number
m110	Percent of days at level 0 heat index (no hazard) in month	percent
m111	Percent of days at level 1 heat index (caution) in month	percent
m112	Percent of days at level 2 heat index (extreme caution) in month	percent
m113	Percent of days at level 3 heat index (danger) in month	percent
m114	Percent of days at level 4 heat index (extreme danger) in month	percent

Wind Chill Index

m220	Number of level 0 (no risk) wind chill days in month	number
m221	Number of level 1 (discomforting) wind chill days in month	number
m222	Number of level 2 (cold) wind chill days in month	number
m223	Number of level 3 (medium cold) wind chill days in month	number
m224	Number of level 4 (very cold) wind chill days in month	number
m225	Number of level 5 (dangerous) wind chill days in month	number
m226	Number of level 6 (very dangerous) wind chill days in month	number
m230	Percent of level 0 (no risk) wind chill days in month	percent
m231	Percent of level 1 (discomforting) wind chill days in month	percent
m232	Percent of level 2 (cold) wind chill days in month	percent
m233	Percent of level 3 (medium cold) wind chill days in month	percent
m234	Percent of level 4 (very cold) wind chill days in month	percent
m235	Percent of level 5 (dangerous) wind chill days in month	percent
m236	Percent of level 6 (very dangerous) wind chill days in month	percent

Precipitation

m300	Number of days with precipitation in month	number
m301	Total amount of precipitation in month	number
m302	Percent of days with precipitation in month	percent
m303	Average amount of precipitation per day in month	number
m304	Average amount of precipitation per precipitation day	number

Temperature

m400	Average minimum temperature in month	degree (F)
m401	Average maximum temperature in month	degree (F)