UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

OCT 19 2018

MEMORANDUM

SUBJECT: Considerations for Identifying Maintenance Receptors for Use in Clean Air Act Section 110(a)(2)(D)(i)(I) Interstate Transport State Implementation Plan Submissions for the 2015 Ozone National Ambient Air Quality Standards

FROM: Peter Tsirigotis
Director

TO: Regional Air Division Directors, Regions 1–10

The purpose of this memorandum is to present information that states may consider as they evaluate the status of monitoring sites that the Environmental Protection Agency (EPA) identified as potential maintenance receptors with respect to the 2015 ozone National Ambient Air Quality Standards (NAAQS) based on EPA's 2023 modeling.[1] States may use this information when developing state implementation plans (SIPs) for the 2015 ozone NAAQS addressing the good neighbor provision in Clean Air Act (CAA) section 110(a)(2)(D)(i)(I). In brief, this document discusses (1) using alternative technical methods for projecting whether future air quality warrants identifying monitors as maintenance receptors and (2) considering current monitoring data when identifying monitoring sites that, although projected to be in attainment, as described below, should be identified as maintenance receptors because of the risk that they could exceed the NAAQS due to year-to-year (*i.e.*, inter-annual) variability in meteorological conditions.

This document does not substitute for provisions or regulations of the CAA, nor is it a regulation itself. Rather, it provides recommendations for states using the included analytical information in developing SIP submissions, and for EPA Regional offices in acting on them. Thus, it does not impose binding, enforceable requirements on any party. State air agencies retain the discretion to develop good neighbor SIP revisions that differ from this guidance.

Following the recommendations in this guidance does not ensure that EPA will approve a SIP revision in all instances where the recommendations are followed, as the guidance may not apply to the facts and circumstances underlying a particular SIP. Final decisions by EPA to approve

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[1] Information on the Interstate Transport State Implementation Plan Submissions for the 2015 Ozone National Ambient Air Quality Standards under Clean Air Act Section 110(a)(2)(D)(i)(I) (March 2018). *https://www.epa.gov/airmarkets/2015-ozone-naaqs-mem.*

a particular SIP revision will only be made based on the requirements of the statute following an air agency's final submission of the SIP revision to EPA and after appropriate notice and opportunity for public review and comment. Interested parties may raise comments about the appropriateness of the application of this guidance to a particular SIP revision. EPA and air agencies should consider whether the recommendations in this guidance are appropriate for each situation.

Introduction

CAA section 110(a)(2)(D)(i)(I), otherwise known as the good neighbor provision, requires states to prohibit emissions "which will contribute significantly to nonattainment in, or interfere with maintenance by, any other state with respect to any" NAAQS. EPA has historically used a 4-step framework to determine upwind state obligations (if any) under the good neighbor provision for regional pollutants like ozone: (1) identify downwind areas, referred to as "receptors," expected to have problems attaining or maintaining the NAAQS; (2) identify upwind states that contribute to those downwind air quality problems and warrant further review and analysis; (3) identify the emissions reductions (if any) necessary to eliminate an upwind state's significant contribution to nonattainment and/or interference with maintenance of the NAAQS in the downwind areas, considering cost and air quality factors; and (4) adopt permanent and enforceable measures needed to achieve those emissions reductions. EPA notes that, in developing their SIP revisions for the 2015 ozone NAAQS, states have flexibility to follow this framework or develop alternative frameworks to evaluate interstate transport obligations, so long as a state's chosen approach has adequate technical justification and is consistent with the requirements of the CAA.

At Step 1, EPA has historically used base year and future year air quality modeling coupled with base period measured ozone design values to project design values to a future analytic year.[2] In a memo issued in March 2018, EPA released updated modeling, which uses 2011 as the base year and 2023 as the future analytic year, to evaluate interstate transport for the 2015 ozone NAAQS.[3] As part of EPA's 2023 modeling analysis, EPA projected the average and maximum base period 2009 – 2013 design values to 2023.[4,5] EPA evaluated the projected 2023 design values in combination with measured 2016 design values using the same methodology used in the Cross-State Air Pollution Rule Update (CSAPR Update)[6] to identify receptors with anticipated potential nonattainment and maintenance issues with respect to the 2015 ozone NAAQS in 2023. Under the CSAPR Update methodology, those sites that are violating the NAAQS based on 2016 design values (*i.e.*, currently not attaining) and that also have projected 2023 *average* design values that exceed the NAAQS (*i.e.*, 2023 average design values of 71 parts per billion (ppb) or greater) are

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[2] Air Quality Modeling Technical Support Document for the Final Cross State Air Pollution Rule Update (August 2016). *https://www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule*.

[3] Information on the Interstate Transport State Implementation Plan Submissions for the 2015 Ozone National Ambient Air Quality Standards under Clean Air Act Section 110(a)(2)(D)(i)(I) (March 2018). *https://www.epa.gov/airmarkets/march-2018-memo-and-supplemental-information-regarding-interstate-transport-sips-2015*.

[4] The base period includes the three design values that contain 2011 monitoring data (*i.e.*, 2009-2011, 2010-2012, and 2011-2013).

[5] The base period maximum design value is the highest of the three design values in the period 2009-2013.

[6] *See* 81 FR 74504 (October 26, 2016).

identified as potential nonattainment receptors in 2023.[7] Under the CSAPR Update methodology, those sites with a 2023 *maximum* 3-year design value that exceeds the NAAQS are identified as potential maintenance receptors. This methodology considers the effects of inter-annual variability in ozone-conducive meteorology to identify sites that may have difficulty maintaining the ozone NAAQS. A projected maximum design value that exceeds the NAAQS indicates that when meteorology is conducive to ozone formation, the receptor struggles with maintenance of the standard. Under the CSAPR Update methodology, maintenance-only receptors therefore include both (1) those sites with projected average and maximum design values above the NAAQS that are currently measuring clean data and (2) those sites with projected average design values below the level of the NAAQS but with projected maximum design values of 71 ppb or greater.[8]

Considerations for Identifying Maintenance Receptors

The D.C. Circuit's decision in *North Carolina v. EPA* requires that EPA and the states identify separate nonattainment and maintenance receptors to give independent significance to the "contribute significantly" and "interfere with maintenance" clauses of the good neighbor provision when identifying downwind air quality problems that must be addressed.[9] In particular, the court held that the good neighbor provision requires states to address emissions that interfere with maintenance in downwind areas struggling to meet the NAAQS despite air quality modeling projecting attainment.[10] While the court did not specify a particular methodology for identifying downwind areas that would struggle to maintain the NAAQS, the court cited the state petitioner's demonstration regarding historic variability in ozone concentrations in areas otherwise projected to attain the NAAQS in support of its holding.[11]

In rules promulgated after *North Carolina*, EPA has relied on projections of base period maximum design values to identify those sites that are at risk of being nonattainment in the future due to inter-annual variability in ozone-conducive meteorology, as indicated above. EPA acknowledges that there may be other valid methodologies for identifying such areas. However, consistent with the holding in *North Carolina*, EPA believes that any alternative methods used to identify maintenance receptors must be different than those used to identify nonattainment receptors and should demonstrate that the alternative method considers variability in meteorological conditions that are conducive for ozone formation in the area containing the monitoring site.

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[7] In determining compliance with the NAAQS, EPA truncates ozone design values to integer values. For example, EPA truncates a design value of 70.9 ppb to 70 ppb, which is attainment. Similarly, EPA considers design values at or above 71.0 ppb to be violations of the 2015 ozone NAAQS.

[8] The nonattainment receptors are also identified as maintenance receptors because the maximum design values for each of these sites is always greater than or equal to the average design value.

[9] 531 F.3d 896, 909-911 (2008).

[10] *Id.*

[11] *Id.* at 909.

Flexibilities Related to Identifying Maintenance Receptors

In response to comments received through stakeholder outreach, EPA has identified two potential flexibilities that states may use to identify maintenance receptors with an appropriate technical demonstration. First, EPA believes that states may, in some cases, eliminate a site as a maintenance receptor if the site is currently measuring clean data. Second, EPA believes that a state may, in some cases, use a design value from the base period that is not the maximum design value.[12] For either of these alternative methods to satisfy the D.C. Circuit's instruction to consider areas struggling to meet the NAAQS, EPA would expect states to include with their SIP demonstration technical analyses showing that:

(1) meteorological conditions in the area of the monitoring site were conducive to ozone formation during the period of clean data or during the alternative base period design value used for projections;
(2) ozone concentrations have been trending downward at the site since 2011 (and ozone precursor emissions of nitrogen oxide (NOx) and volatile organic compounds (VOC) have also decreased); and
(3) emissions are expected to continue to decline in the upwind and downwind states out to the attainment date of the receptor.

The intent of these analyses is to demonstrate that monitoring sites that would otherwise be identified as maintenance receptors under the CSAPR Update approach, as previously described, are not likely to violate the NAAQS in the future analytic year. EPA expects that, with such analyses, the state could justify exclusion of a monitoring site as a maintenance receptor, notwithstanding modeling projections showing a maximum design value exceeding the 2015 ozone NAAQS.

To assist states with the recommended analyses, EPA is providing the following information related to analyzing meteorological conduciveness and ozone and emissions trends:

(1) information on meteorological conduciveness for ozone formation based on regional and state-level historical and current climatological data for summertime monthly and seasonal temperature (*see* Attachment A);
(2) a data file containing ozone design values for individual monitoring sites nationwide for the years 2008 through 2017 and for 2023, based on EPA's modeling. This information is available on EPA's website at: *https://www.epa.gov/airmarkets/march-2018-memo-and-supplemental-information-regarding-interstate-transport-sips-2015-0*; and
(3) a data file containing state-level annual NOx and VOC emissions from anthropogenic sources with a breakout by major source category, for individual years from 2011 through 2017 and for 2023, based on EPA's projections. This information is available on EPA's website at:

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[12] Stakeholder comments on potential 2015 NAAQS transport flexibilities can be found at *https://www.epa.gov/airmarkets/march-2018-memo-and-supplemental-information-regarding-interstate-transport-sips-2015*.

https://www.epa.gov/airmarkets/march-2018-memo-and-supplemental-information-regarding-interstate-transport-sips-2015-0.

States developing the technical analyses necessary to support use of the flexibilities described in this memo are encouraged to supplement EPA-provided information with additional data (as appropriate) to support a showing that a specific monitoring site is not at risk of exceeding the NAAQS in the future. For example, states may show that such a site should not be identified as a maintenance receptor by providing (1) a more refined analysis of meteorological conduciveness that considers additional relevant or more locally tailored meteorological parameters, (2) a more temporally or spatially refined emissions trends analysis, and/or (3) an analysis of historical ozone trends that considers, in addition to the design value, trends in other ozone metrics such as annual 4th high 8-hour daily maximum ozone concentrations and the number of days with measured exceedances of the 2015 NAAQS.

Please share this information with the air agencies in your Region.

For Further Information

If you have any questions concerning this memorandum, please contact Norm Possiel at (919) 541-5692, *possiel.norm@epa.gov* for modeling information or Chris Werner at (919) 541-5133, *werner.christopher@epa.gov* for any other information.

Attachment

Attachment A

Information on Meteorological Conduciveness for Ozone Formation

Meteorological conditions including temperature, humidity, winds, solar radiation, and vertical mixing affect the formation and transport of ambient ozone concentrations. Ozone is more readily formed on warm, sunny days when the air is stagnant and/or when the winds are favorable for transport from upwind source areas. Conversely, ozone production is more limited on days that are cloudy, cool, rainy, and windy (*http://www.epa.gov/airtrends/weather.html*). Statistical modeling analyses have shown that temperature and certain other meteorological variables are highly correlated with the magnitude of ozone concentrations (Camalier, et al., 2007).[1] The overall extent to which meteorological conditions vary from year-to-year (*i.e.*, inter-annual variability) depends on the nature of large scale meteorological drivers such as the strength and position of the jet stream. Inter-annual cycles in the jet stream contribute to inter-annual variability in the degree to which summertime meteorological conditions are favorable for ozone formation within a particular region. Meteorological conditions that frequently correspond with observed 8-hour daily maximum concentrations greater than the National Ambient Air Quality Standards (NAAQS) are referred to as being conducive to ozone formation.

This attachment contains information to help evaluate whether particular summers had ozone-conducive or unconducive meteorology within the 10-year period 2008 through 2017. Information is provided on a state-by-state basis and for individual regions (*see* Figure 1).

- Table A-1 contains tabular summaries of the difference (*i.e.*, anomaly[2]) of monthly average temperature compared to the long-term average.[3]
- Figure A-2 contains maps of the 3-month (June, July, August) statewide anomalies and rank[4] for average temperature compared to the long-term average.
- Figure A-3 contains maps showing spatial fields of daily maximum temperature anomalies (percentiles) for the period June through August for the years 2011 through 2017 (maps are unavailable for years prior to 2011).
- Figure A-4 contains graphical summaries of the total number of cooling degree days for the 3-month period June through August in each region.

The above tabular and graphic information was obtained from the NOAA National Centers for Environmental Information (NCEI) at *https://www.ncdc.noaa.gov/temp-and-precip/us-maps/* and *https://www.ncdc.noaa.gov/cag/.*

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[1] Additional references related to ozone formation and meteorology are provided on page A-3.

[2] "The term temperature anomaly means a departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value." *https://www.ncdc.noaa.gov/monitoring-references/faq/anomalies.php*.

[3] Note that because of the relatively large inter-annual variability in certain meteorological conditions such as temperature and precipitation, long-term "average" conditions, usually referred to as "normal," are often the mathematical mean of extremes and thus, "average" or "normal" values of temperature or precipitation should not necessarily be considered as representing "typical" conditions.

[4] "In order to place each month and season into historical context, the National Centers for Environmental Information assigns ranks for each geographic area (division, state, region, etc.) based on how the temperature or precipitation value compares with other values throughout the entire record when sorted from lowest to highest value. In other words, the numeric rank value within the area represents the position or location of the sorted value throughout the historical record (1895-present)." *https://www.ncdc.noaa.gov/monitoring-references/dyk/ranking-definition*.

In general, below average temperatures are an indication that meteorological conditions are unconducive for ozone formation, whereas above average temperatures are an indication that meteorology is conducive to ozone formation. Within a particular summer season, the degree that meteorology is conducive for ozone formation can vary from region to region and fluctuate with time within a particular region. For example, the temperature-related information presented below suggests that summer meteorology was generally conducive for ozone formation in 2010, 2011, 2012, and 2016 in most regions. In contrast, the summer of 2009 was generally unconducive for ozone formation, overall, in most regions. In addition, the summers of 2013 and 2014 were not particularly conducive for ozone formation in the Upper Midwest, Ohio Valley, South, Southeast.

Additional information on the relationships between ozone and meteorological conditions can be found in the following publications:

Blanchard et al., 2010 - *NMOC, ozone, and organic aerosol in the southeastern United States, 1999-2007: 2. Ozone trends and sensitivity to NMOC emissions in Atlanta, GA.*
Reinforces the relationship between temperature, relative humidity and winds to ozone formation.
https://www.sciencedirect.com/science/article/pii/S1352231010005996?via%3Dihub

Blanchard et al., 2014 - *Ozone in the southeastern United States: An observation-based model using measurements from the SEARCH network.*
Update to the 2007 paper by Camalier with data from the SEARCH network from 2002-2011.
https://www.sciencedirect.com/science/article/pii/S1352231014001022?via%3Dihub

Bloomer et al., 2009 – *Observed relationships of ozone air pollution with temperature and emissions.*
Statistical analysis of 21 years of ozone and temperature data (1987-2008). From a climate scenario perspective, authors examine the climate penalty or how ozone levels change as temperature changes. Reinforces the standing that as temperature increases, ozone concentrations increase, but indicates that due to decreasing emissions, the rate is slower in future scenarios.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2009GL037308

Kavassalis & Murphy, 2017 - *Understanding ozone-meteorology correlations: A role for dry deposition.*
Authors observe the strong correlation between temperature and relative humidity, but work to understand other reasoning why models under predict the strength of the correlation between relative humidity and ozone. Includes a statistical analysis of 28 years of data and examines vapor pressure deficit and dry deposition as factors. Reinforces meteorological conditions that lead to high ozone days.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL071791

Reddy & Pfister, 2016 - *Meteorological Factors contributing to the interannaul variability of midsummer surface ozone in Colorado, Utah, and other western US States.*

Authors found strong correlation between 500-mb and 7008-mb patterns, surface temperature, and zonal winds with the resulting high 8-hour daily maximum ozone values.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015JD023840

Tawfik and Steiner, 2013 - *A proposed physical mechanism for ozone-meteorology correlations using land-atmosphere coupling regimes.*
Discusses the north-south gradient of temperature and relative humidity correlations with ozone formation. Examines 17 years of ozone, NOx, and isoprene measurements.
https://linkinghub.elsevier.com/retrieve/pii/S1352231013001672

White et al., 2007 - *Comparing the impact of meteorological variability on surface ozone during the NEAQS (2002) and ICARTT (2004) field campaigns.*
Authors found that while deep boundary layers are noted during periods of elevated ozone, this is likely due to being coincident with other meteorological factors (high temperatures, high pressure systems, low winds).
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JD007590

Zhang et al., 2017 – *Quantifying the relationship between air pollution events and extreme weather events.*
Authors examined ozone from 1980-2009 and built a statistical model to examine the impacts of extreme meteorological events on extreme air quality conditions. Found ozone extremes have decreased over the last 30 years, more rapidly recently, but remain highly correlated to extreme temperature events. Highest correlation was found in the eastern United States (U.S.).
https://www.sciencedirect.com/science/article/pii/S0169809516306093?via%3Dihub

Figure 1. U.S. climate regions.
http://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php

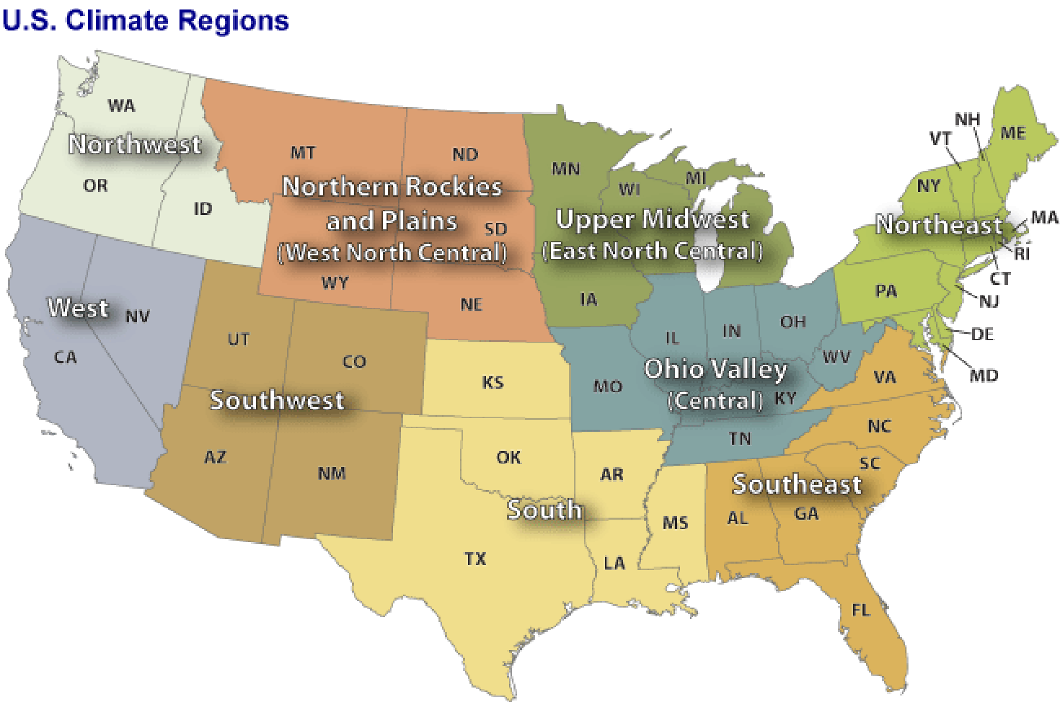


Table A-1. Temperature anomalies by month for May through September for each climate region for the years 2008 through 2017.[1]

2008	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	C	W	W	C	N
Southeast	C	WW	N	C	N
Ohio Valley	C	W	C	C	N
Upper Midwest	C	N	N	N	W
South	N	W	N	C	CC
Northern Rockies	C	C	N	N	N
Southwest	N	W	W	W	N
Northwest	N	N	W	W	N
West	N	W	W	WW	W

[1] Unshaded boxes with the "N" marker represent near-normal temperatures that fall within the interquartile range. Blue colors indicate cooler than normal conditions, with the number of "C"s indicating the degree of the anomaly. CCC = coolest on record, CC = coolest 10th percentile, C = coolest 25th percentile. Red colors indicate warmer than normal conditions, with the number of "W"s indicating the degree of the anomaly. WWW = warmest on record, WW = warmest 10th percentile, W = warmest 25th percentile. N/A = data not available. More on the definition of temperature ranks can be found at: *https://www.ncdc.noaa.gov/monitoring-content/monitoring-references/dyk/images/ranking-definition-legend.png.*

2009	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	N	C	CC	W	C
Southeast	N	W	CC	N	N
Ohio Valley	N	W	CC	C	N
Upper Midwest	N	C	CC	C	W
South	N	W	N	N	C
Northern Rockies	N	C	C	C	WW
Southwest	WW	C	W	W	W
Northwest	W	C	WW	W	WW
West	WW	C	W	N	WWW

2010	May	Jun	Jul	Aug	Sep
Northeast	WW	W	WW	W	W
Southeast	WW	WW	WW	WW	W
Ohio Valley	W	WW	W	WW	N
Upper Midwest	W	N	W	WW	C
South	W	WW	N	WW	W
Northern Rockies	C	N	N	W	N
Southwest	C	W	W	W	WWW
Northwest	CC	C	N	N	W
West	CC	W	W	N	W

2011	May	Jun	Jul	Aug	Sep
Northeast	W	W	WW	N	WW
Southeast	N	WW	WW	WW	N
Ohio Valley	N	W	WW	W	C
Upper Midwest	N	N	WW	W	N
South	N	WW	WWW	WWW	N
Northern Rockies	C	N	W	W	W
Southwest	C	W	WW	WWW	W
Northwest	CC	C	C	W	WW
West	C	C	N	W	WW

2012	May	Jun	Jul	Aug	Sep
Northeast	WW	N	WW	W	N
Southeast	WW	C	WW	N	N
Ohio Valley	WW	N	WW	N	C
Upper Midwest	W	W	WW	N	N
South	WW	W	WW	N	N
Northern Rockies	W	W	WW	W	W
Southwest	WW	WW	W	WW	W
Northwest	N	C	W	WW	W
West	W	W	N	WWW	WW

2013	May	Jun	Jul	Aug	Sep
Northeast	W	W	WW	N	N
Southeast	C	W	C	C	N
Ohio Valley	N	N	C	C	N
Upper Midwest	N	N	N	N	W
South	C	W	C	N	W
Northern Rockies	N	N	N	W	WW
Southwest	W	WW	W	W	W
Northwest	W	W	WW	WW	WW
West	W	WW	WW	N	W

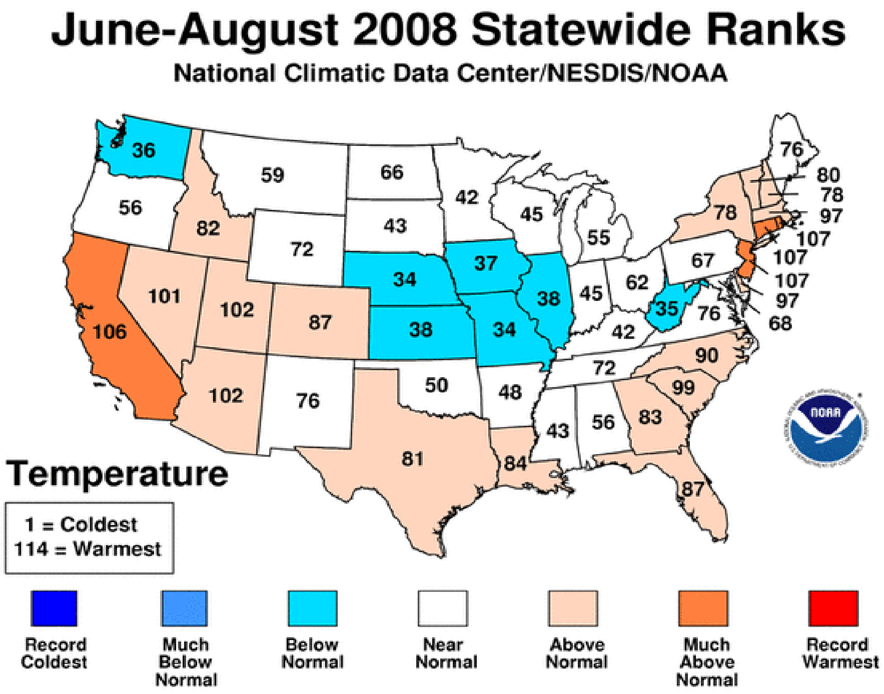
2014	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	W	W	N	N	W
Southeast	W	W	C	N	W
Ohio Valley	N	W	CC	N	N
Upper Midwest	N	W	CC	N	N
South	N	N	C	N	N
Northern Rockies	N	C	N	N	N
Southwest	N	W	W	C	WW
Northwest	W	N	WW	W	W
West	W	W	WW	N	WW

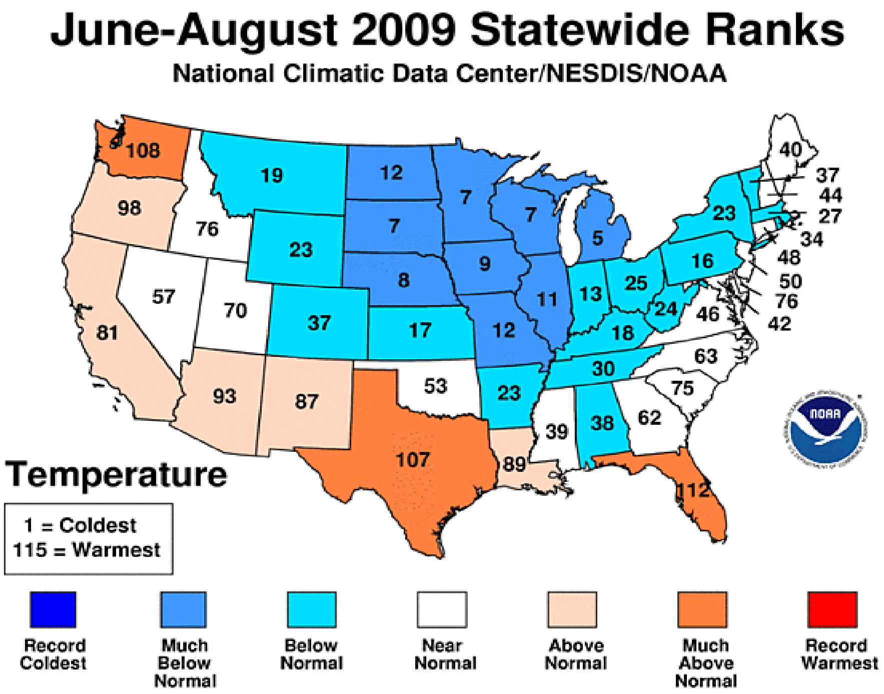
2015	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	WWW	N	N	W	WW
Southeast	W	WW	W	N	N
Ohio Valley	W	W	N	C	W
Upper Midwest	N	N	N	N	WWW
South	C	N	W	N	WW
Northern Rockies	C	WW	N	N	WW
Southwest	C	WW	C	WW	WWW
Northwest	W	WWW	W	W	N
West	N	WWW	C	WW	WW

2016	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	N	W	W	WWW	WW
Southeast	N	W	WW	WW	WW
Ohio Valley	N	W	W	W	WW
Upper Midwest	N	W	N	W	WW
South	C	W	WW	N	W
Northern Rockies	N	WW	N	N	W
Southwest	C	WWW	WW	N	N
Northwest	W	WW	C	W	N
West	N	WW	W	W	N

2017	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Northeast	N	W	N	N	WW
Southeast	N	N	W	N	N
Ohio Valley	N	N	W	CC	N
Upper Midwest	N	W	N	C	WW
South	C	N	W	C	N
Northern Rockies	N	W	WW	N	W
Southwest	N	WW	WW	W	W
Northwest	W	W	WW	WWW	W
West	W	WW	WW	WW	N

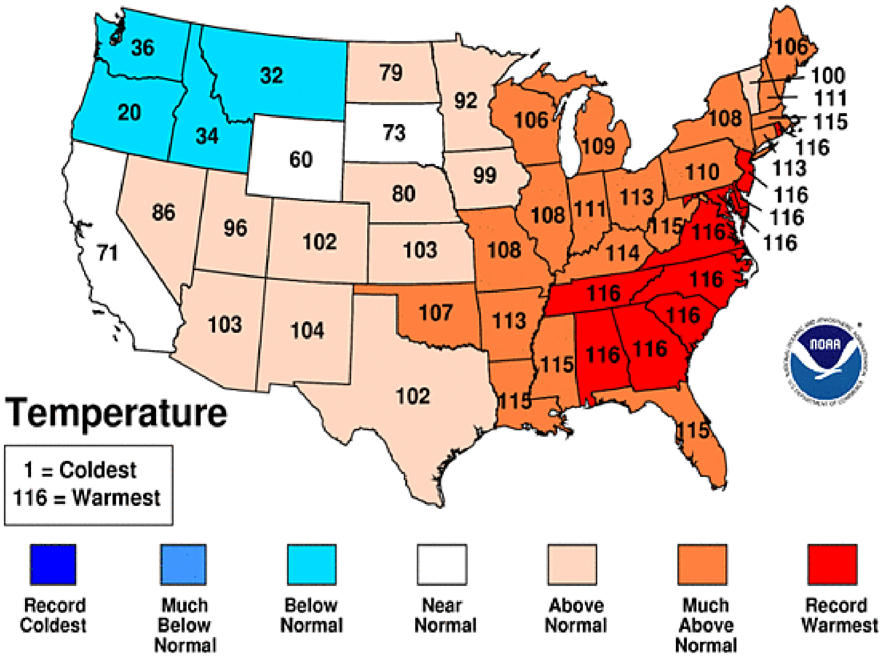
Figure A-2. Statewide average temperature ranks for the period June through August for the years 2008 through 2017. Note that the NCEI changed the display format of temperature rank maps beginning in 2014.





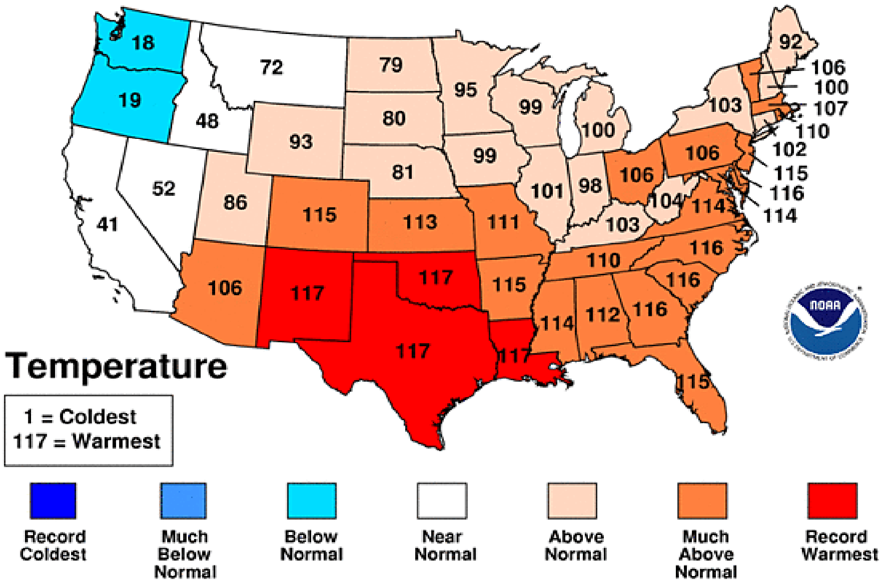
June-August 2010 Statewide Ranks

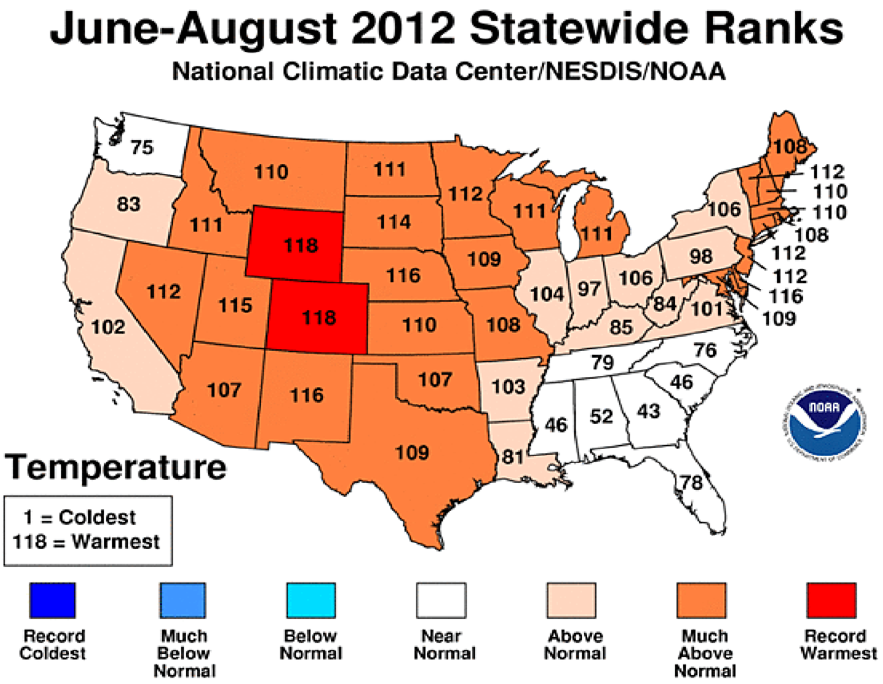
National Climatic Data Center/NESDIS/NOAA



June-August 2011 Statewide Ranks

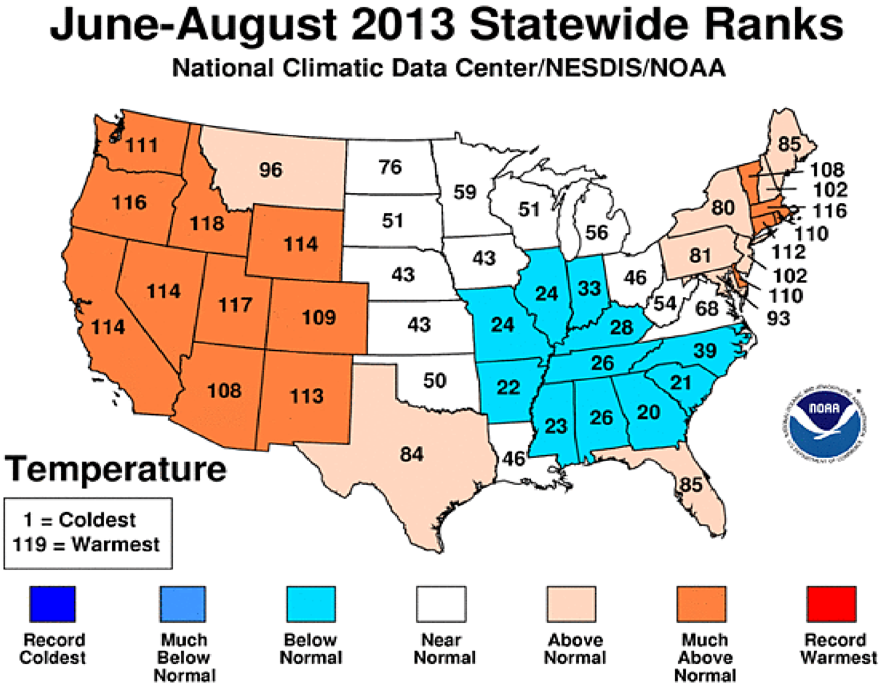
National Climatic Data Center/NESDIS/NOAA





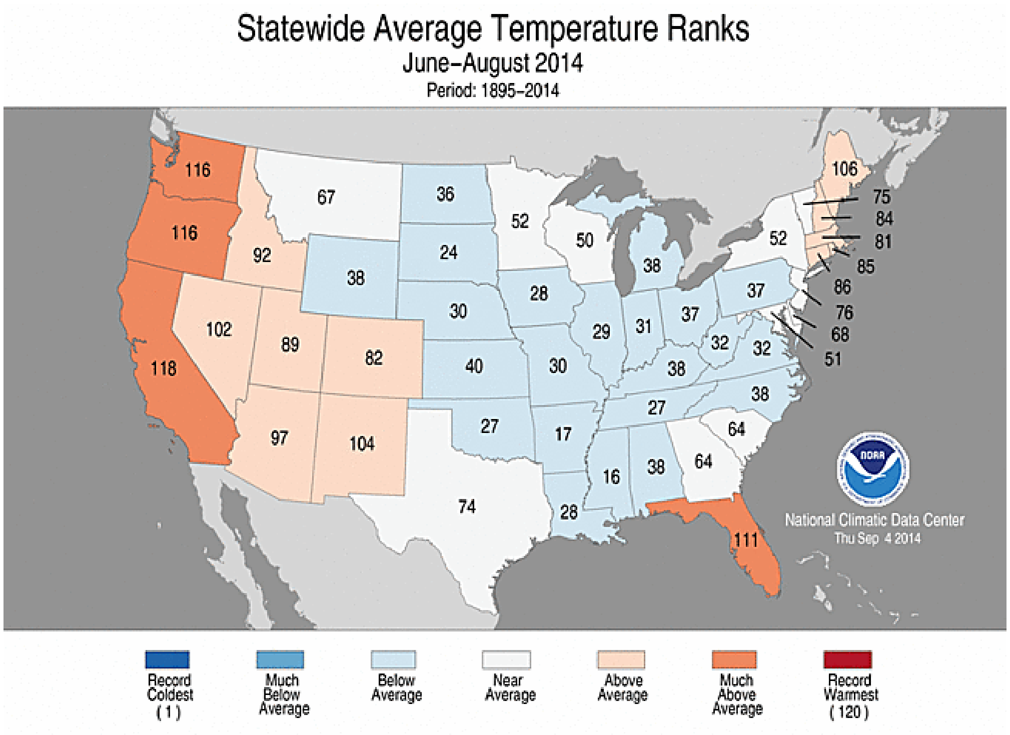
June-August 2012 Statewide Ranks

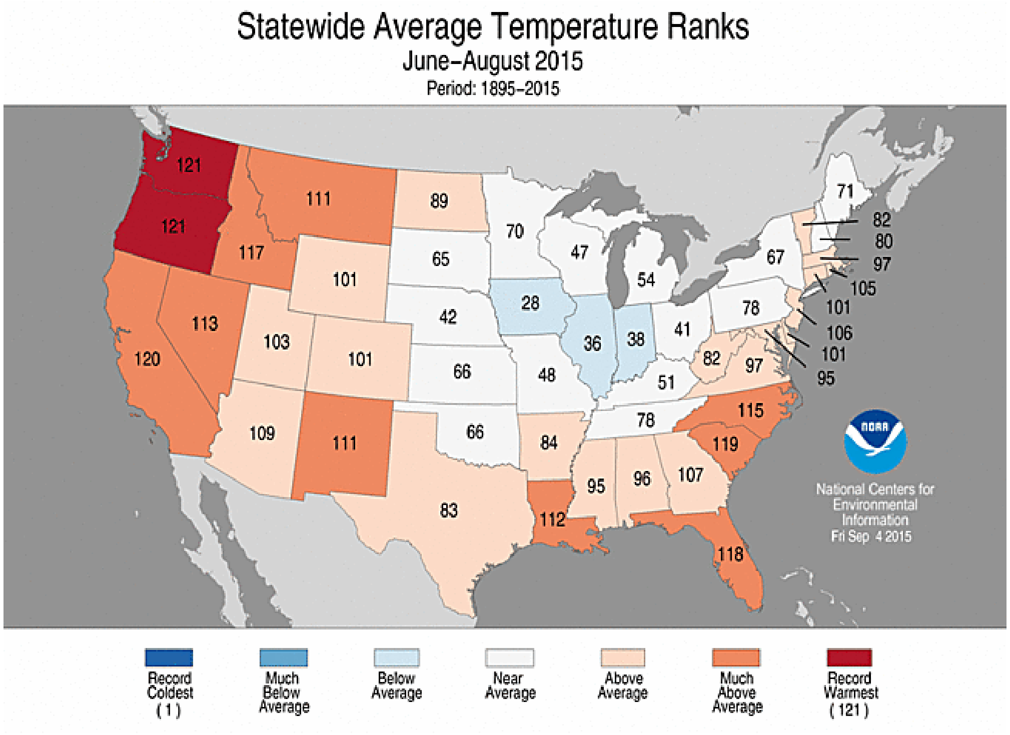
National Climatic Data Center/NESDIS/NOAA

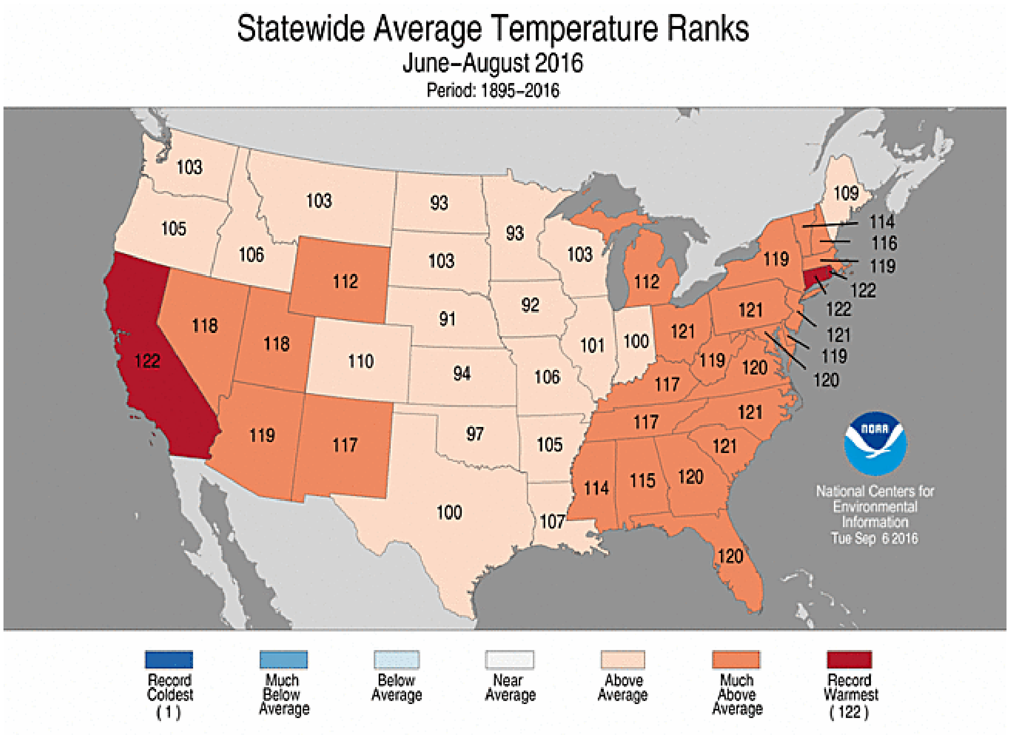


June-August 2013 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA

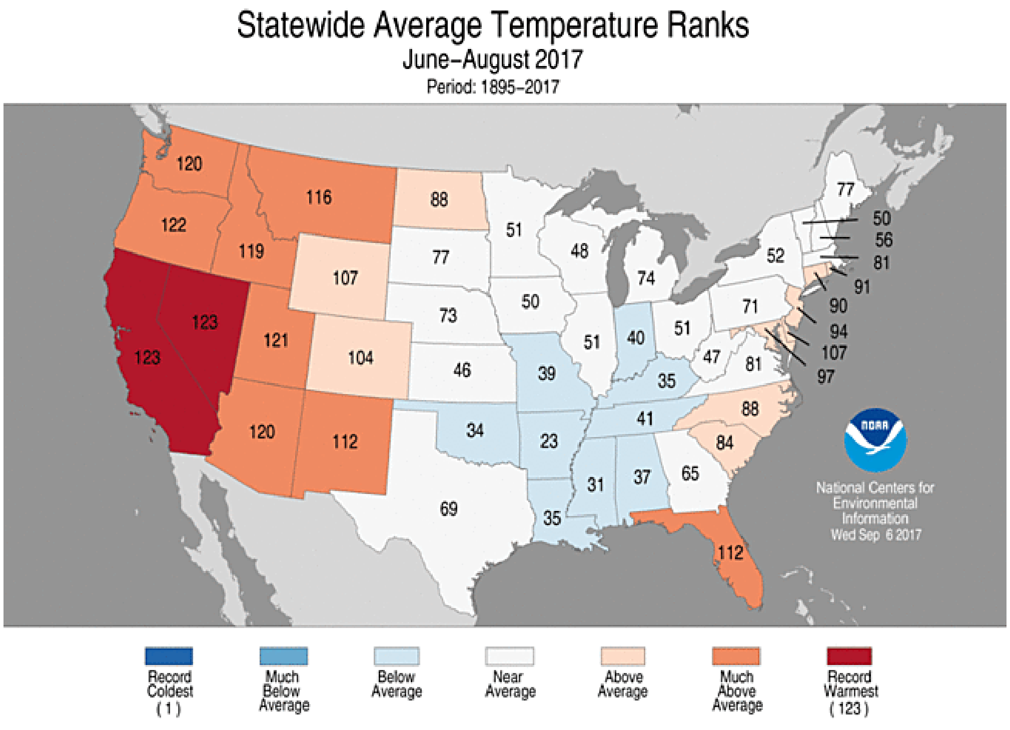

Statewide Average Temperature Ranks
June–August 2014
Period: 1895–2014
116
116
92
67
36
24
52
50
38
38
102
89
30
28
37
52
106
75
84
81
85
86
76
68
51
118
82
40
30
29
31
37
32
32
38
97
104
27
17
27
38
64
16
38
64
74
28
111
National Climatic Data Center
Thu Sep 4 2014
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (120)


Statewide Average Temperature Ranks
June–August 2015
Period: 1895–2015
121
121
111
89
70
47
71
117
65
101
54
67
82
80
97
105
101
106
101
95
28
78
42
113
103
101
66
48
36
38
41
82
97
120
51
115
78
109
111
66
84
119
95
96
107
83
112
118
National Centers for Environmental Information
Fri Sep 4 2015
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (121)



Statewide Average Temperature Ranks
June–August 2016
Period: 1895–2016

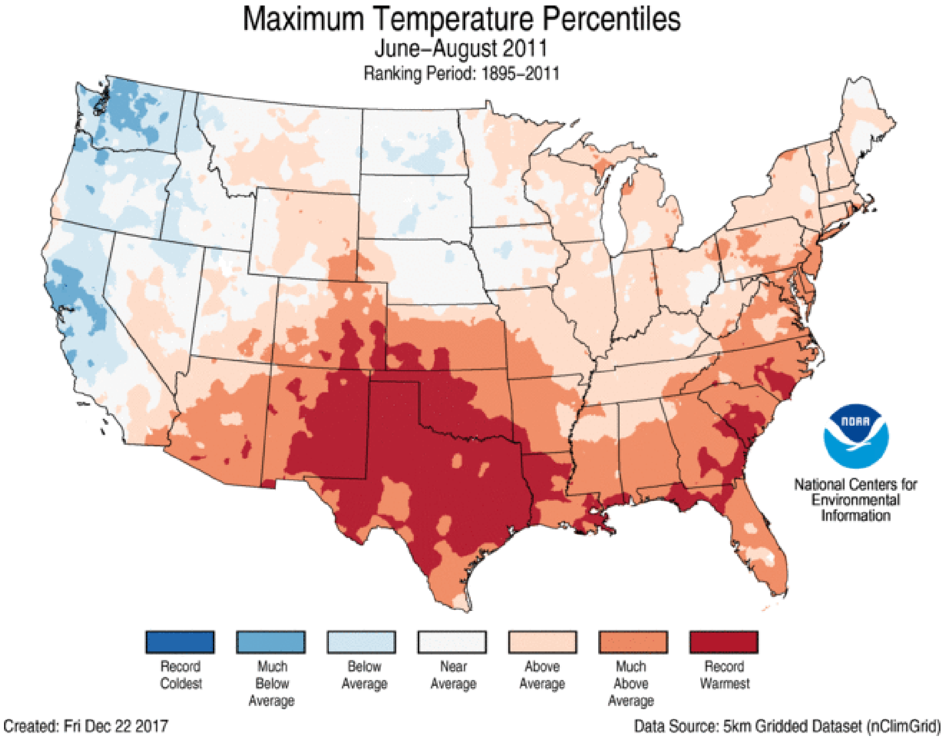
National Centers for Environmental Information
Tue Sep 6 2016

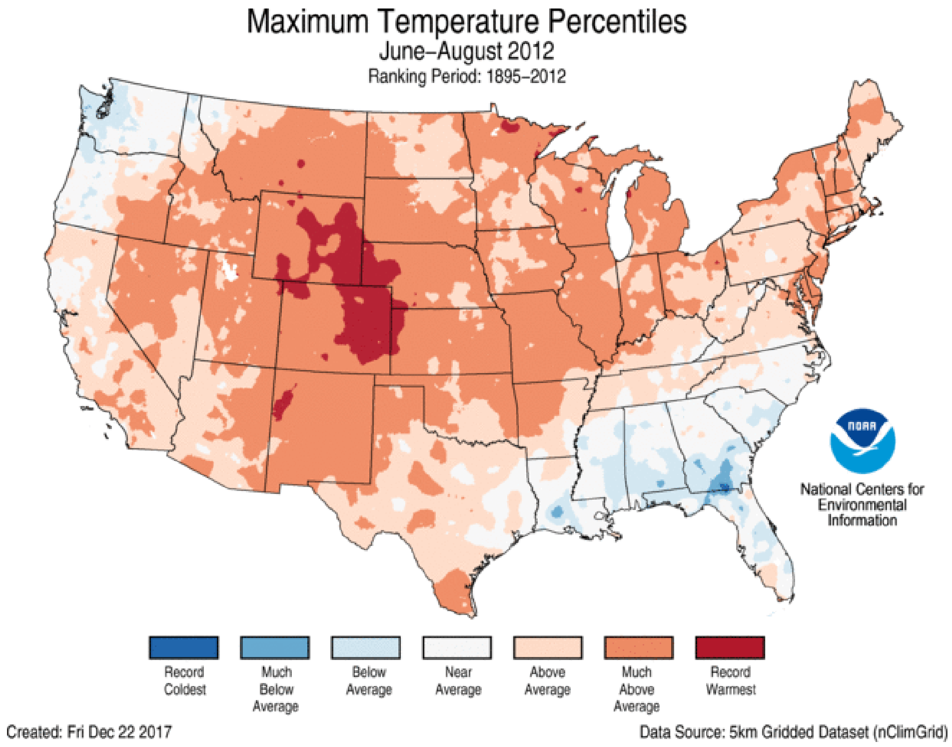


Statewide Average Temperature Ranks
June–August 2017
Period: 1895–2017

National Centers for Environmental Information
Wed Sep 6 2017

Figure A-3. Spatial fields of daily maximum temperature anomalies (percentiles) for the period June through August for the years 2011 through 2017. Note that the NCDC began creating these maps in 2011.

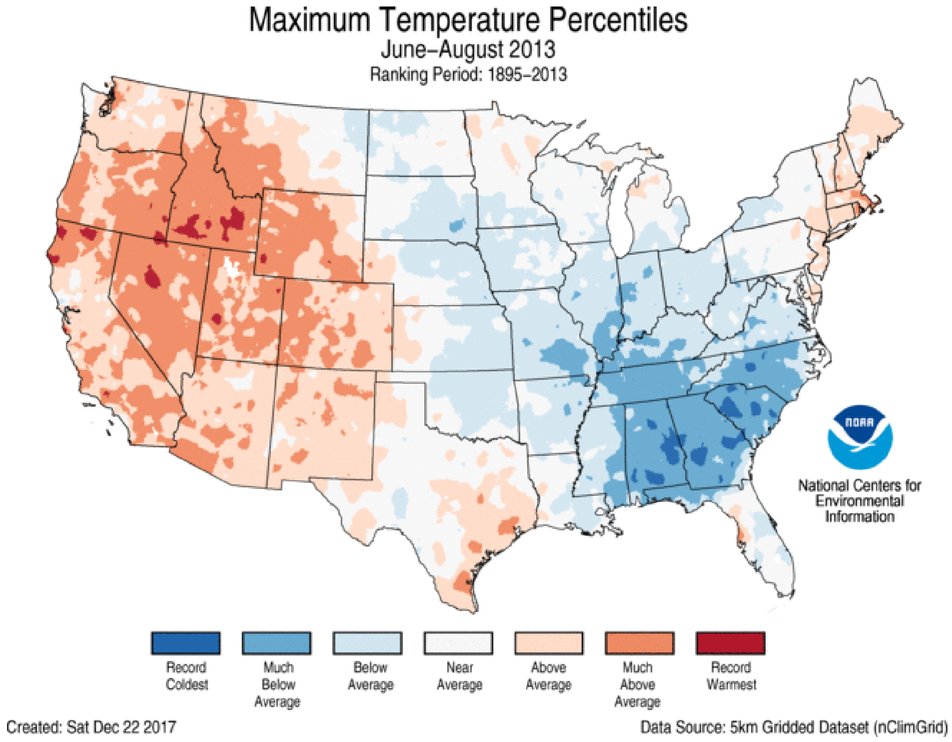




Maximum Temperature Percentiles
June–August 2012
Ranking Period: 1895–2012

Created: Fri Dec 22 2017

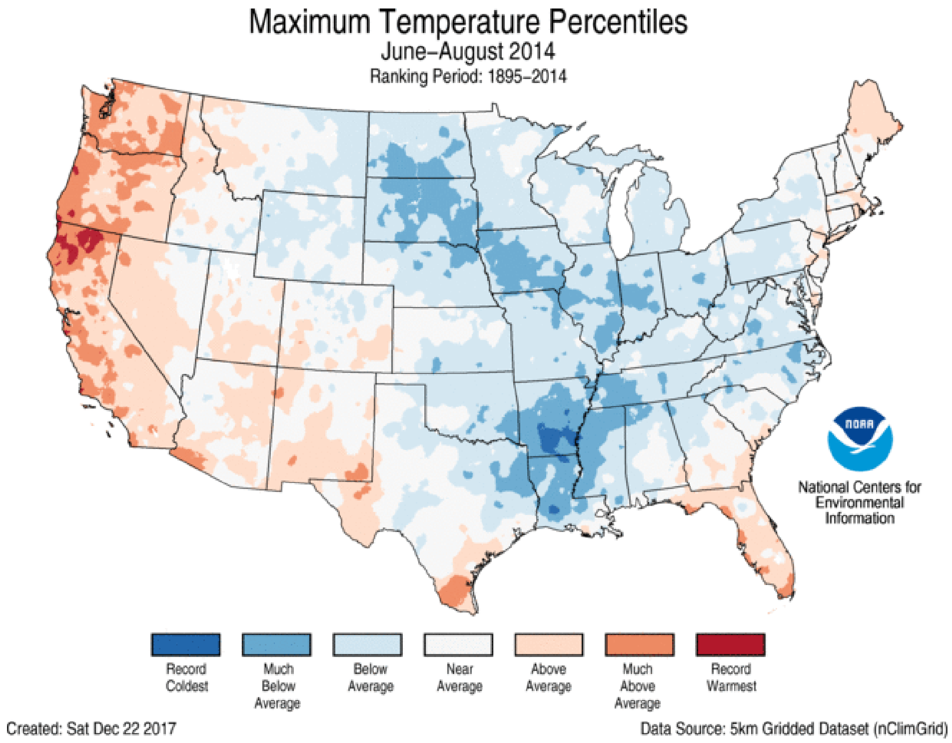
Data Source: 5km Gridded Dataset (nClimGrid)

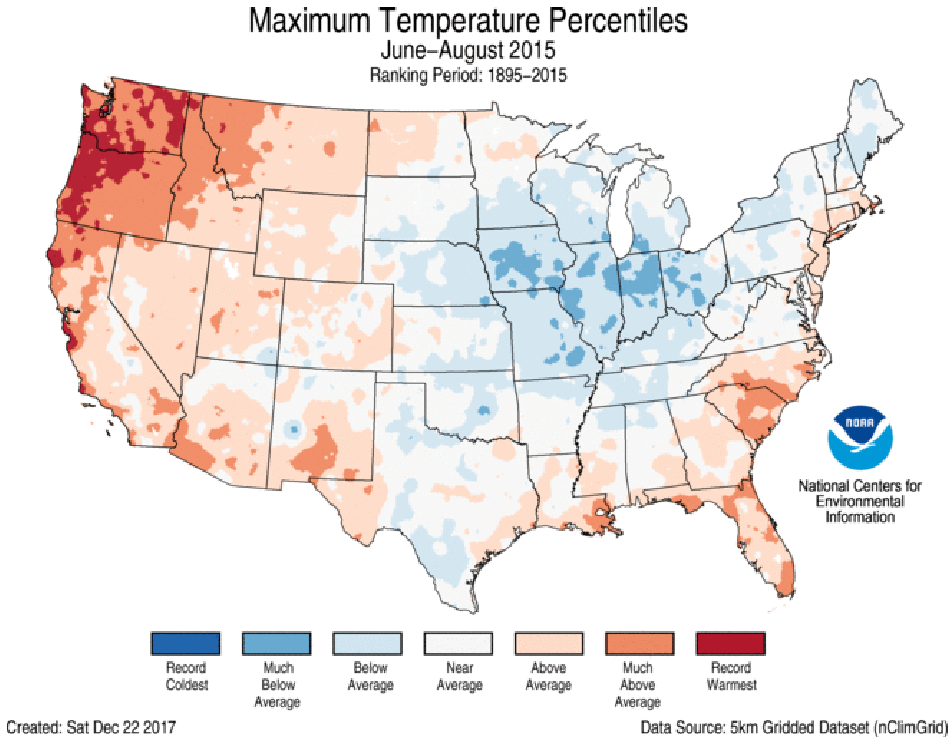


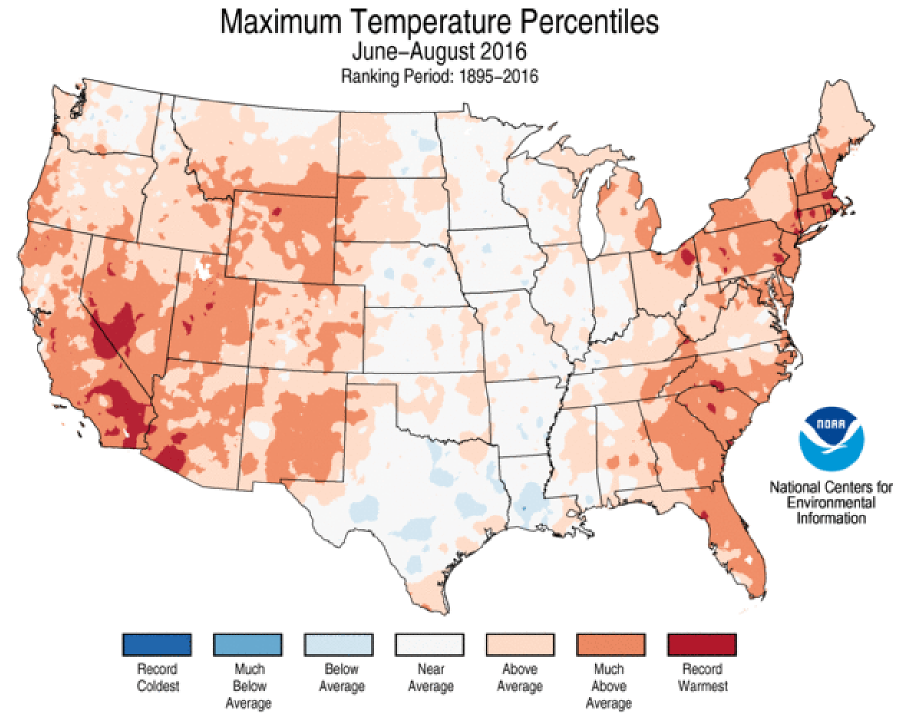
Maximum Temperature Percentiles
June–August 2013
Ranking Period: 1895–2013

Created: Sat Dec 22 2017

Data Source: 5km Gridded Dataset (nClimGrid)


Maximum Temperature Percentiles
June–August 2014
Ranking Period: 1895–2014
NOAA
National Centers for Environmental Information
Record Coldest
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest
Created: Sat Dec 22 2017
Data Source: 5km Gridded Dataset (nClimGrid)

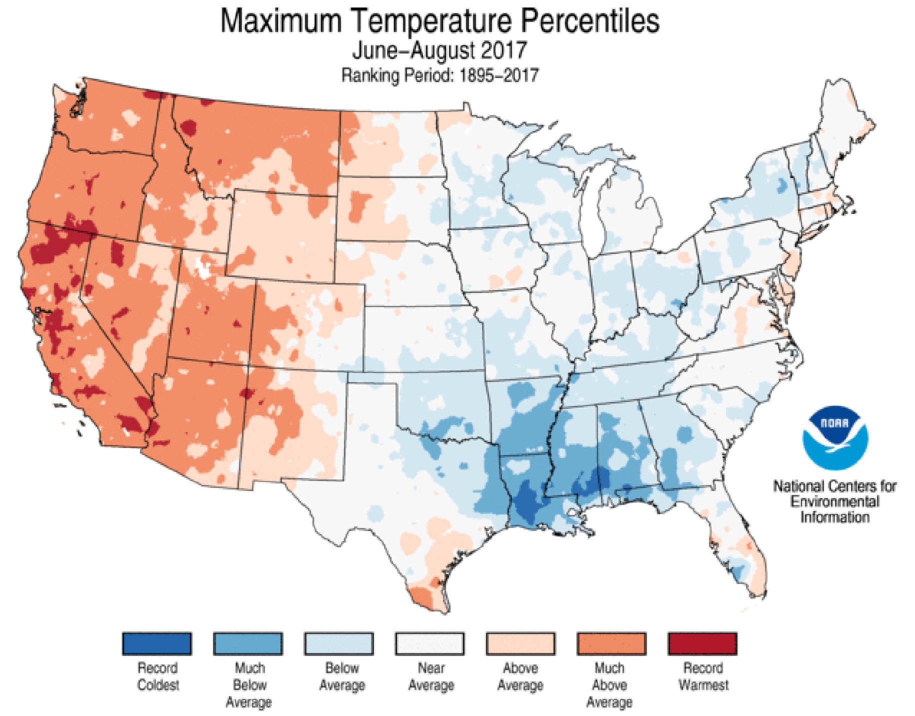

Maximum Temperature Percentiles
June–August 2015
Ranking Period: 1895–2015
NOAA
National Centers for Environmental Information
Record Coldest
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest
Created: Sat Dec 22 2017
Data Source: 5km Gridded Dataset (nClimGrid)



Maximum Temperature Percentiles
June–August 2016
Ranking Period: 1895–2016

Created: Sat Dec 22 2017

Data Source: 5km Gridded Dataset (nClimGrid)

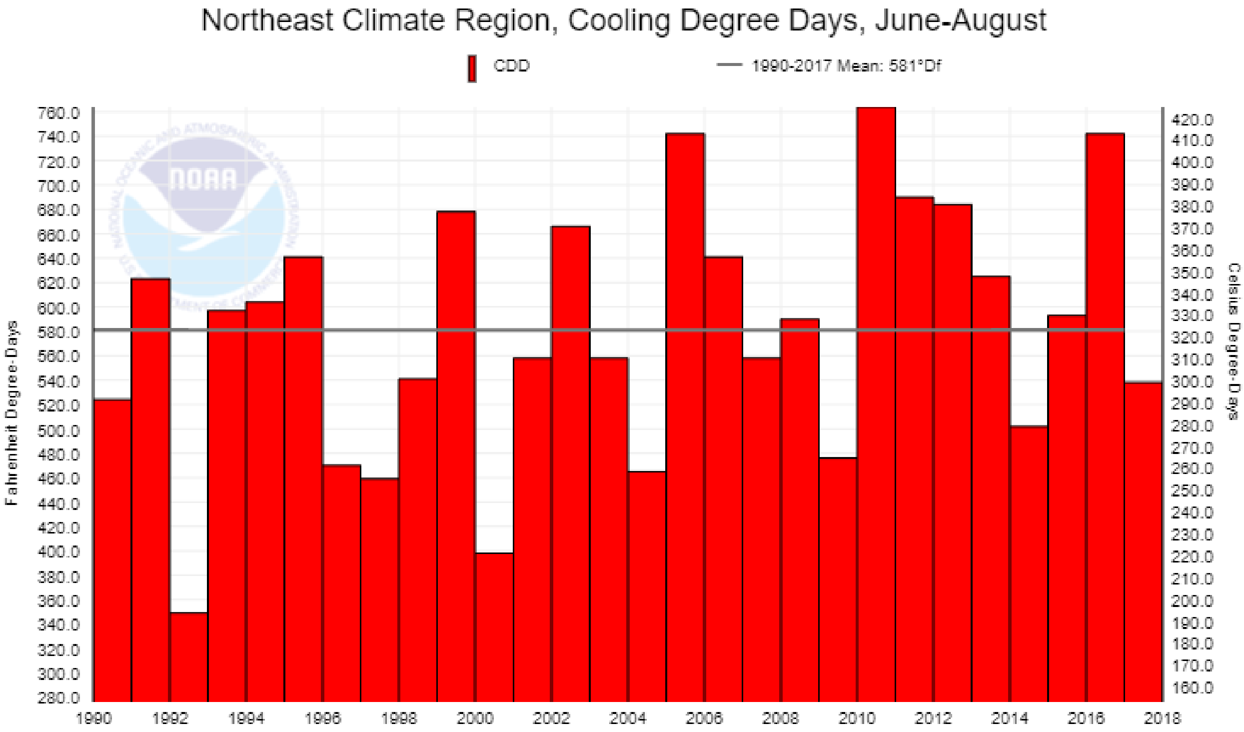


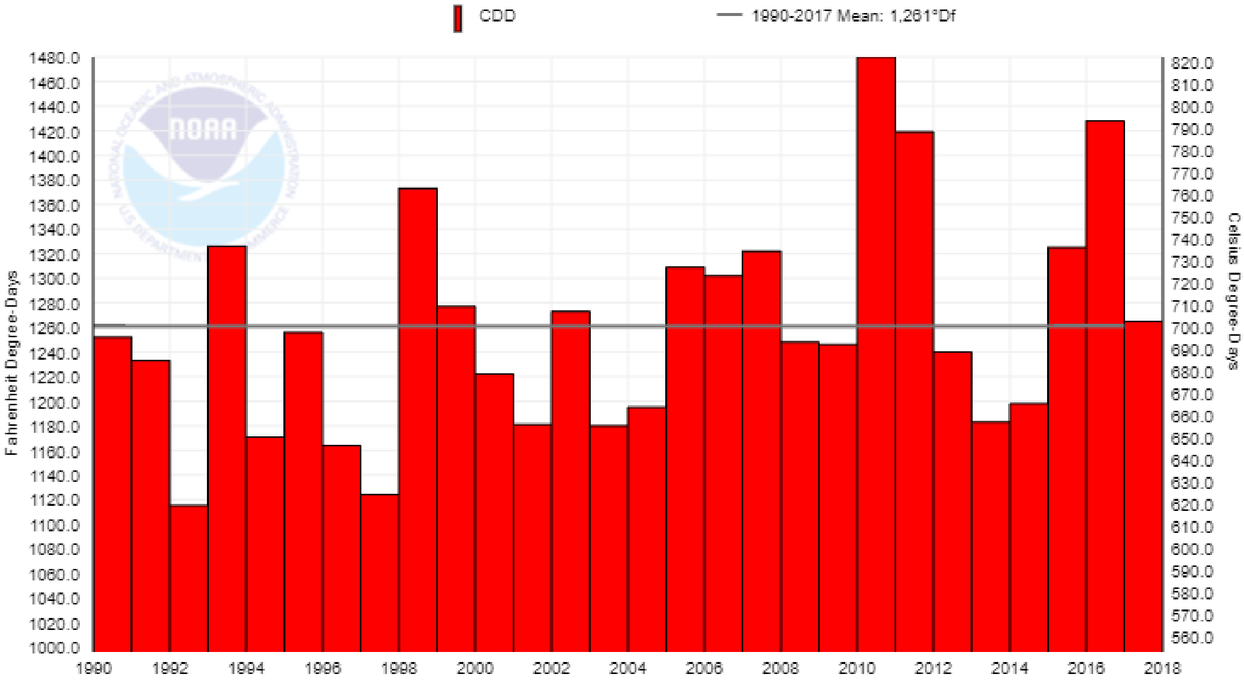
Maximum Temperature Percentiles
June–August 2017
Ranking Period: 1895–2017

Created: Fri Sep 08 2017

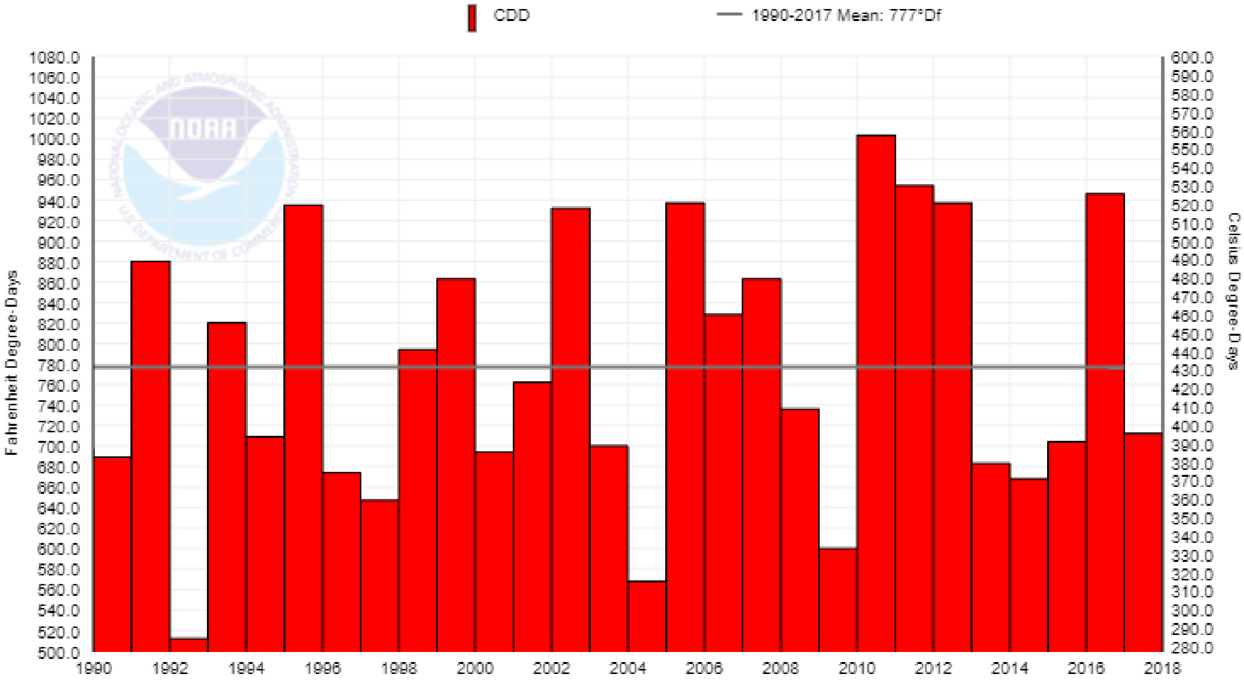
Data Source: 5km Gridded Dataset (nClimGrid)

Figure A-4. Cooling degree days for June through August for each climate region. Note that (1) data are provided back to 1990 and (2) the range of the y-axis differs in some cases by climate region.

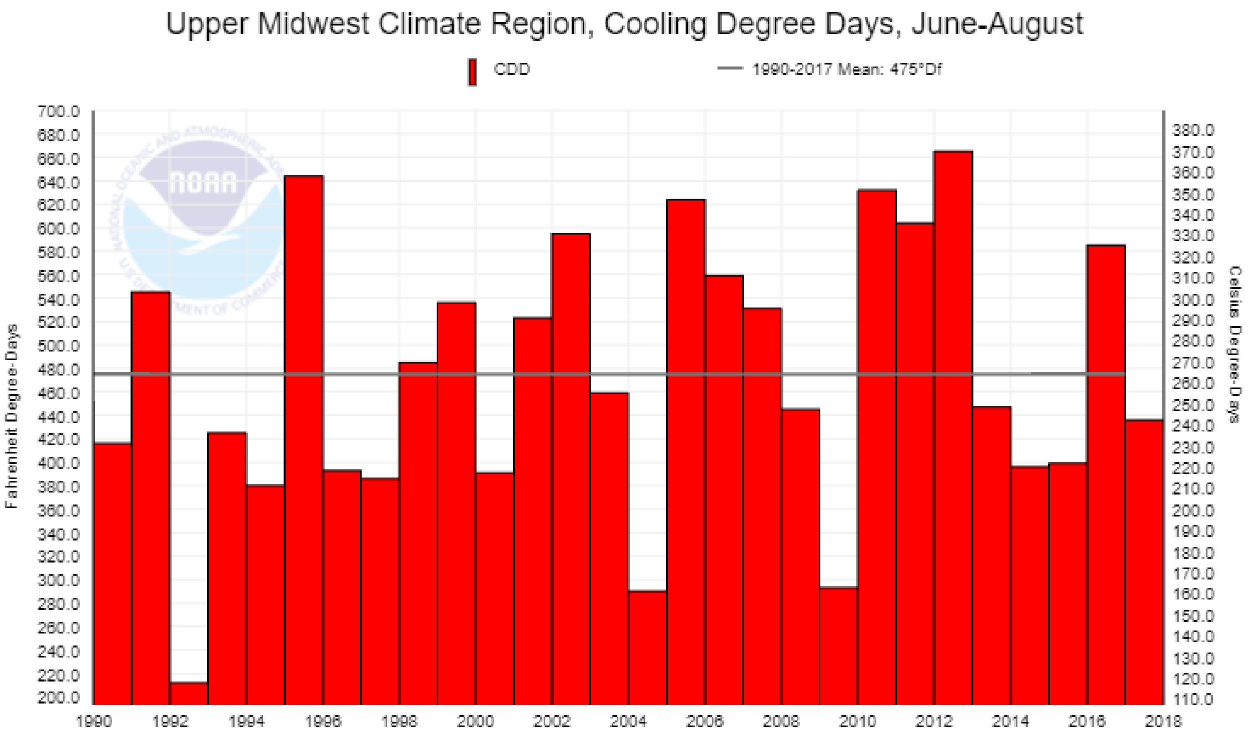




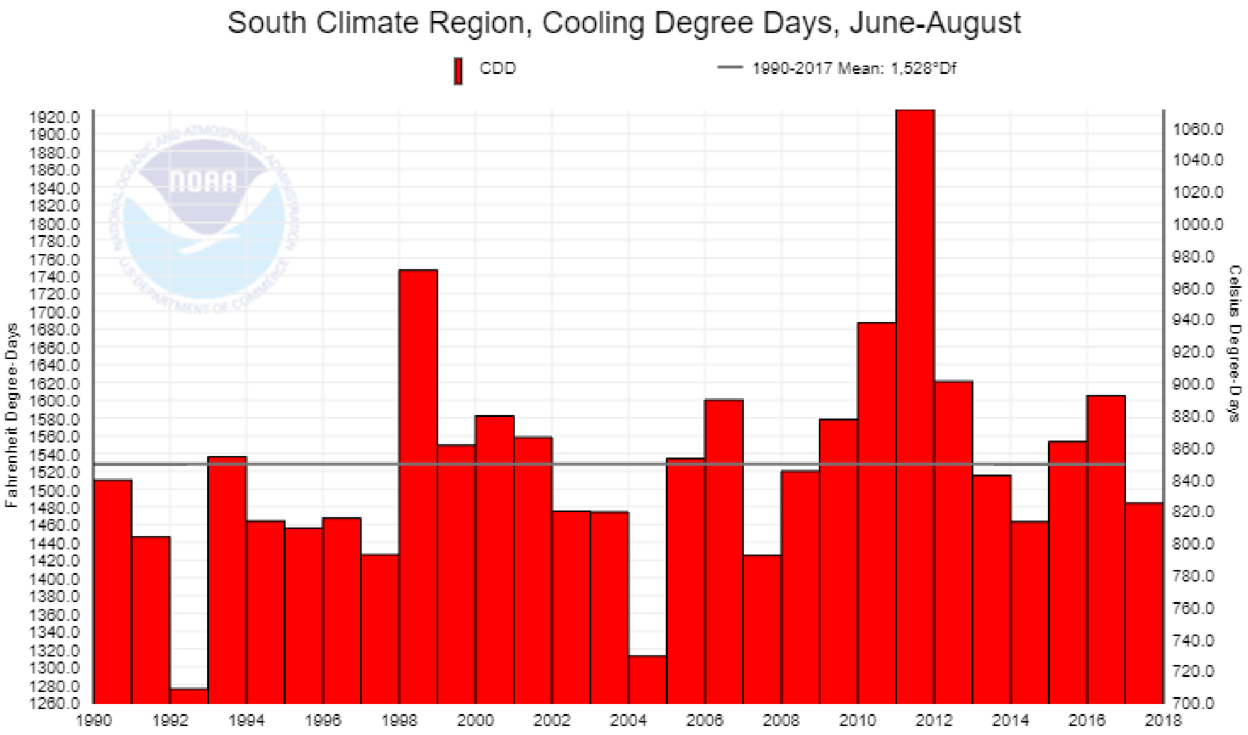
Southeast Climate Region, Cooling Degree Days, June-August



Ohio Valley Climate Region, Cooling Degree Days, June-August

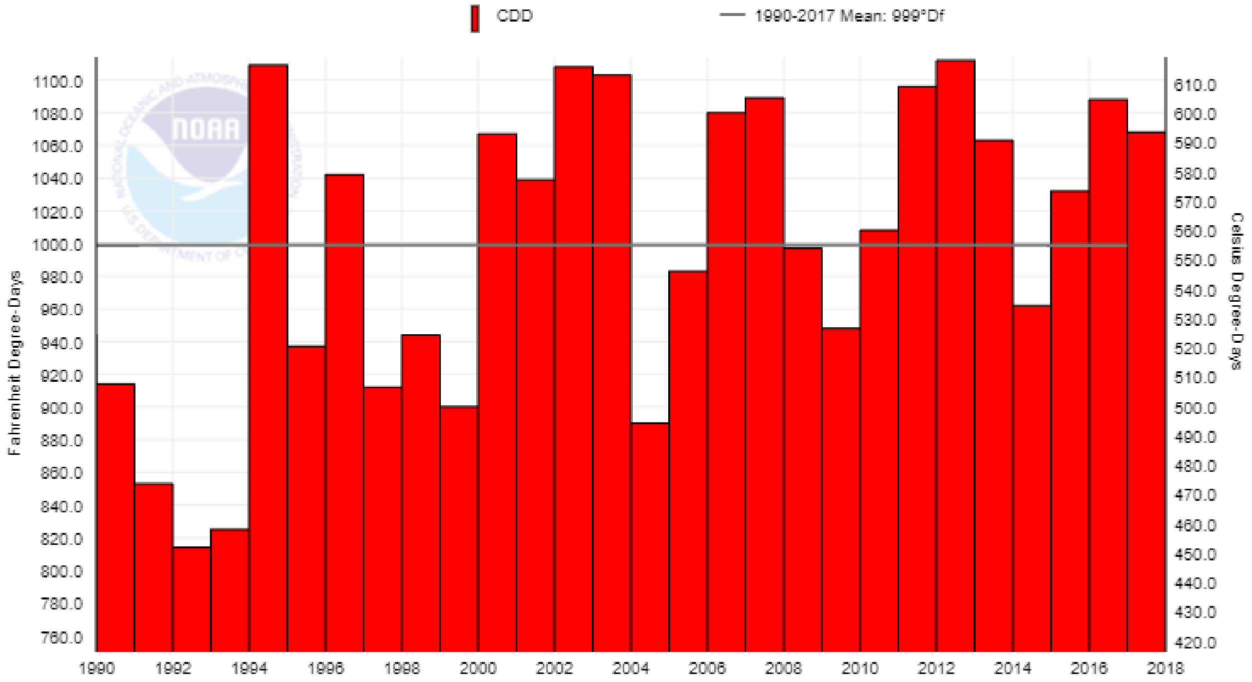


Upper Midwest Climate Region, Cooling Degree Days, June-August

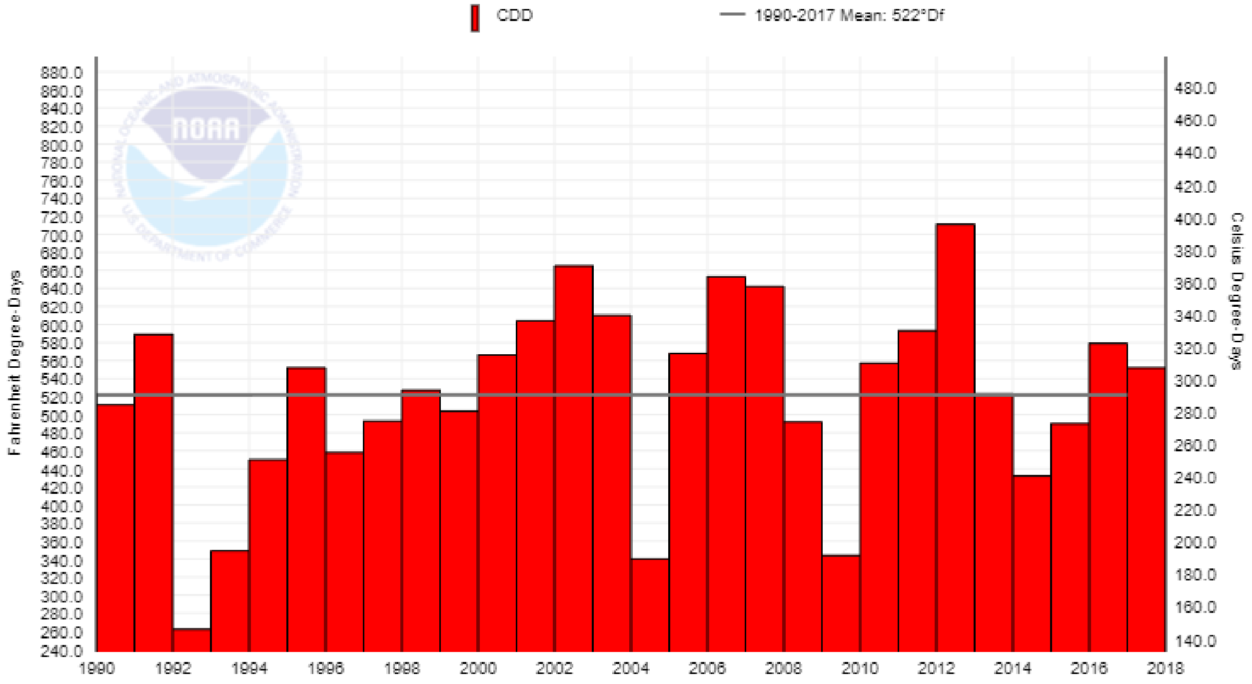


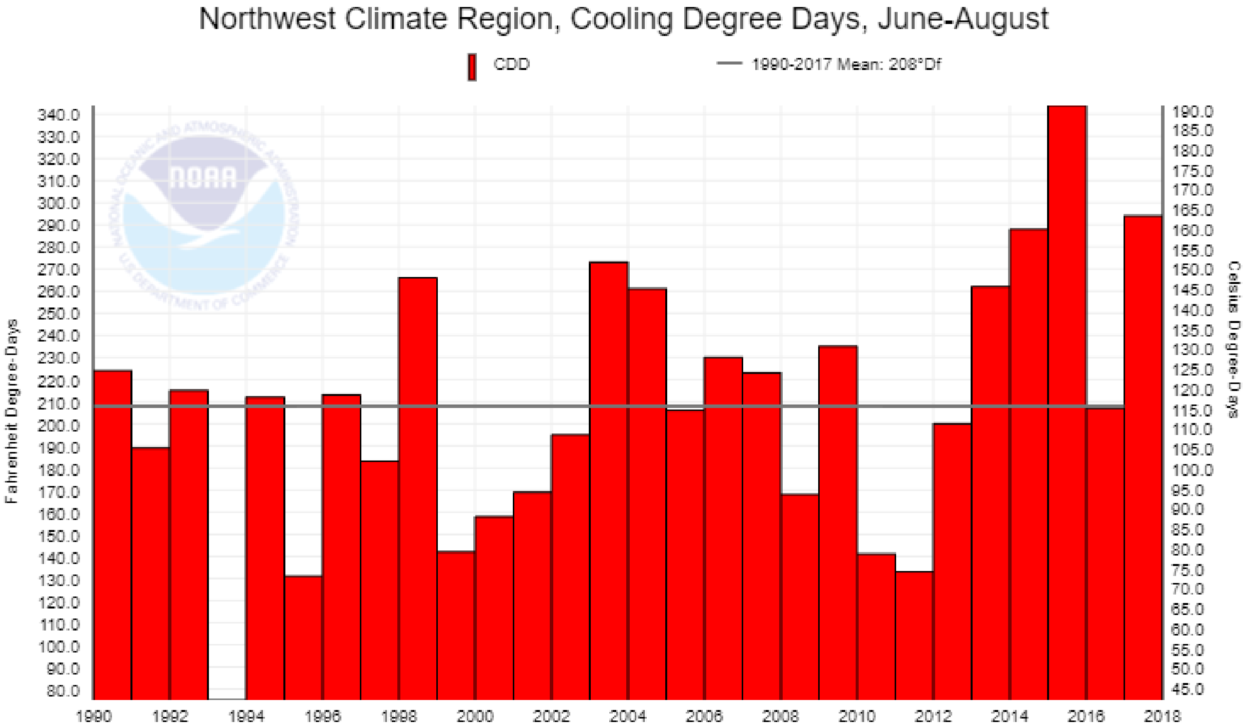
South Climate Region, Cooling Degree Days, June-August

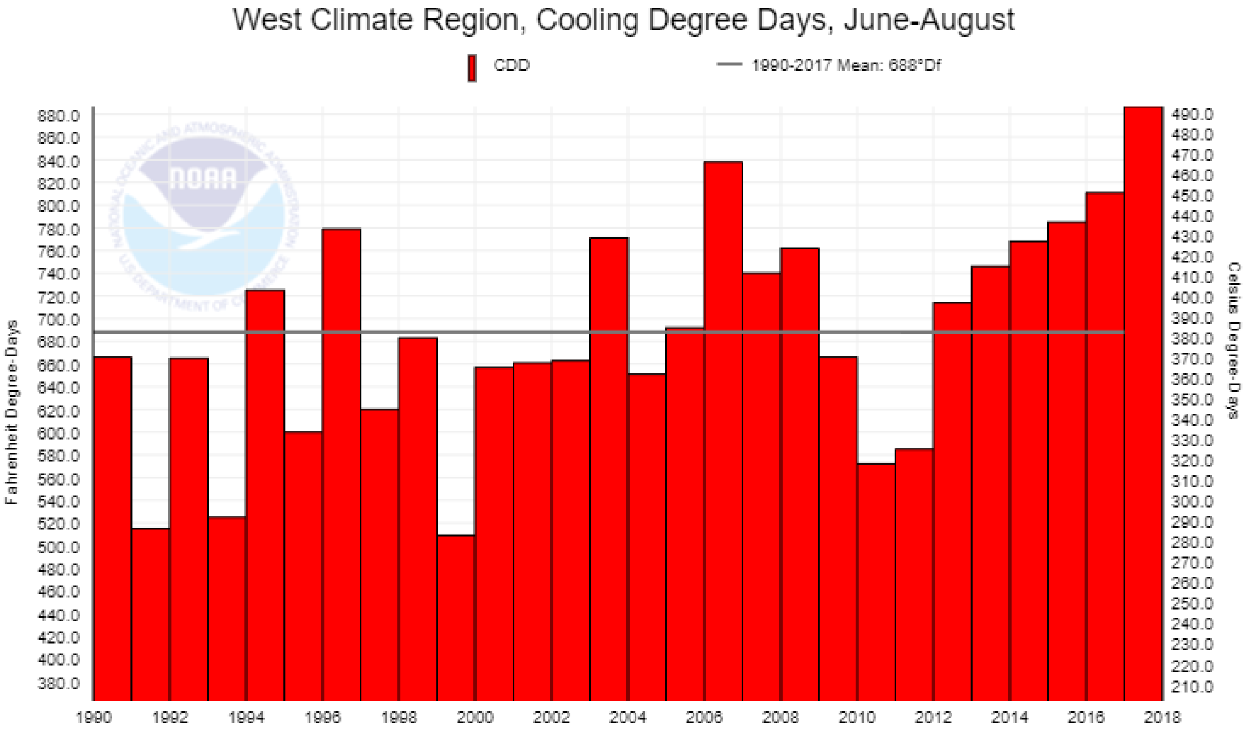
Southwest Climate Region, Cooling Degree Days, June-August



Northern Rockies and Plains Climate Region, Cooling Degree Days, June-August




Northwest Climate Region, Cooling Degree Days, June-August
CDD
1990-2017 Mean: 208°Df
Fahrenheit Degree-Days
340.0
330.0
320.0
310.0
300.0
290.0
280.0
270.0
260.0
250.0
240.0
230.0
220.0
210.0
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
Celsius Degree-Days
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018


West Climate Region, Cooling Degree Days, June-August
CDD
1990-2017 Mean: 688°Df
Fahrenheit Degree-Days
880.0
860.0
840.0
820.0
800.0
780.0
760.0
740.0
720.0
700.0
680.0
660.0
640.0
620.0
600.0
580.0
560.0
540.0
520.0
500.0
480.0
460.0
440.0
420.0
400.0
380.0
Celsius Degree-Days
490.0
480.0
470.0
460.0
450.0
440.0
430.0
420.0
410.0
400.0
390.0
380.0
370.0
360.0
350.0
340.0
330.0
320.0
310.0
300.0
290.0
280.0
270.0
260.0
250.0
240.0
230.0
220.0
210.0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018