

SECTION 1

How Are Global and National Climate Changing?

Global and national temperatures have increased throughout much of the 20th century. Global sea level is rising, the oceans are warming, and ocean chemistry is changing. Many aspects of the earth's physical and biological systems are changing in ways consistent with human-caused warming. Natural variability continues to result in short-term periods that are warmer or cooler than the long-term average. Recent studies have made use of longer observational records and investigated trends in greater detail. These studies have provided new and stronger evidence that warming trends are largely due to human activities.

1. The Earth's climate is continuing to warm, sea level is rising, and the oceans are changing. Since the 1950s, many of the observed changes are unprecedented over decades to millennia.^[1]

- *Increasing global temperatures.* Average global temperature increased +1.5°F between 1880 and 2012 (Figure 1-1; Table 1-1). Globally, heat waves and heavy rainfall events have become more frequent since 1950 and cold snaps are becoming rarer.^{[A][1]}
- *Northern Hemisphere warming.* Each of the last three decades has been successively warmer than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years.^[1]
- *Rising sea level.* Global sea level has risen about +7 inches since 1901. The rate of global mean sea level rise has accelerated during the last two centuries.^[1]
- *Increasing ocean temperatures.* Ocean surface waters (top 250 ft.) warmed by +0.6 to +0.9°F from 1971 to 2009 (global average). Warming trends are evident at nearly all depths in the ocean.^[1]
- *Ocean acidification.* The acidity of the ocean has increased by about +26% since 1750. The current rate of acidification is nearly ten times faster than any time in the past 50 million years.^{[B][1][2]}

2. The U.S. is experiencing similar changes in climate.

- *Increasing U.S. temperature.* U.S. average temperature increased about +1.5°F since record keeping began in 1895, with different rates of warming in different locations (Figure 1-2).^[3]

^A In this section, trends are only reported if they are statistically significant at the 90% level or more.

^B Although the acidity of the ocean is projected to increase, the ocean itself is not expected to become acidic (i.e., drop below pH 7.0). Ocean pH has decreased from 8.2 to 8.1 (a 26% increase in hydrogen ion concentration, which is what determines the acidity of a fluid) and is projected to fall to 7.8-7.9 by 2100. The term “ocean acidification” refers to this shift in pH towards the acidic end of the pH scale.

Observed Change in Temperature, 1901-2012

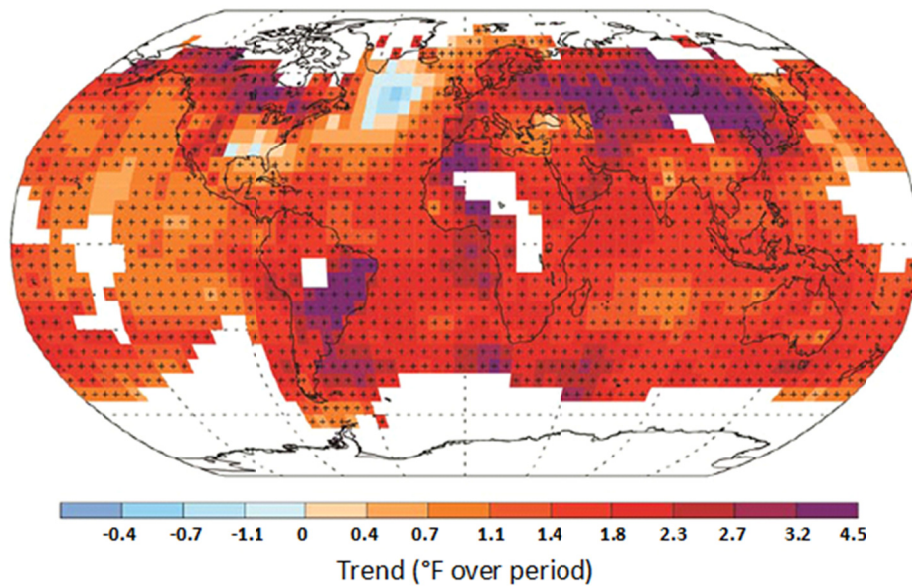


Figure 1-1. Significant warming has been observed in most locations. Observed changes in air temperature at the Earth's surface between 1901 and 2012. Red and purple colors indicate places that warmed while blue colors indicate places that cooled. White areas indicate places where data were insufficient to permit a robust trend estimate. The '+' signs indicate grid boxes where the direction of the trend is statistically significant. *Figure and caption adapted from IPCC 2013 (Figure SPM1.b).*^[1]

Observed U.S. Temperature Change from 1901-1960 to 1991-2011

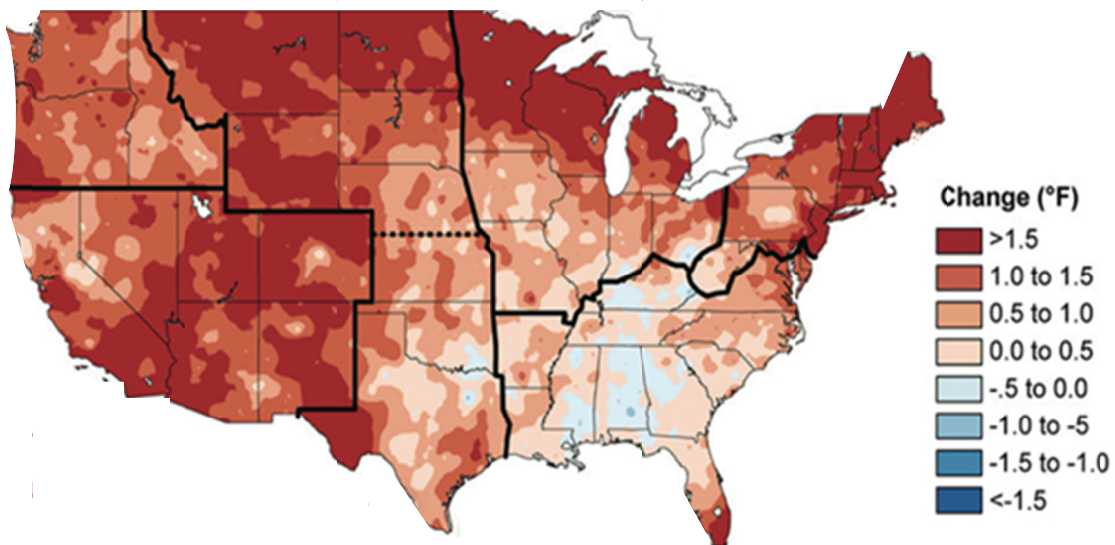


Figure 1-2. Warming has been observed for much of the continental U.S. Red colors indicate places that warmed while blue colors indicate places that cooled. In both cases this was calculated as the difference in temperature between the average for 1991-2011 and average temperature for 1901-1960. *Figure and caption adapted from Ch. 2 in Draft 2014 U.S. National Climate Assessment*^[3]

- *More heavy rainfall events.* Heavy downpours are increasing in most regions of the U.S., especially over the last three to five decades, although trends for the Pacific Northwest are ambiguous.^{[3][4]}
- *Longer frost-free season.* The length of the frost-free season (and the corresponding growing season) has been increasing nationally since the 1980s. During 1991-2011, the average frost-free season was about 10 days longer than during 1901-1960. The largest increases for this period occurred in the western U.S.^{[3][4]}

3. Evidence of change is increasingly visible throughout Earth's physical and biological systems.

- *Widespread declines in glaciers, sea ice, and ice sheets.* Glaciers around the world have become smaller, on average, and Greenland and Antarctica are losing ice overall.^[1] Summertime minimum Arctic sea ice extent decreased more than -40% between 1978 and 2012 (relative to the median for 1979-2000), recovering slightly in 2013.^[5] Annual average Antarctic sea ice extent increased by +4 to +6% between 1979 and 2012.^[6]
- *Declining U.S. ice and snow.* Rising temperatures across the U.S. have reduced lake ice, sea ice, glaciers, and seasonal snow cover over the last few decades.^[7] In the Great Lakes, for example, total winter ice coverage decreased substantially between the early 1970s and 2010.^[8]
- *Shifting species ranges.* Plant and animal ranges are shifting northward (in the Northern Hemisphere) and to higher elevations (Section 8 of this report).^{[9][10]}

4. The role of human activities in changing global climate is becoming clearer.

- *Continued increases in greenhouse gas emissions.* Globally, greenhouse gases emissions are higher and increasing more rapidly since 2000 than during the 1990s.^[1]
- *Rising concentrations of greenhouse gases.* The atmospheric concentration of carbon dioxide (CO₂) increased +40% between 1750 and 2011 as a result of human activities, nearly reaching 400 ppm in 2013. Atmospheric concentrations of CO₂, methane, and nitrous oxide have increased to levels unprecedented in at least 800,000 years.^[1]
- *Identifying and quantifying human influence.* Human influence is becoming increasingly detectable in the observed warming of the atmosphere and ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes.
 - The IPCC now estimates that “more than half of the observed increase in global average surface [air] temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.”^[1]

- The effects of human emissions of greenhouse gases must be included in order for models to correctly simulate the observed 20th century pattern of warming.^{[1][11]}
- Studies conducted at the scale of the western U.S. have attributed some of the observed increases in temperature, decreases in snowpack, and shifts in the timing of peak streamflows to human influence.^{[12][13][14]}

5. Natural climate variability continues to contribute to shorter-term (annual to decades-long) periods that are warmer or cooler than the long-term average.

- *Short-term trends can differ from long-term trends.* There have been periods of accelerated warming and even slight cooling at global and regional scales throughout the course of the 20th century due, in part, to important patterns of natural climate variability such as El Niño, La Niña, and the Pacific Decadal Oscillation.^[1]
- *Trends based on shorter periods of time can be misleading.* Due to natural variability, short-term trends can differ substantially from long-term trends.
- *Recent warming “hiatus” is associated with natural variability that favors cool conditions.* The slower rate of global average warming observed for 1998-2012 has coincided with a higher rate of warming at greater depths in the oceans and a dominance of La Niña and the cool phase of the Pacific Decadal Oscillation, two large-scale natural patterns of climate variability that favor cooler surface temperatures in large parts of the world.^[1]
- *All climate model scenarios project warming over the course of the 21st century.*^[1] The amount of warming observed at any given location and point in time will depend on the combined influences of human-caused global warming and natural climate variations. This means that long-term warming projected for this century will be punctuated by shorter periods of reduced warming, or even cooling, as well as periods of accelerated warming, for both the globe as a whole and for specific places like Washington State.

For more details on observed changes in global and national climate, see Table 1-1.

Table 1-1. Observed trends in national and global climate.

<i>Variable and Region</i>	<i>Observed Change</i>
Global Greenhouse Gas Emissions	<p>Increasing</p> <ul style="list-style-type: none"> Emissions increased +3.2% per year between 2000 and 2009. This rate was notably higher than in previous decades; emissions increased at a rate of +1.0% per year during the 1990s.^[1] The atmospheric concentration of carbon dioxide (CO₂) increased +40% between 1750 and 2011 as a result of human activities.^[1] Atmospheric concentrations of CO₂, methane, and nitrous oxide have increased to levels unprecedented in at least 800,000 years.^[1]
Temperature	
<i>Average Annual: Global</i>	Warming: +1.5°F (+1.2 to +1.9°F; 1880-2012) ^[1]
<i>Average Annual: U.S.</i>	Warming: +1.5°F (1895-2011) ^{[3][4]} Greatest warming in winter and spring ^[3]
<i>Extremes</i>	More heat events and fewer cold events globally (1950-2012). No significant trends for the U.S. ^{[C][1][4]}
Precipitation	
<i>Annual: Global</i>	No significant trend (1901-2012). Trends vary with location ^[1]
<i>Annual: U.S.</i>	Slightly wetter (1900-2011) <ul style="list-style-type: none"> +5% increase in annual precipitation over the U.S. Largest increase (+9%) in Midwest No significant trend for the Pacific Northwest.^[3]
<i>Heavy Precipitation: Global</i>	Increasing; more frequent high rainfall events since 1950 ^[1]
<i>Heavy Precipitation: U.S.</i>	Increasing overall (1901-2011), although highly variable by region. <ul style="list-style-type: none"> Greatest increase regionally: Midwest and Northeast^[3] Since 1991, all regions have experienced a greater than normal occurrence of extreme events relative to the 1901-2011 average. Significant trends observed for Southwest (decreasing) and Midwest (increasing), other U.S. regions do not have statistically significant trends.^{[D][4]}

^C Nationally, the 1930s remain the decade with the highest number of extreme heat events when averaged over the U.S., followed by 2001-2011. In the western U.S., however, the 2000s are the decade with the highest number of extreme heat events.

^D Extreme events were defined as the number of 2-day extreme precipitation events exceeding a 1 in 5-year recurrence interval for the period of 1901-2011.

<i>Variable and Region</i>	<i>Observed Change</i>
<i>Snow and Ice</i>	
<i>Glaciers, Sea Ice, and Land-based Ice Sheets</i>	Ice coverage is shrinking overall, with some growth in sea ice in the Antarctic <ul style="list-style-type: none"> ▪ Melting ice from glaciers, Greenland and Antarctica contributed +0.6 to +1.1 inches to sea level rise from 1971 to 2009^[1]
<i>Arctic Sea Ice</i>	Decreasing <ul style="list-style-type: none"> ▪ Average annual extent: decreased –3.5 to –4.1%/decade (1979-2012)^[1] ▪ Average summer minimum extent: decreased –9.4 to –13.6%/decade (1979-2012)^[1]
<i>Snow Cover: Northern Hemisphere</i>	Decreasing <ul style="list-style-type: none"> ▪ Total area covered by snow in spring (March-April) decreased by –0.8 to –2.4%/decade (1967-2012)^[1]
<i>Oceans</i>	
<i>Ocean Temperature: Global</i>	Warming <ul style="list-style-type: none"> ▪ +0.16 to +0.23°F warming in the upper ocean (top 250 ft.; 1979-2010)^[1] ▪ Over the past 40 years (1971-2010), the oceans have absorbed more than 90% of the excess energy trapped by greenhouse gases emitted due to human activities.^[1]
<i>Sea Level: Global</i>	Rising, although amount and rate of rise varies by location and over time. <ul style="list-style-type: none"> ▪ Rate of rise accelerated between 1993 and 2010, although similarly high rates are likely to have occurred between 1930 and 1950. <ul style="list-style-type: none"> +0.6 to +0.7 in./decade (1901-2010)^[1] +0.7 to +0.9 in./decade (1971-2010)^[1]
<i>Ocean Acidification</i>	Increasing acidity. Global ocean acidity has increased by +26% since the beginning of the industrial era (~1750) (this is equivalent to a decline in pH of –0.1) ^{[1][2]}

^[1] (IPCC) Intergovernmental Panel on Climate Change. 2013. *Working Group I, Summary for Policymakers*. Available at: http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf

^[2] Feely, R.A. et al., 2012. *Scientific Summary of Ocean Acidification in Washington State Marine Waters*. NOAA OAR Special Report.

^[3] Walsh, J. et al., 2014. Our Changing Climate. Chapter 2 in the draft 2014 U.S. National Climate Assessment, <http://ncadac.globalchange.gov/>.

^[4] Kunkel et al., 2013. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 9. Climate of the Contiguous United States*, NOAA Technical Report NESDIS 142-9, NOAA National Environmental Satellite, Data, and Information Service, Washington, D.C.

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