National Future Extreme Heat Scenarios for Assessment of Climate Impacts on Public Health

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Development of National Future Extreme Heat Scenarios to Enable the Assessment of Climate Impacts on Public Health

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National Future Extreme Heat Scenarios for Assessment of Climate Impacts on Public Health

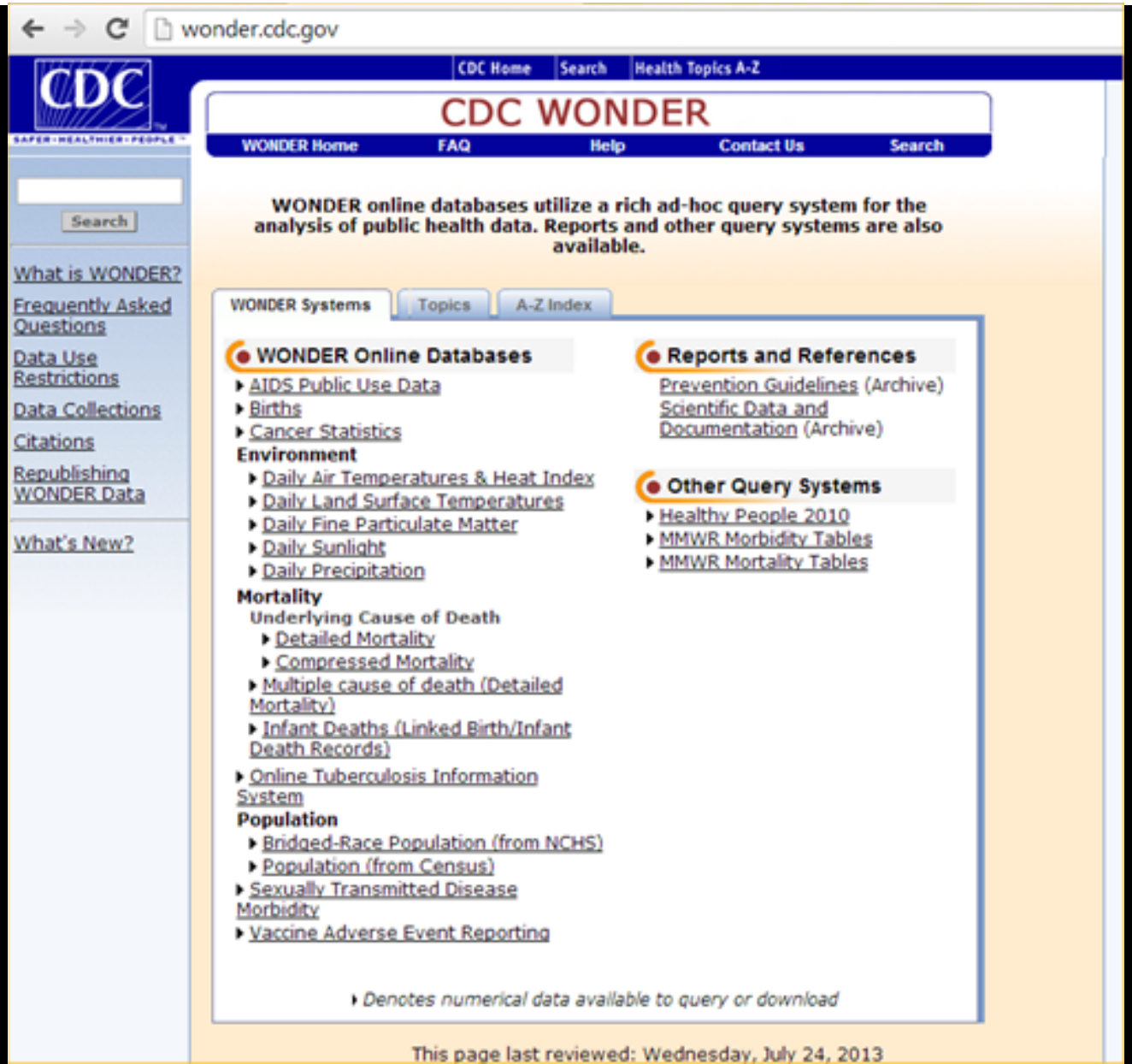
Project Objective: **To provide historical and future measures of climate-driven heat events to enable assessments of heat impacts on public health over the coterminous U.S.**

- The project's emphasis is on providing assessments of the magnitude, frequency and geographic distribution of EHEs to facilitate public health studies.

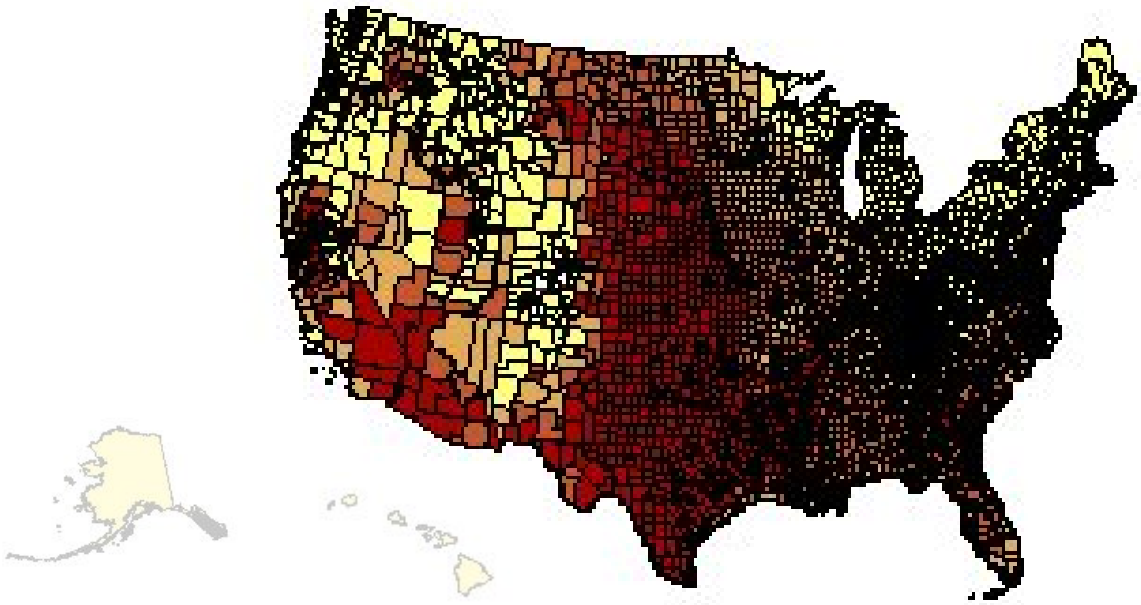
- We focus on the daily to weekly time scales on which EHEs occur, not on decadal-scale climate changes.

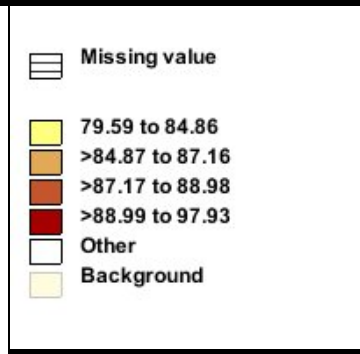
- There is, however, a very strong connection between air temperature patterns at the two time scales and long-term climatic changes will certainly alter the frequency of EHEs.

CDC WONDER Databases



CDC WONDER OUTPUT EXAMPLE





US Average Maximum Daily Air Temperature - 2000-2011

Definitions of Extreme Heat Events

We define Extreme Heat Events (EHE) separately for each of three heat variables:

1. **Daily maximum temperature**
2. **Daily maximum Heat Index**
3. **Net Daily Heat Stress**

➢ An EHE is defined when the variable exceeds the 95th percentile for two consecutive days.
➢ Percentiles are determined for each county based on 1981-2010 NLDAS data for the 'warm season' of May-September.

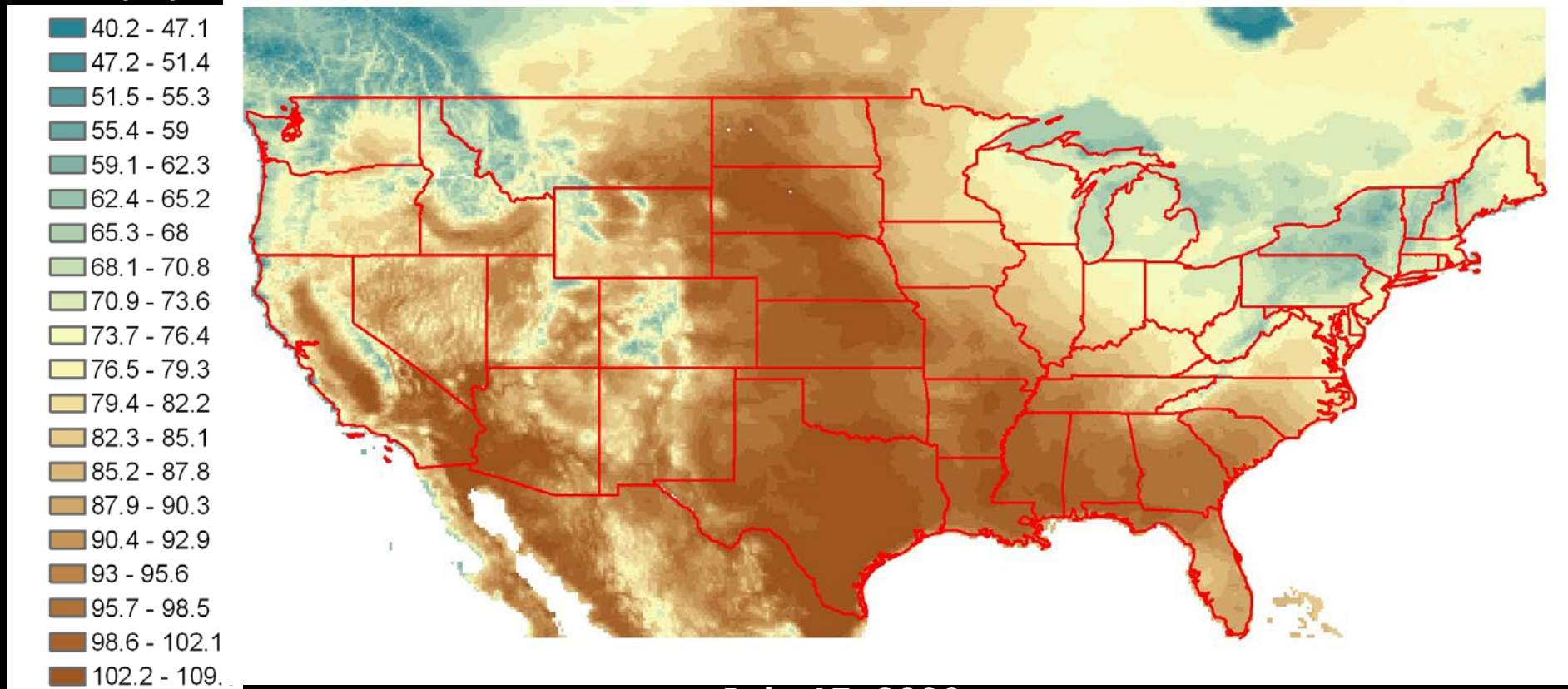
Other EHE definitions incorporate daily minimum temperatures or impose **absolute** thresholds, for example, requiring a daily maximum temperature of 90 ^{o}F (32 ^{o} C), in addition to the **relative** (percentile) criteria.

Metrics of Excessive Heat

1. Daily Maximum Air Temperature

- Daily maximum air temperature, the highest temperature recorded at an observation site between midnight and midnight local standard time, is a traditional measure of heat, and one with which everyone is familiar.

We used National Land Data Assimilation System (NLDAS) data to calculate daily maximum air temperature.

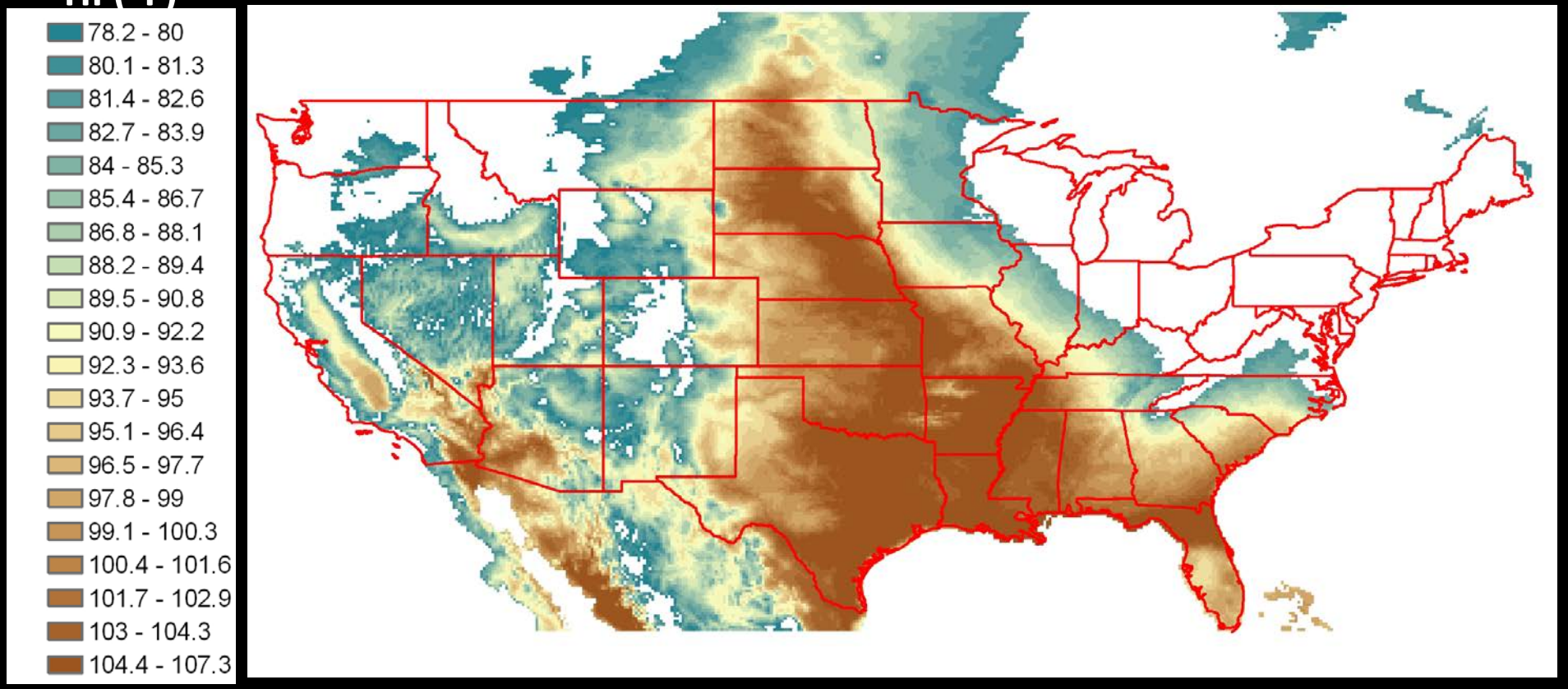


July 15, 2000

Metrics of Excessive Heat

2. Heat Index (HI)

We used NLDAS data to calculate daily maximum Heat Index (HI).
Heat Index is only calculated for air temperatures above 80°F.



July 15, 2000

Metrics of Excessive Heat

3. Net Daily Heat Stress (NDHS)

Net Daily Heat Stress is a new heat variable that gives an integrated measure of heat stress (and relief) over the course of a day, defined as:

$$NDHS = \Sigma(HI_i - HI_{hot}) - \Sigma(T_{cool} - T_i)$$

where the summations are over the hours in a day, but only positive terms are included. In other words, the first sum, the 'heat stress', is only calculated when $HI_i > HI_{hot}$, where HI_{hot} is a threshold above which HI is considered a stressor, set to 90^o F.

The second term, 'heat relief', is only computed when $T_i < T_{cool}$, a temperature below which relief from heat occurs, set to 75^o F. This term is based on air temperature since HI is only defined when $T > 80^o$ F.

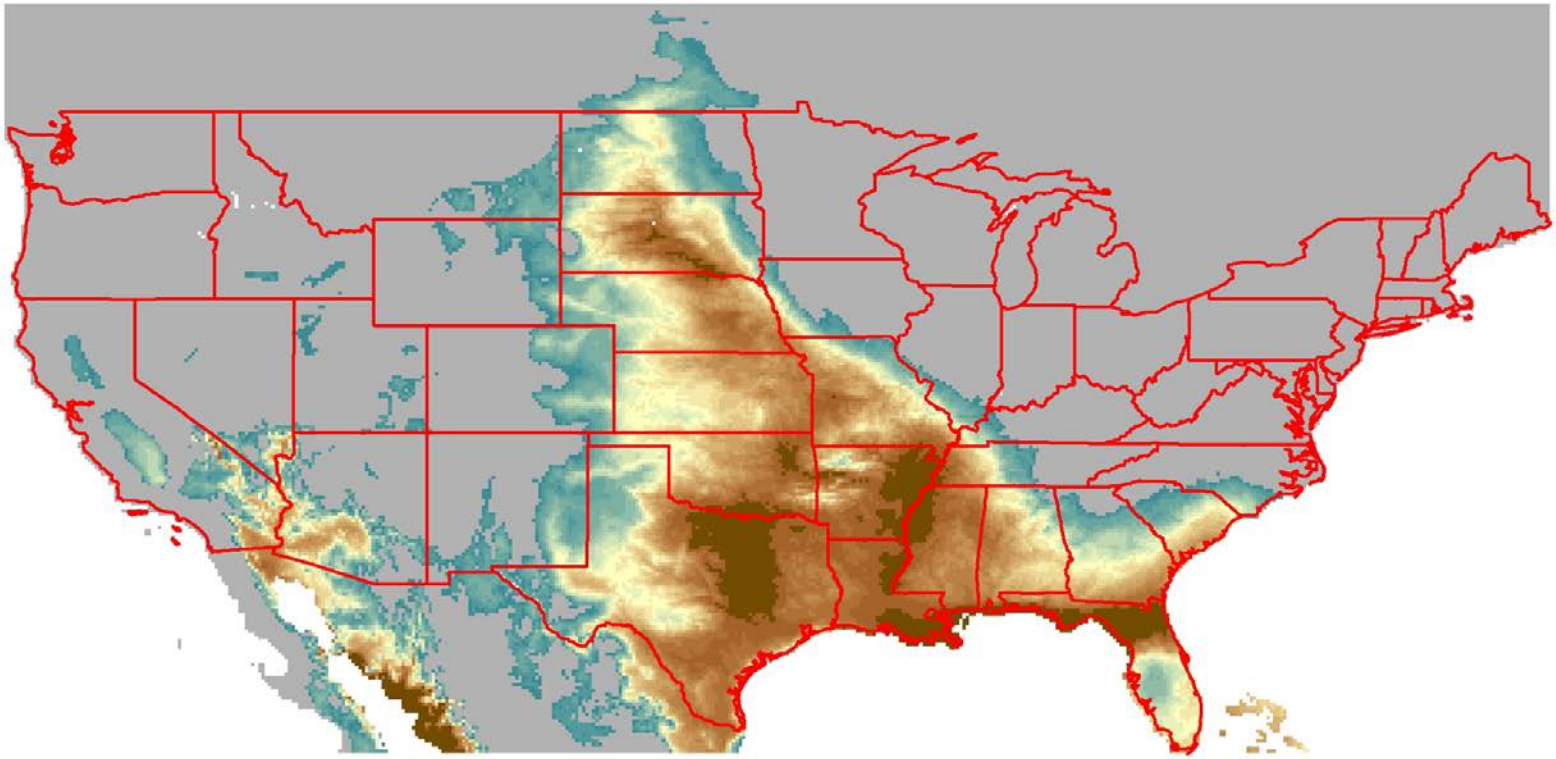
If heat relief is greater than heat stress, NDHS is set to 0.

Metrics of Excessive Heat

3. Net Daily Heat Stress (NDHS)

NDHS (degree-hours)

- 0
- 0.1 - 3
- 3.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 36
- 36.1 - 42.5
- 42.6 - 49.1
- 49.2 - 55.9
- 56 - 62.9
- 63 - 70.3
- 70.4 - 77.9
- 78 - 85.7
- 85.8 - 94.4
- 94.5 - 103.9
- 104 - 113.7
- 113.8 - 124.1
- 124.2 - 134.7
- 134.8 - 146.5
- 146.6 - 162.5
- 162.6 - 187.2



July 15, 2000

North American Land Data Assimilation System (NLDAS)

- North American Land Data Assimilation System (NLDAS) combines meteorological data from models with observations from ground stations and satellites for the conterminous U.S.
  - 1/8th degree (about 14 km) spatial resolution
  - Available hourly
  - Data available from http://www.emc.ncep.noaa.gov/mmb/nldas/

- Hourly air temperature and humidity data have been used to create grid-level daily maximum and minimum temperatures and other heat-related variables.

- Gridded data have been aggregated to county level for linkage with health data.

National Future Extreme Heat Scenarios for Assessment of Climate Impacts on Public Health

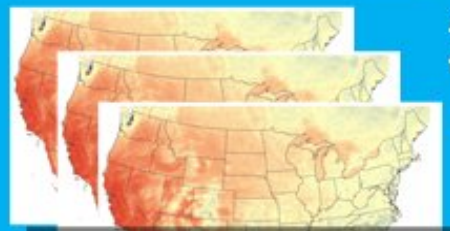
GCM monthly mean grids (1990 climate)

GCM monthly mean grids (2040, 2090 scenarios)

Compute monthly differences, averaged over 20-year periods

Future – current monthly difference grids (Δ climate)

Add D climate to NLDAS-2



Hourly climate realizations 2040, 2090 scenarios

Hourly NLDAS-2 historical (1981-2000) data

Daily heat metrics 2040, 2090 scenarios

Gridded Statistics of Heat Stress:

- mean annual #of days when T > threshold
- mean annual #of days when HI > threshold
- mean annual #of days when NDHS > 0
- mean annual total NDHS

Users:

Public health professionals

General public

CDC WONDER and EHTB:

- archive & host county-level heat stress data and statistics

GCMs

We obtained GCM output of monthly mean minimum and maximum daily temperatures and monthly mean specific humidity.
Source: Coupled Model Intercomparison Project (CMIP3) Multi-Model Dataset Archive at Program for Climate Model Diagnosis and Intercomparison (PCMDI).
This activity was in support of the 4th Assessment Report (AR4).

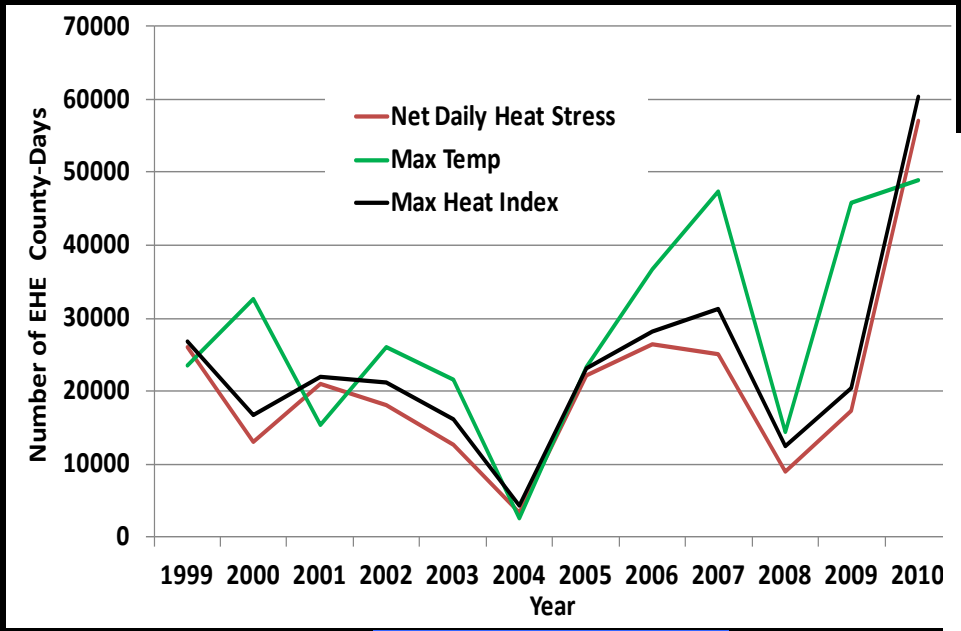
Scenarios:
20th Century Climate for 1980 -1999
SRES A2 ('Business as Usual') for 2030-2049 ('2040') and 2080-2099 ('2090')
SRES A1B ('Balanced Energy') for 2030-2049 ('2040') and 2080-2099 ('2090')

	Model	# Ensemble members used
1.	CCSM3 (NCAR)	2
2.	CSIRO-MK3.0 (Australia)	2
3.	CSIRO-MK3.5 (Australia)	3
4.	BCCR-BCM2.0 (Norway)	1
5.	INM CM3.0 (Russia)	1
6.	MIROC 3.2 Med. Res. (Japan)	3

Means of each variable were computed across ensembles, then across models.

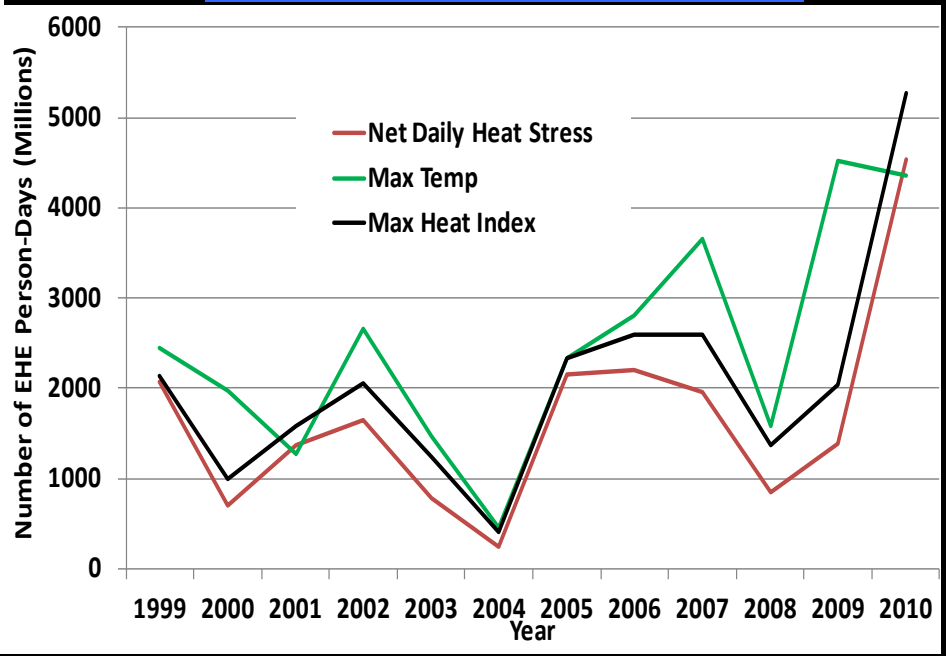
Frequency of Extreme Heat Days

- Annual variability over the U.S. is quite large.
- Over regions, variability is even greater in a relative sense.

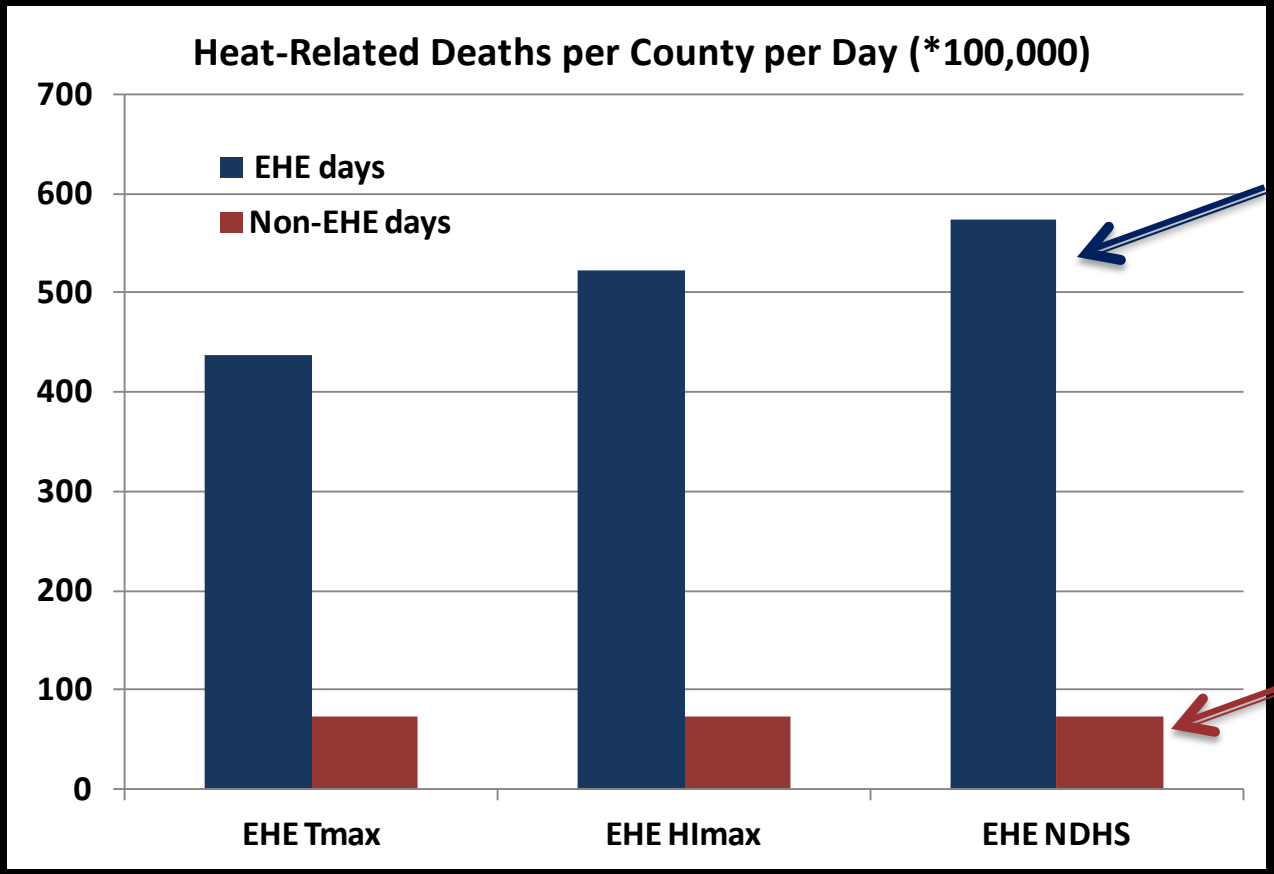


Number of Days

Number of Persons Exposed



Death Rates on EHE Days and non-EHE Days

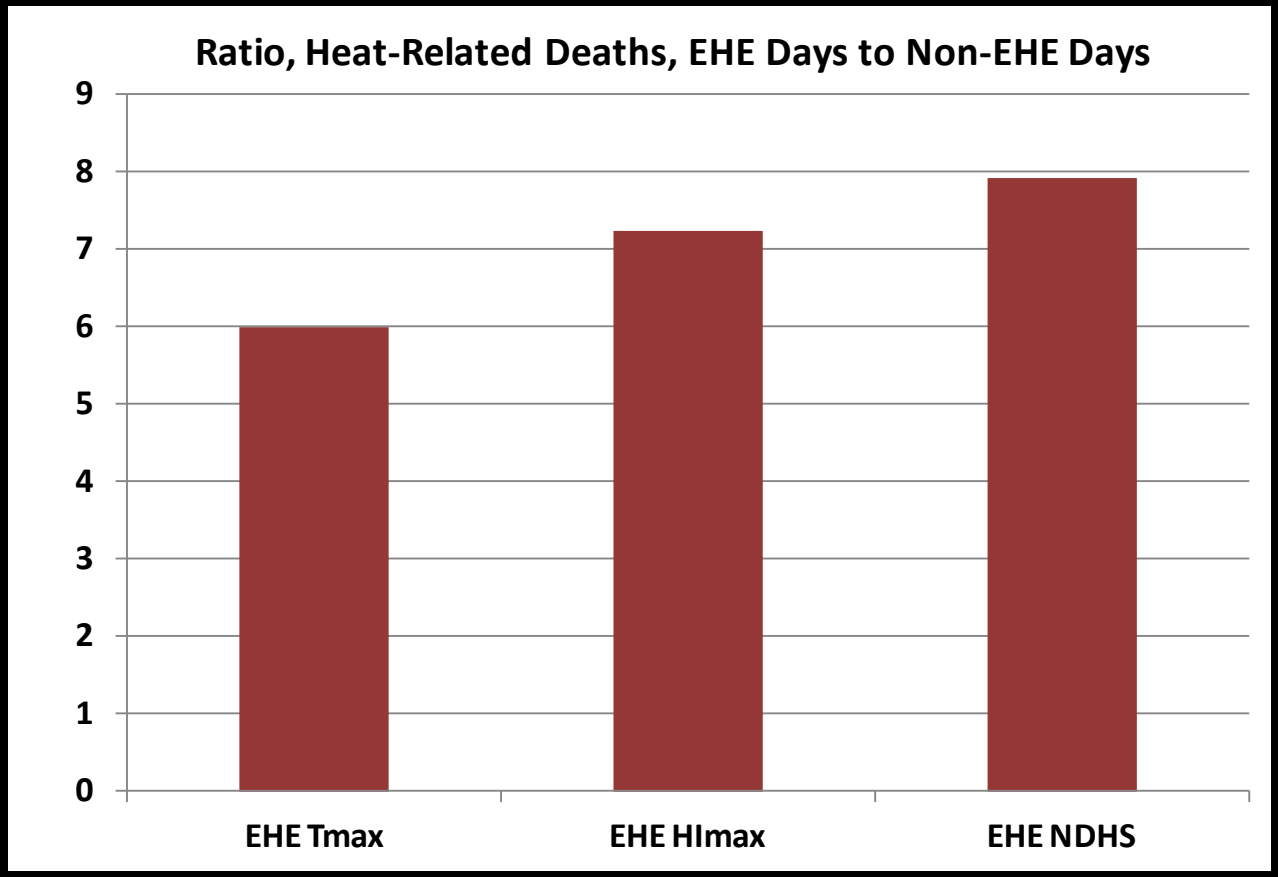


Deaths on EHE days highest for NDHS definition, lowest for max T definition.

Deaths on non-EHE days almost independent of EHE definition.

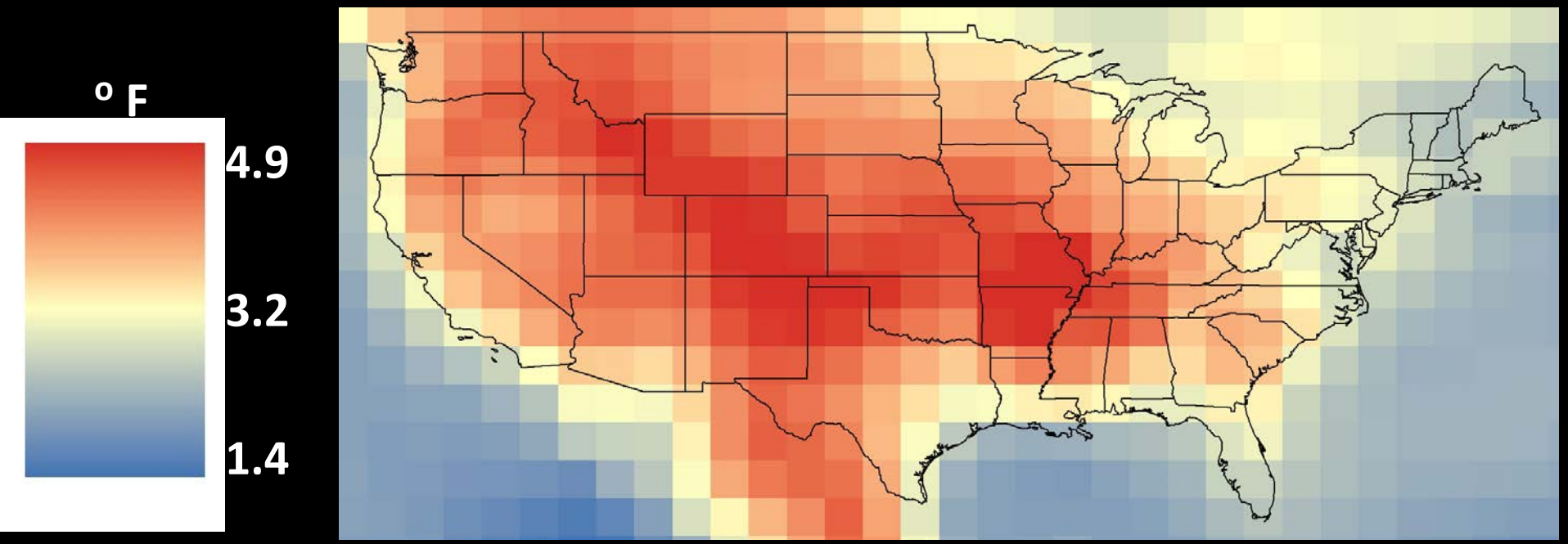
Comparison of EHE Definitions

The ratio of deaths per county per day on EHE days to deaths on non-EHE is a good indicator of the discriminating power of the EHE definition.



Mean Maximum Temperature Difference - August

2030-2049 minus 1980-1999, mean of all models, all ensemble members, A2 scenario

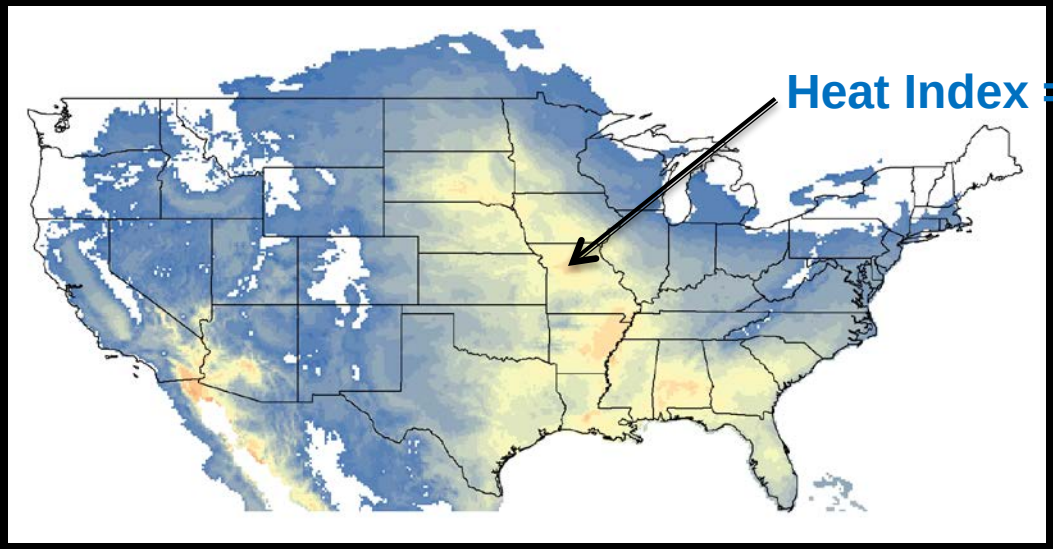


Example of current and future climates

Daily maximum Heat Index, A2 scenario

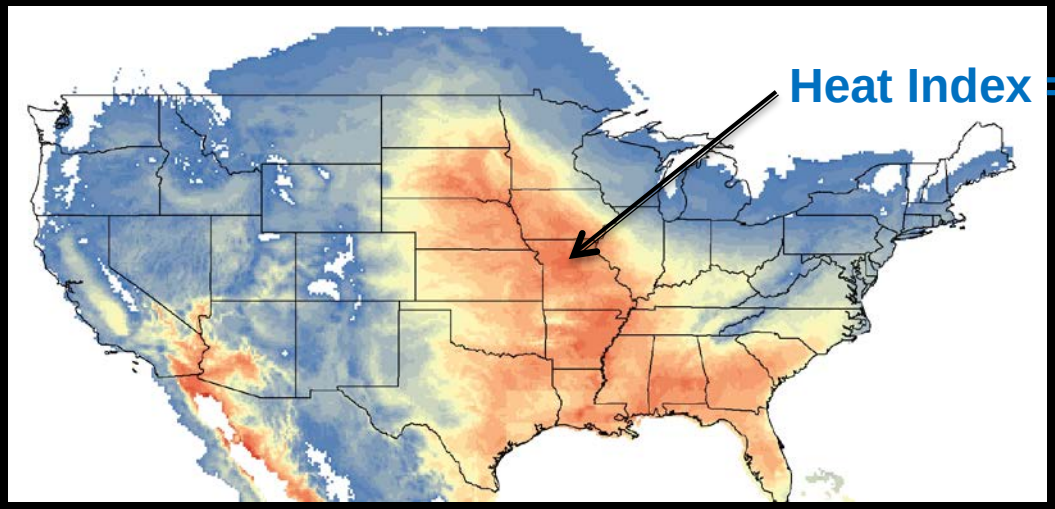
Heat Index (ºF)

- 78 - 80
- 80 - 84
- 84 - 88
- 88 - 92
- 92 - 96
- 96 - 100
- 100 - 102
- 102 - 104
- 104 - 106
- 106 - 108
- 108 - 110
- 110 - 112
- 112 - 114
- 114 - 116
- 116 - 118
- 118 - 120
- 120 - 122
- 122 - 124
- 124 - 126
- 126 - 128



Daily maximum
Heat Index
August 13, 2007

Add 2040-1990 Δ-climate (temperature & humidity) to obtain HI projections:



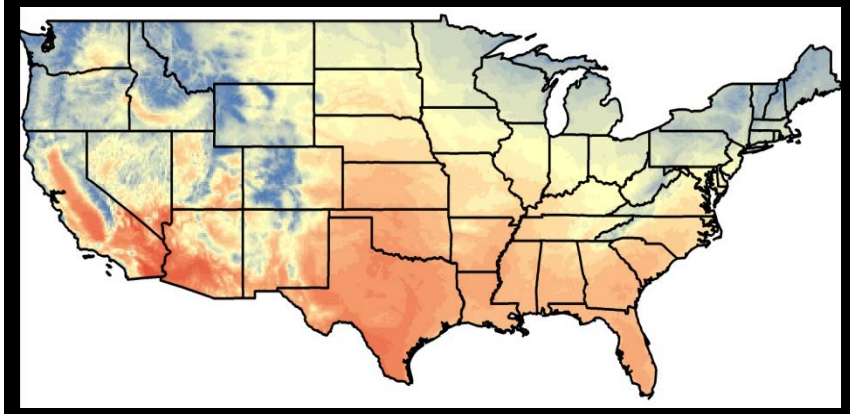
Daily maximum
Heat Index
August 13, 2007
analog
in 2041-2060 climate

May – September mean daily maximum temperatures
A2 Climate Scenario

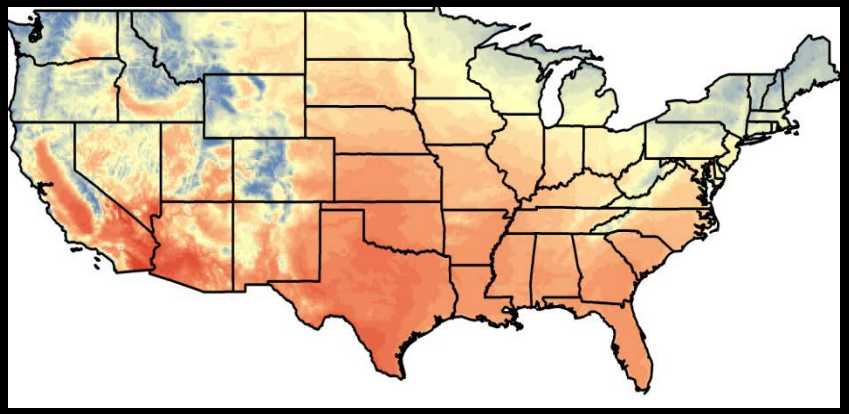
ºF

45 - 50
50 - 55
55 - 60
60 - 62
62 - 64
64 - 66
66 - 68
68 - 70
70 - 72
72 - 74
74 - 76
76 - 78
78 - 80
80 - 82
82 - 84
84 - 86
86 - 88
88 - 90
90 - 93
93 - 96
96 - 99
99 - 102
102 - 105
105 - 109
109 - 114

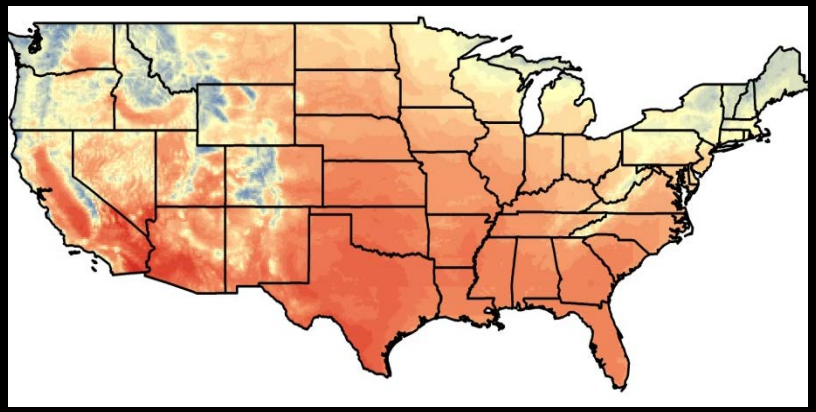
1981-2010



2031-2060



2081-2110

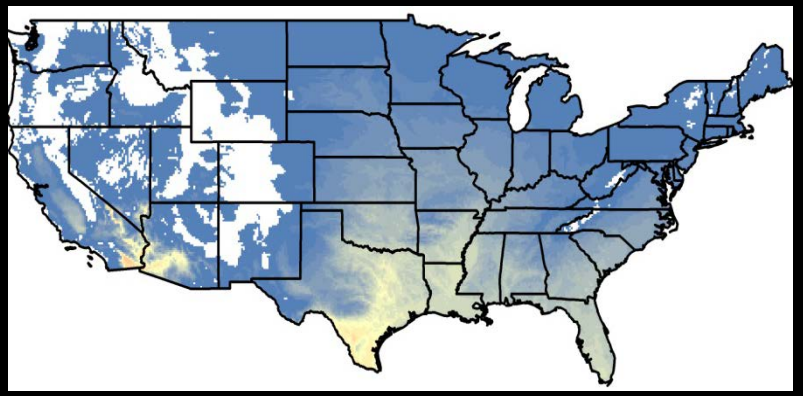


May – September mean total Net Daily Heat Stress
A2 Climate Scenario

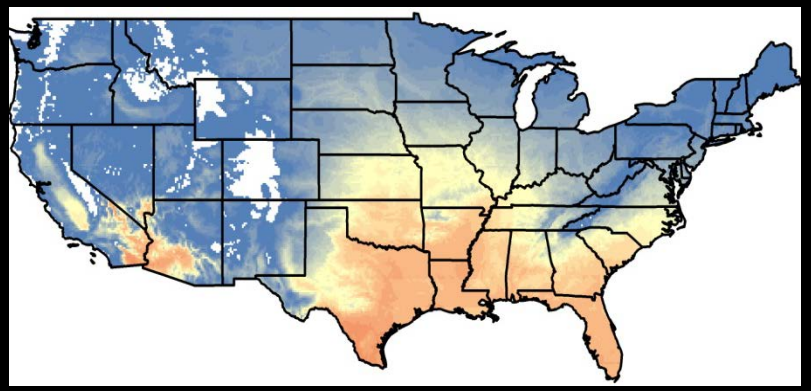
NDHS (degree-hrs)

- 0
- 0 - 500
- 500 - 1,000
- 1,000 - 2,000
- 2,000 - 3,000
- 3,000 - 4,000
- 4,000 - 5,000
- 5,000 - 6,000
- 6,000 - 7,000
- 7,000 - 8,000
- 8,000 - 9,000
- 9,000 - 10,000
- 10,000 - 12,000
- 12,000 - 14,000
- 14,000 - 17,000
- 17,000 - 20,000
- 20,000 - 25,000
- 25,000 - 30,000
- 30,000 - 35,000
- 35,000 - 40,000
- 40,000 - 45,000
- 45,000 - 50,000
- 50,000 - 55,000
- 55,000 - 65,000
- 65,000 - 75,000

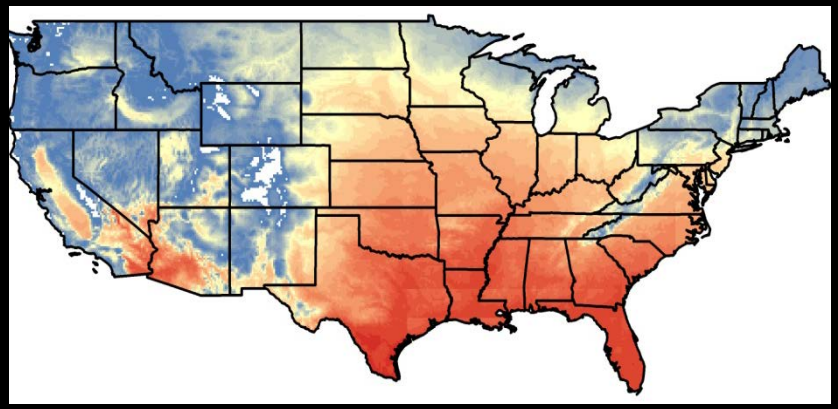
1981-2010



2031-2060

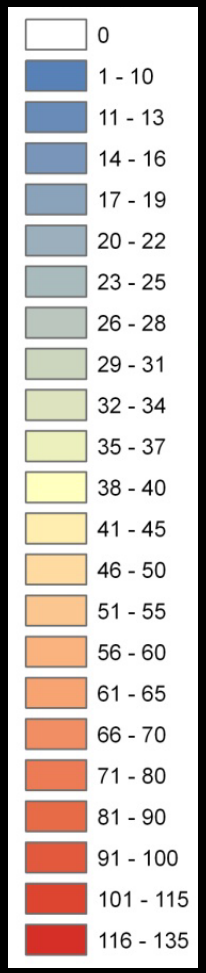


2081-2110

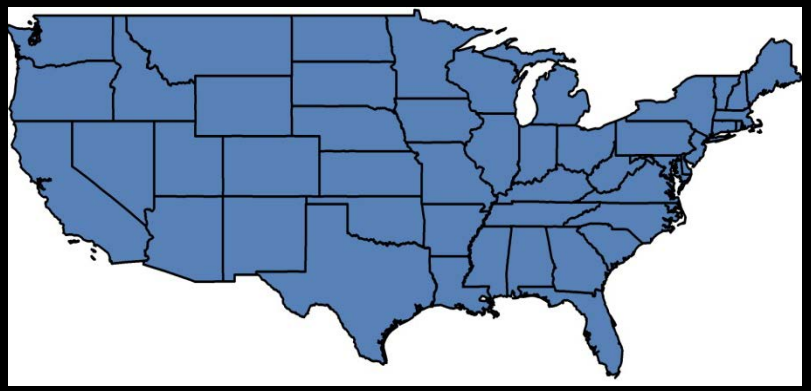


May – September Mean Number of Extreme Heat Event Days
Maximum Temperature Definition - A2 Climate Scenario

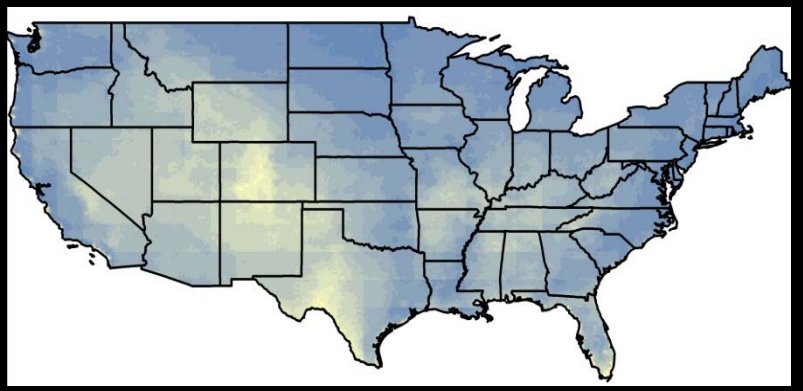
Number of days



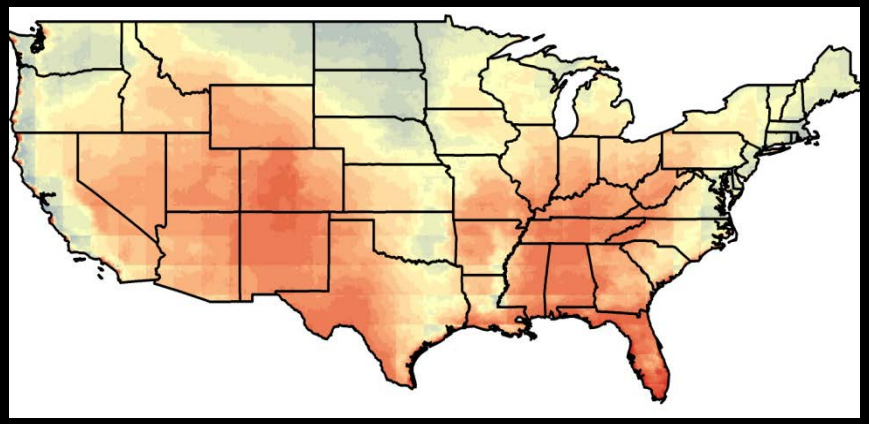
1981-2010



2031-2060



2081-2110



Note: Since EHE days are based on days exceeding percentiles for the local climate, the number of EHE days for the baseline period (1981-2010) is nearly uniform across the country, at about 6 days per year.

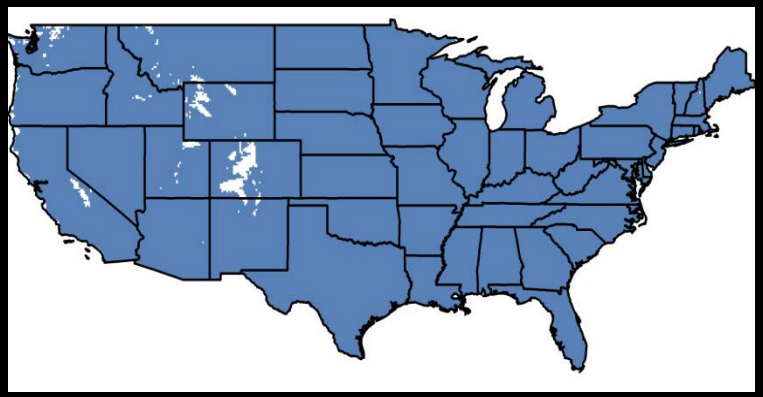
Based on the Maximum Temperature EHE definition, the mean annual number of EHE days rises to 20-40 for much of the country by mid-century , and to 50 – 100+ by the end of the century.

May – September Mean Number of Extreme Heat Event Days
Maximum Heat Index Definition - A2 Climate Scenario

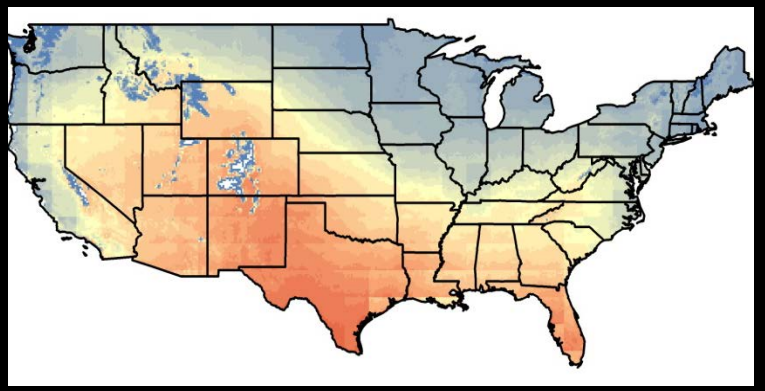
Number of days

- 0
- 1 - 10
- 11 - 13
- 14 - 16
- 17 - 19
- 20 - 22
- 23 - 25
- 26 - 28
- 29 - 31
- 32 - 34
- 35 - 37
- 38 - 40
- 41 - 45
- 46 - 50
- 51 - 55
- 56 - 60
- 61 - 65
- 66 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 125
- 126 - 150

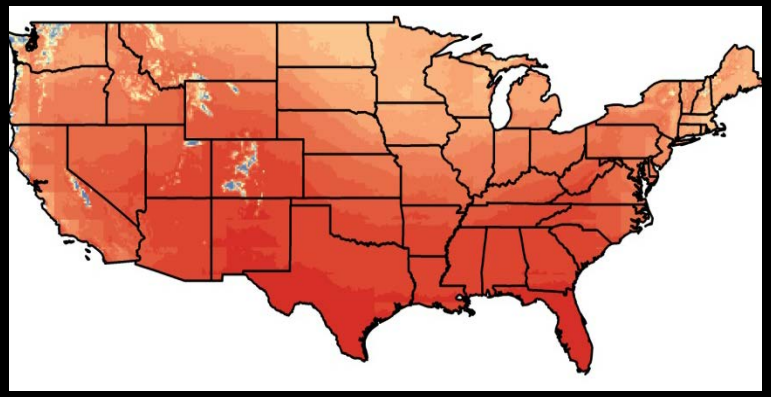
1981-2010



2031-2060



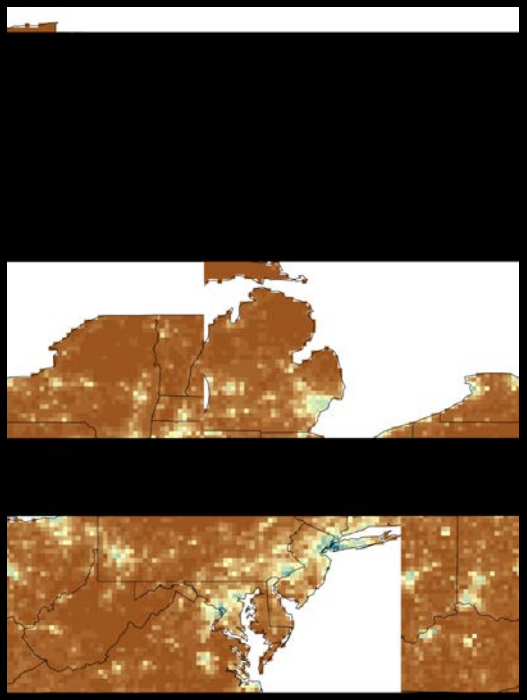
2081-2110



Based on the Maximum Heat Index EHE definition, the mean annual number of EHE days rises to 30-60 for much of the country by mid-century , and to 60 – 150 by the end of the century.

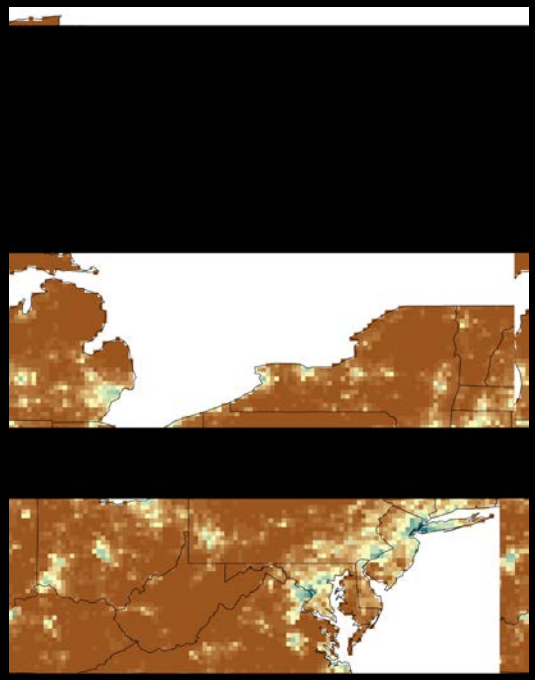
Population Projections on NLDAS Grid

Combine current gridded population estimates with county-level projections



2010 Population
NLDAS Grid

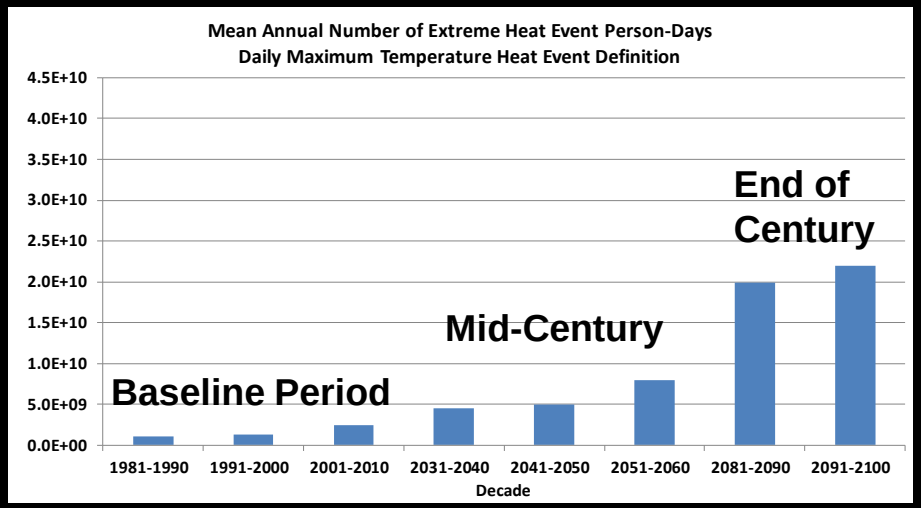
2050 County Projections
(EPA-ICLUS)

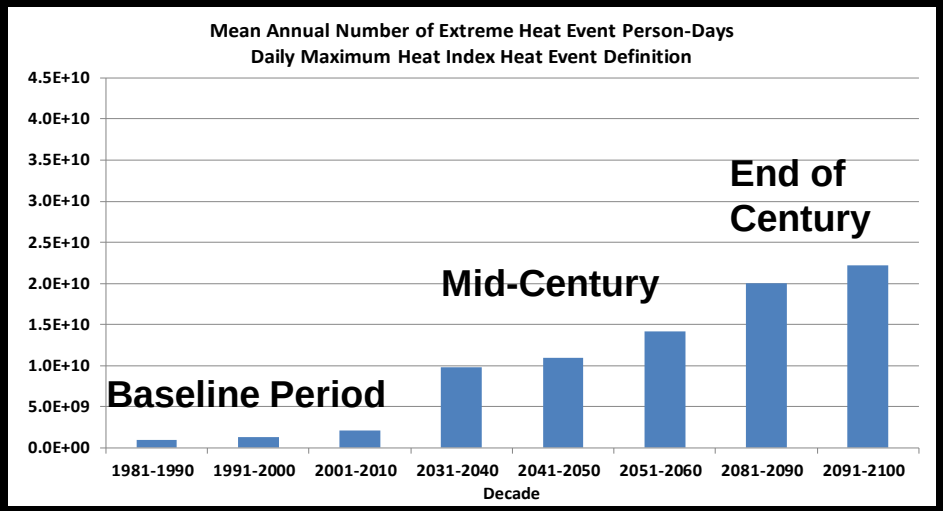


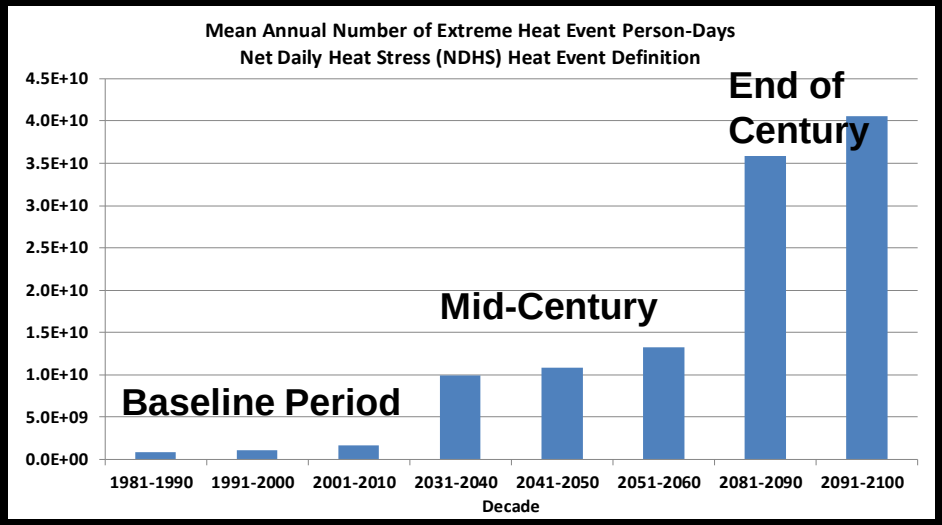
2050 Population
NLDAS Grid - A2 Scenario

- Population on the NLDAS grid were determined from 2010 U.S. Census Tract populations.
- County populations were determined by aggregating the NLDAS grid populations.
- The proportion of the county population within each NLDAS grid cell was computed by dividing the grid cell population by the respective county population.
- Populations in 5-year intervals to 2100 were estimated using projected county populations from EPA-ICLUS (Integrated Climate and Land Use Scenarios), keeping in-county distribution constant. The A2 climate scenario projections were used here.
- The 5-year projections were interpolated to create annual projections.

Population-Weighted Heat Wave Days Index
i.e. Mean Annual Number of Person-Days Experiencing Extreme Heat







These graphs show the mean annual number of EHE person-days by decade for the Continental US, based on three EHE definitions.

Products

- GCM-scale monthly climatologies of max/min air temperature and specific humidity for the historical period 1981-2000, and future changes relative to this period.
- NLDAS-scale daily max/min temperatures, maximum heat index and Net Daily Heat Stress for historical period.
- NLDAS-scale statistics over 20-year past and future periods of heat stress measures.
- County-level heat stress measures to enable assessments of heat impacts on public health.
- Population-weighted NDHS for coterminous U.S.

Summary

- GCM monthly means of max/min air temperature and specific humidity for a historical period (1981-2000) and mid-century and late-century periods were used together with NLDAS data to simulate realizations of future heat-related metrics: daily max/min temperatures, maximum Heat Index and Net Daily Heat Stress over the CONUS.

- Summertime mean values of each heat metric are shown to increase substantially over the next century.

- Population data projected to 2100 were used to calculate population-weighted heat metrics.

- Three definitions of Excessive Heat Events were used to determine the number of heat wave days, on a CONUS grid, for the future climate scenarios.

- The number of heat wave days and the number of persons exposed to excessive heat are expected to increase greatly over the next century.

Ongoing Research

- Incorporate county populations to evaluate EHE indicators on a per-exposure basis.

- Perform U.S. regional analyses to determine if different EHE definitions are more suited for certain regions.

- Perform analysis with additional EHE definitions, including some with fixed thresholds of temperature and Heat Index.

- Include contributing death factors in analysis.

- Consider other causes of death that may be indirectly heat-related, such as cardiovascular and respiratory causes.