San Antonio Climate Trends Update
Updates by Darrian Bertrand and Simone Speizer, Southern Climate Impacts Planning Program (SCIPP)
June 2021

Why does climate matter?

For cities, states, and agencies charged with managing and maintaining public infrastructure and services, climate is important because it dictates the range of conditions that might be expected in a given location. Climate is typically defined as the long-term average of weather over multiple decades. It encompasses a host of relevant variables relevant to city planning, including:

- average winter and summer temperatures, which in turn can be translated into demand for heating and cooling;
- the frequency of heat waves and cold snaps that affect public health as well as the integrity of energy systems and infrastructure;
- the growing season, which determines the types of trees and plants that can grow in a given place, as well as which invasive species and pests might be expected;
  average rainfall amounts and how they vary from year to year, which help cities plan for water availability and drought; and
- rainfall extremes that affect transportation infrastructure and buildings and determine the frequency of events such as the hundred-year flood.

When planning for the future, it is often assumed that past climate will serve as a reliable guide for future conditions, as illustrated in Figure 1a. Today, however, the climate is changing here in Texas, across the United States, and around the world. This is affecting average conditions and the risk of many types of weather extremes both now and in the future. Today, the climate looks more like Fig. 1b.

Infrastructure, building codes and many other types of planning require information on climate conditions to meet performance standards. Most such planning assumes stationarity – that climate will be stable, or stationary, over multiple decades despite variations in temperature, rainfall, and other aspects of climate from year to year. Climate change matters to cities because it introduces non-stationarity into our systems. If the long-term climate is changing, it is no longer stable. This means that historical conditions are no longer a reliable predictor for the future. In fact, in a changing climate, relying on historical conditions to predict the future could give us the wrong answer to many of our questions.

[Insert original Figure 1]

Figure 1. A conceptual illustration of year-to-year average temperature in (a) a stable climate versus (b) a changing climate. ***Source: K. Hayhoe***

Why is climate changing?

Over the last 150 years, long-term weather station records have documented a nearly 2°F increase in the Earth's average temperature[1]. At the global scale, each decade has successively been warmer than the decade before, and 2016 was the warmest year on record to date, with 2020 just behind. Furthermore, the top 10 warmest years on record have all occurred since 2005[1]. Although 2°F may not sound like much, over the course of western civilization, the Earth's temperature has been as stable as that of the human body. Just as a small increase in our body's temperature serves as a warning of a possible fever, in the same way a small increase in the Earth's temperature also warns us that climate is changing.

Climate has changed before, as a result of natural causes. These natural causes are well-known. They include: (1) changes in the amount of energy the Earth receives from the Sun, (2) natural cycles like El Niño that exchange heat between the ocean and atmosphere, (3) periodic cycles in the Earth's orbit that bring the ice ages and the warm interglacial periods like we are in right now, and (4) the cooling effects of dust clouds from powerful volcanic eruptions.

When we see climate changing today, the first place to look is these "usual suspects". Could the Earth's temperature be warming because of natural causes?

- **The Sun.** For the Sun to be responsible for the observed increase in the Earth's temperature, the energy from the Sun should be increasing. However, the Sun's energy has been going down, not up, since the mid-1970s. Hence, if the Sun were responsible for climate change today, the planet would be getting cooler, not warmer (Figure 2, top).

- **Natural Cycles.** Natural cycles like El Niño occur inside the Earth's climate system. These cycles do not create or destroy heat – they just move it back and forth, from east to west, or north to south, or between the ocean and atmosphere. So if the Earth's near-surface air temperature were warming all around the entire planet due to a natural cycle like El Niño, that heat would have to be coming from somewhere else within the Earth system, like the ocean. Measurements of the heat content of the entire Earth system, however, have shown that every part of the climate system is warming: the atmosphere, the land surface, the cryosphere (ice), and the ocean. In fact, the ocean is absorbing 20 times more heat than the rest of the climate system put together. This means that the observed warming can't be due to a natural cycle within the Earth system, because that cycle can only move heat around, it can't create extra heat. The warming has to be coming from somewhere else.

- **The Earth's Orbit.** Slow, periodic changes in the shape of the Earth's orbit and the tilt of the Earth's axis of rotation alter how the Sun's energy falls on the Earth. These changes, in turn, can trigger the advance of the ice sheets, or the end of the ice ages and the beginning of the warm interglacial periods such as we are in today. Could the Earth still be warming since the last ice age? According to long-term climate records, the warming

---

[1] NOAA, https://www.ncdc.noaa.gov/sotc/global/202013

after the last ice age peaked around 8,000 years ago. Since then, the Earth has been cooling gradually in preparation for the next ice age – until just recently, that is (Figure 2, bottom).

- **Volcanoes.** When volcanoes erupt, they spew dust, ash and soot high up into the atmosphere. If the volcano is powerful enough, these particles can reach all the way to the stratosphere, where they can circle the globe for months and even years. There, they act as an umbrella, reflecting the Sun's energy back to space and cooling the Earth. Because they have a cooling effect, they cannot be causing the planet to warm.

  Figure 2 provides a clue as to why climate may be changing today. Since the Industrial Revolution, atmospheric levels of heat-trapping gases such as carbon dioxide and methane have been rising due to the burning of fossil fuels such as coal, oil, and natural gas. Other activities, such as agriculture, wastewater treatment, and extraction and processing of fossil fuels also produce heat-trapping gases and particles that affect climate. Volcanoes produce some carbon dioxide and methane as well; however, emissions from natural geologic sources are less than 10% of emissions from human sources.

[Insert original Figure 2]

Figure 2. (TOP) Observed changes in the Earth's temperature (red) and energy from the Sun (black) from 1950 to present. Thin lines show the year-to-year values, while thick lines show the long-term trends. (BOTTOM) Observed changes in the Earth's temperature (red) and carbon dioxide levels in the atmosphere (blue) over the last 6,000 years. ***Source: K. Hayhoe, with data from NASA GISS, Lean et al., PMOD, Marcott et al., Mauna Loa, and Epica.***

These heat-trapping gases exist naturally in the atmosphere, where they act like a blanket, trapping the heat given off by the Earth that would otherwise escape to space. The trapped heat keeps the Earth nearly 60°F warmer than it would be otherwise. However, artificially adding more of these gases in the atmosphere is like wrapping an extra blanket around the planet. This extra blanket traps too much of the heat given off by the Earth. This extra heat is what's increasing the temperature, and the heat content, of the atmosphere and ocean.

Recent studies have concluded that human influence, specifically the increases in emissions of carbon dioxide and other heat-trapping gases from human activities, is responsible for most of the warming over the last 150 years. A number of studies conclude that humans are responsible for more than 100% of the warming over the last 60 years, since the Sun and orbital cycles would be causing the planet to get cooler, not warmer, over this time. Surveys of the scientific literature and of climate scientists studying this topic have found that over 97% of scientists agree that humans are the primary reason climate is changing today.[2,3]

Even if humans are causing climate to change, why does it matter what or who is responsible? Can't we just look at past trends and use those as a guide to the future?

The reason why climate is changing matters, because it affects our future projections. If climate is changing due to natural causes, we would base our future projections on those causes: the Sun, or natural cycles. However, if climate is changing due to human activities, then we must base our future projections on how much heat-trapping gases we produce from human activities.

Over the next few decades, climate will continue to change regardless of how much carbon we are putting into the atmosphere. This is due to two reasons: first, the inertia of the climate system in responding to human emissions, and second, the inertia of the global economy in transitioning from carbon-emitting to clean sources of energy. The further out we go, however, the more the amount of future climate change depends on human emissions of carbon dioxide and other heat-trapping gases occurring now and over the next few decades. By the 2050s, there is a noticeable difference between the amount of climate change projected under a higher versus a lower emissions scenario.

Higher scenarios of carbon emissions (Figure 3, red line), that assume continued dependence on fossil fuels such as coal, gas, and oil, produce greater amounts of temperature change. Lower scenarios (Figure 3, blue and green lines), that envision a transition from fossil fuels to non carbon-emitting renewable energy sources, result in smaller amounts of temperature change. To quantify the range of future climate change that might result from human choices over this century, the projections used by the National Climate Assessment usually compare the climate changes that would be expected under a higher versus a lower scenario.

---

[2] Cook, J., D. Nuccitelli, S. Green, M. Richardson, B. Winkler, R. Painting, R. Way, P. Jacobs and A. Skuce. 2013. Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters*, 8, 024024.

[3] Doran, P. & M. Zimmerman. 2009. Examining the scientific consensus on climate change. *EOS Trans. Am. Geophys. Union*, 90(3) 22–23. Available from: https://doi.org/10.1029/2009EO030002.

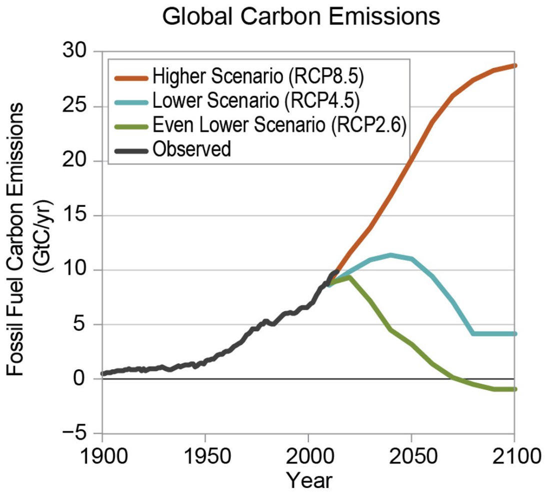


Figure 3. Climate change projections used in the U.S. National Climate Assessment and other regional analyses typically contrast the climate change expected under a higher scenario (red), where human emissions of carbon dioxide and other heat-trapping gases continue to rise, with a lower scenario (blue), where emissions peak and then begin to decline by mid-century, and with an even lower scenario (green), where emissions have already peaked and decline steadily. This figure compares the carbon emissions corresponding to each scenario, in units of gigatons of carbon per year (GtC/yr). ***Source: NCA4***

For more information, see the Third National Climate Assessment's Climate Science Appendix, the Fourth National Climate Assessment's Frequently Asked Questions, and Katharine Hayhoe's TEDx talk, "What if climate change is real?".

How is climate changing in Texas and the United States?

In the United States, average temperature has increased by 1.9°F since 1895, with most of the increase occurring in the last 30 years (Figure 4, top). The Fourth National Climate Assessment (NCA4)[4] highlights a number of observed changes in climate, including:

- More frequent heavy precipitation events, particularly in the Northeast and Midwest, but also over the South-Central region that includes Texas
- Increasing heat waves across the U.S.
- Increased risk of drought, particularly in the Southwest and Southern Great Plains that includes Texas, and wildfire risk
- Decreases in Arctic sea ice, earlier snow melt and less snowpack, and glacier retreat
- Sea level rise and increased storm surge risk
- Warming oceans and stronger hurricanes
- Poleward shifts in many animal and plant species, as well as a longer growing season

[4] Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose, and M. Wehner, 2018: Our Changing Climate. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 72–144. doi: 10.7930/NCA4.2018.CH2

In Texas, annual average temperature has increased by slightly less than the national average, 1.4°F since 1895 (Figure 4, bottom). The referenced baseline time period in Figure 4 is 1901-1960, as was used by NCA4. Trends at individual weather stations are more variable, as they reflect both long-term regional trends as well as more localized influences such as land use change. Despite their variability, station-based analyses show that seasonal average temperatures are increasing in both winter and summer at many locations across Texas (Figure 5, top), and there are also consistent trends in the number of nights per year below freezing at most locations (Figure 5, bottom). For more information on this analysis, see Gelca et al.[5], "Observed trends in air temperature, precipitation, and water quality for Texas reservoirs: 1960-2010".

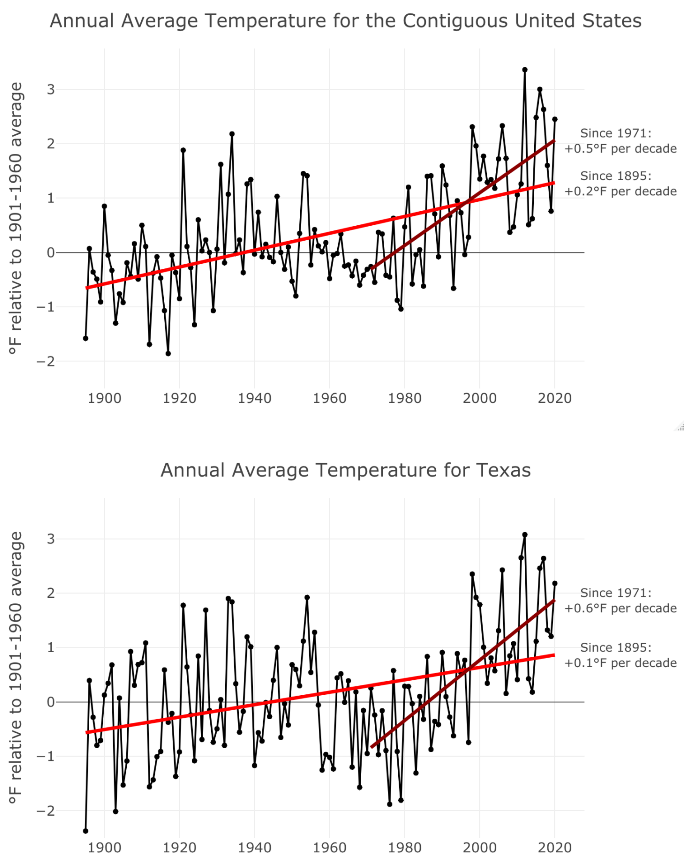


Figure 4. Observed change in annual mean temperature for the contiguous United States (top) and the state of Texas (bottom), in degrees F relative to the 1901–1960 average. Year-to-year values are indicated by the jagged lines, and long-term trends by the straight lines. ***Source: K. Hayhoe, updated by SCIPP with data from the NCEI Climate at a Glance (U.S. data) and NClimDiv dataset (Texas data)***

[Insert original Figure 5]

[5] Gelca, R., Hayhoe, K., and I. Scott-Fleming. 2014. Observed trends in air temperature, precipitation, and water quality for Texas reservoirs: 1960-2010. *Texas Water Journal,* 5(1):36-54. Available from: https://doi.org/10.21423/twj.v5i1.7001.

Figure 5. This map shows observed trends from 1960-2010 for individual weather stations across the state of Texas. Each dot indicates one weather station. The color and size of each dot shows the direction and strength of the trend. Blue dots indicate decreasing trends while red dots indicate increasing trends. Larger dots with darker colors show stronger trends.

The four maps show observed trends in four different variables: (1) average winter (Dec-Jan-Feb) temperature (top left), (2) average summer (Jun-Jul-Aug) temperature (top right), (3) the number of nights per year with minimum temperature below 32°F (bottom left) and (4) precipitation intensity, measured as annual average rainfall divided by the number of wet days per year (bottom right). Only trends that are significant (with a p-value equal or less than 0.1, indicating that there is a 90% or greater chance that the trend is real) are shown. *Source: Gelca, Hayhoe & Scott-Fleming (2014)*

Annual precipitation trends vary by geographic region and season. In general, wet areas are becoming wetter, while dry areas experience more frequent dry conditions. This axiom is borne out in the state of Texas, which has experienced an increase in rainfall over the eastern and central parts of the state and a slight decrease in some areas in the western part of the state over the past century (Figure 6, top).

As air temperatures warm, more water evaporates out of soils, oceans, lakes, rivers, and streams. This leaves behind drier conditions, but also means that when a storm comes along, there is more water vapor available for the storm to pick up and dump as precipitation.

This simple relationship explains both the increasing risk of stronger droughts and the simultaneous increase in heavy precipitation events that is being observed across many parts of the United States and around the world. At the global scale, the increase in heavy precipitation has been formally attributed to human-induced warming. While trends at the local scale are more variable, they are still consistent with the relationship between warmer temperatures and more frequent extreme precipitation. In Texas, very heavy precipitation events increased 12% from 1958 to 2016 (Figure 6, bottom right).

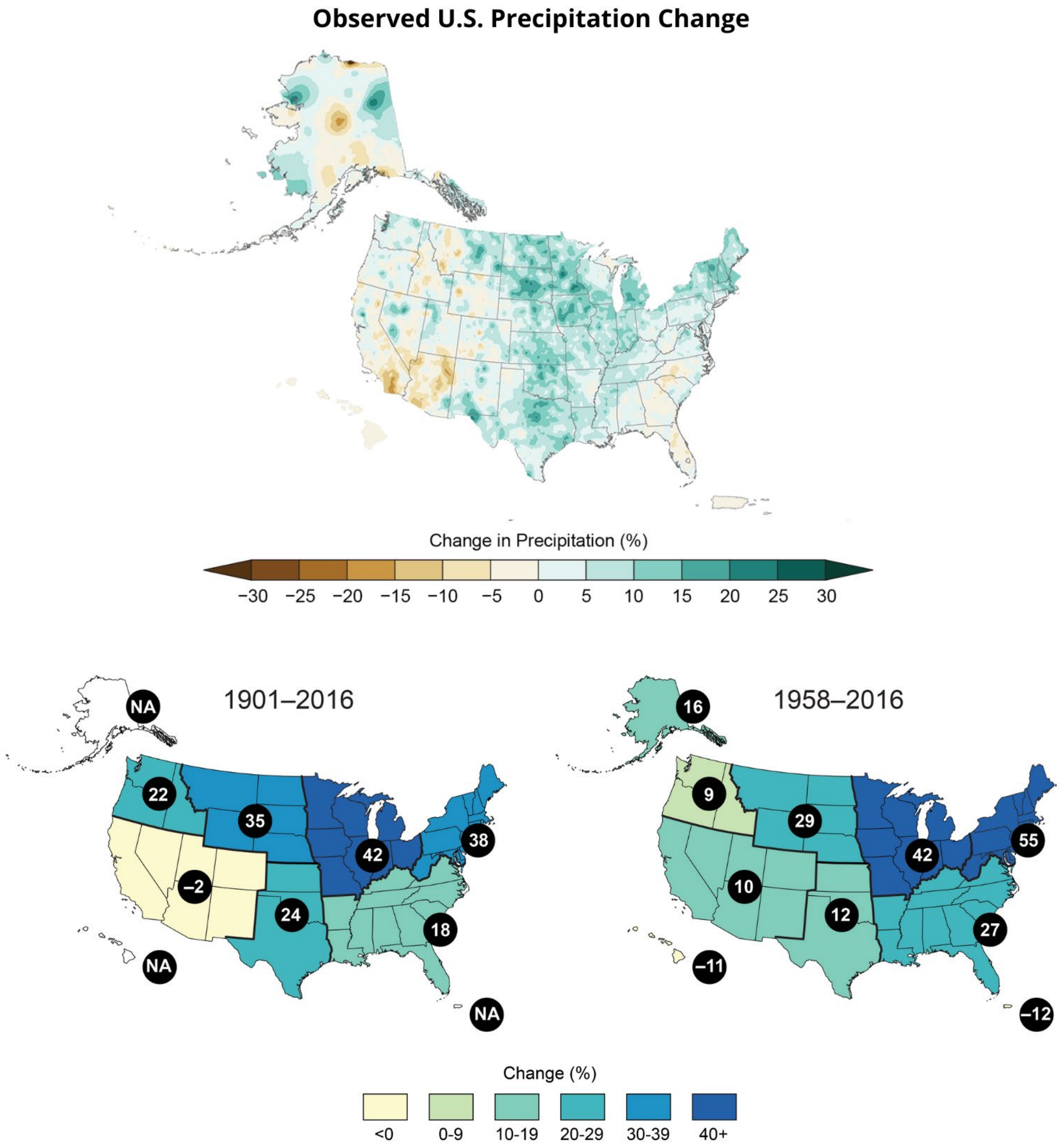


Figure 6. Observed change in (top) average annual precipitation for 1986-2015 compared to the 1901-1960 average and in (bottom) average annual precipitation for very heavy precipitation events (defined as the heaviest 1% of all daily rain events). The difference between the 1901-1960 average and the 1986-2015 average (bottom left) and the linear trend from 1958-2016 (bottom right) are displayed. ***Source:* [*NCA4*]**

At the level of the individual weather station, precipitation intensity can be affected by many factors, including local sources of water, such as irrigation or reservoirs. Even so, analysis of long-term weather stations across Texas shows significant increases in precipitation intensity across central and eastern Texas, where average rainfall has also increased (Figure 5, bottom right).

How has San Antonio's climate changed?

At the San Antonio ThreadEx weather station, a long-term record of San Antonio data threaded together, analysis of observed daily temperature and rainfall records shows trends that are consistent with those observed over the United States and Texas, as described above.

For temperature, we found significant[6] and positive (increasing) trends in all but two temperature indicators tested over both the 1895-2020 time period and the 1971-2020 time period. The tested indicators include:

- Average winter and summer temperature
- The number of "warm and hot days" per year, with maximum daytime temperatures greater than 80°F, 90°F, and 100°F
- The number of "warm nights" per year, with minimum nighttime temperatures above freezing

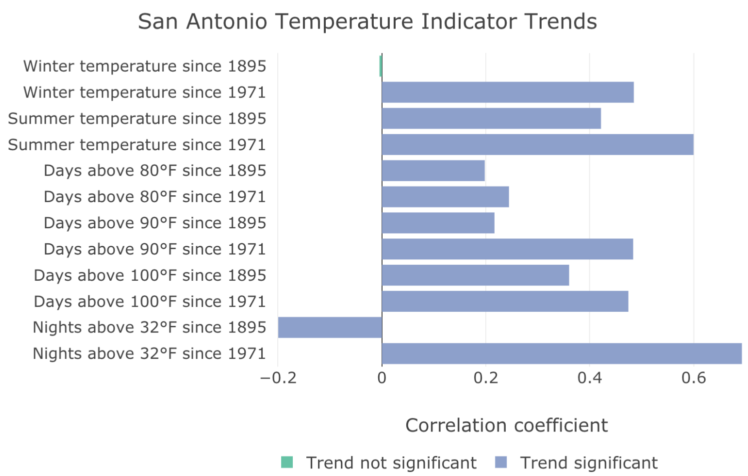
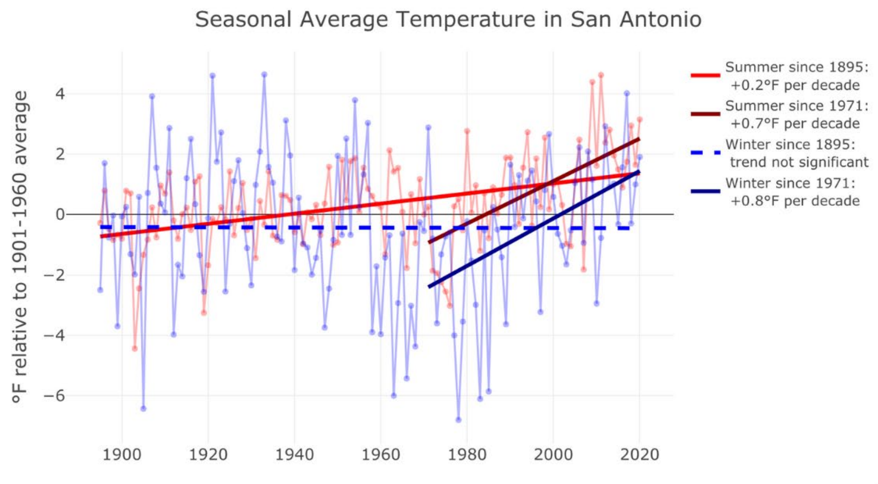
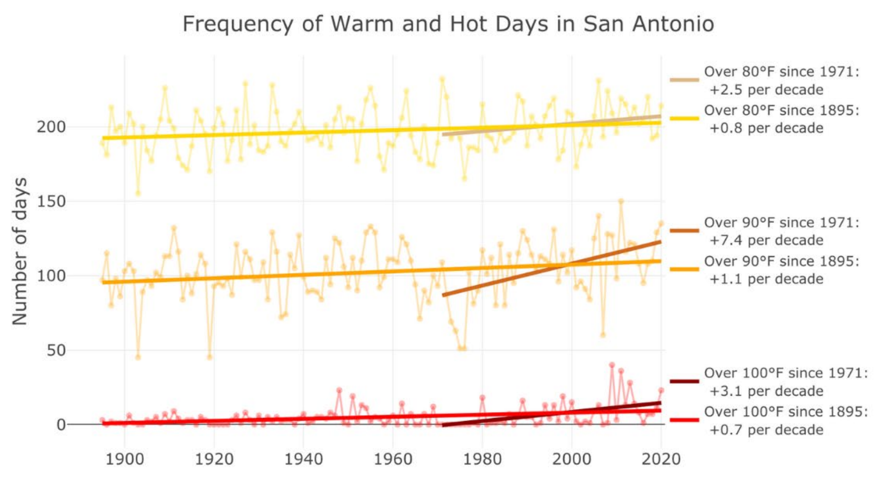


Figure 7. Observed trends in temperature indicators in San Antonio from 1895-2020 and 1971-2020. Significance is labeled at the p<0.1 level. Values are the Pearson correlation coefficient; higher values indicate stronger trends. *Source: K. Hayhoe, updated by SCIPP with data from ThreadEx for the San Antonio area*

[6] Throughout this report, the word "significant" is used in its formal statistical sense, to denote trends that are significant at or above the 90th percentile – in other words, that there is a 90% or greater chance that the trend is real. Significance is measured by p-value; for significant trends, the p-value must be below 0.1. A variable may have a trend, but if the trend is not yet strong enough and/or if the data is very noisy, the trend will not be significant according to the formal statistical definition.

The magnitude of the trend for each of these indicators is summarized in Figure 7, while Figure 8 compares the long-term trends, both from 1895-2020 and from 1971-2020, with year-to-year variations. Temperature trends since 1971 were particularly strong, indicating that the rate of warming has increased in recent decades.





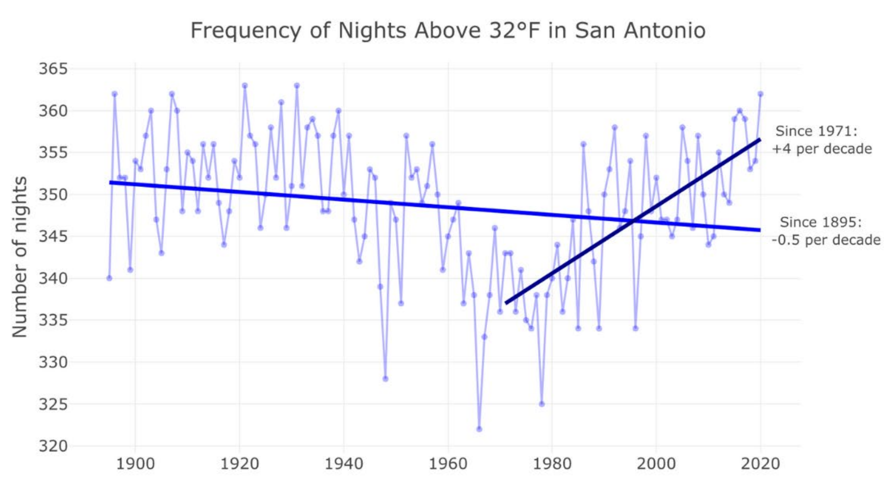


Figure 8. Observed year-to-year values (jagged lines) and long-term trends (straight lines) in winter and summer mean temperature (top), number of days per year with maximum temperatures exceeding 80, 90, and 100°F (middle), and number of days per year with minimum temperatures exceeding 32°F (bottom) in San Antonio. Significant trends ($p<0.1$) have solid lines; trends that are not significant have dashed lines. ***Source: K. Hayhoe, updated by SCIPP with data from ThreadEx for the San Antonio area***

There were trends in many of the precipitation indicators tested here as well (Figure 9). Many trends were significant in the formal statistical sense[6]. Three indicators, including winter and spring rainfall and number of dry days, were not significant. Furthermore, only trends from 1895-2020 were shown due to few significant trends from 1971-2020. Lack of significance may mean that a trend was not yet strong enough, or the data were too noisy, or a trend was spurious.

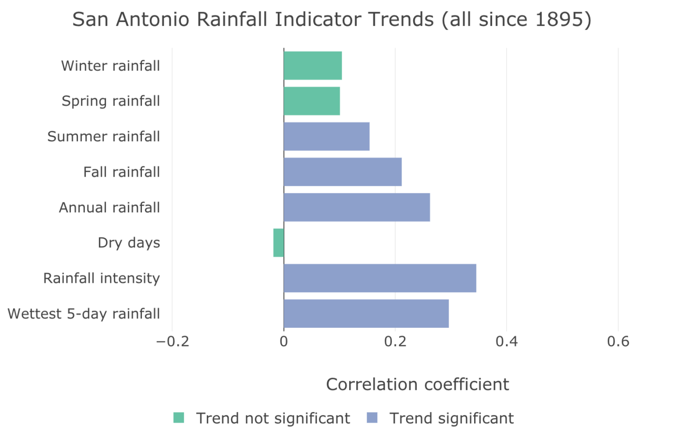


Figure 9. Observed trends in precipitation indicators in San Antonio from 1895-2020. Significance is labelled at the $p<0.1$ level. Values are the Pearson correlation coefficient; higher values indicate stronger trends. ***Source: K. Hayhoe, updated by SCIPP with data from ThreadEx for the San Antonio area***

Of the trends in observed seasonal rainfall over the 1895-2020 period, only the summer and fall trends were significant (Figs. 9 and 10). In both of these seasons, the trends were positive, indicating that the amount of rainfall in these seasons increased over time. Yearly seasonal rainfall variations and trends are displayed in Figure 10, showing an increase of 0.2-0.3” per decade for these seasons. Overall annual rainfall also had a statistically significant and increasing trend (Fig. 11a). This trend is consistent with the broader regional trend shown in Figure 6 (top).

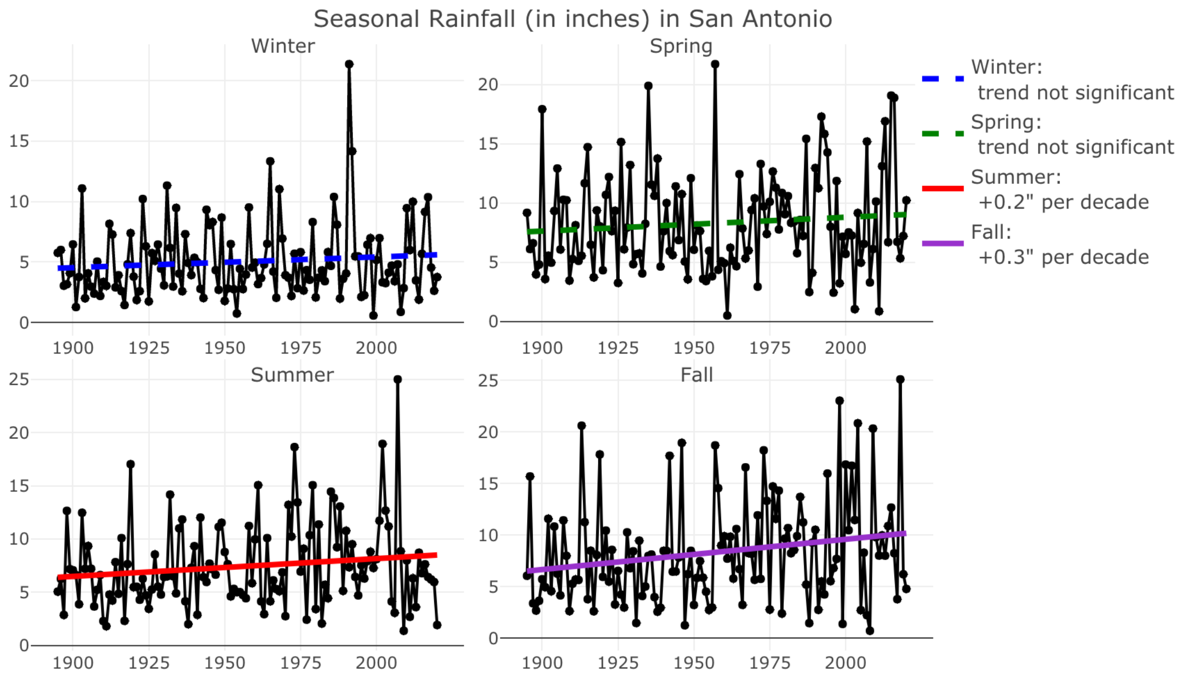


Figure 10. Observed year-to-year values (jagged lines) and long-term trends (straight lines) in seasonal rainfall in San Antonio from 1895-2020. Significant trends (p<0.1) have solid lines; trends that are not significant have dashed lines. *Source: SCIPP, with data from ThreadEx for the San Antonio area*

Statistically significant trends were also observed in some measures of rainfall intensity. We observed increases in average rainfall intensity (the average amount of rain falling on any given wet day during the year) and the amount of rainfall in the wettest 5 days of the year (Fig. 11). In contrast, the trend in the number of dry days per year was not significant. The trends in rainfall intensity and rainfall in the wettest 5 days are consistent with the overall increase in annual rainfall and no change in dry days. If the total amount of rainfall is increasing, but the number of dry days is not changing much, then there must be more rainfall occurring on the wet days. These trends are also consistent with the broader regional trends discussed in the previous section, and summarized in Figure 6 (bottom).

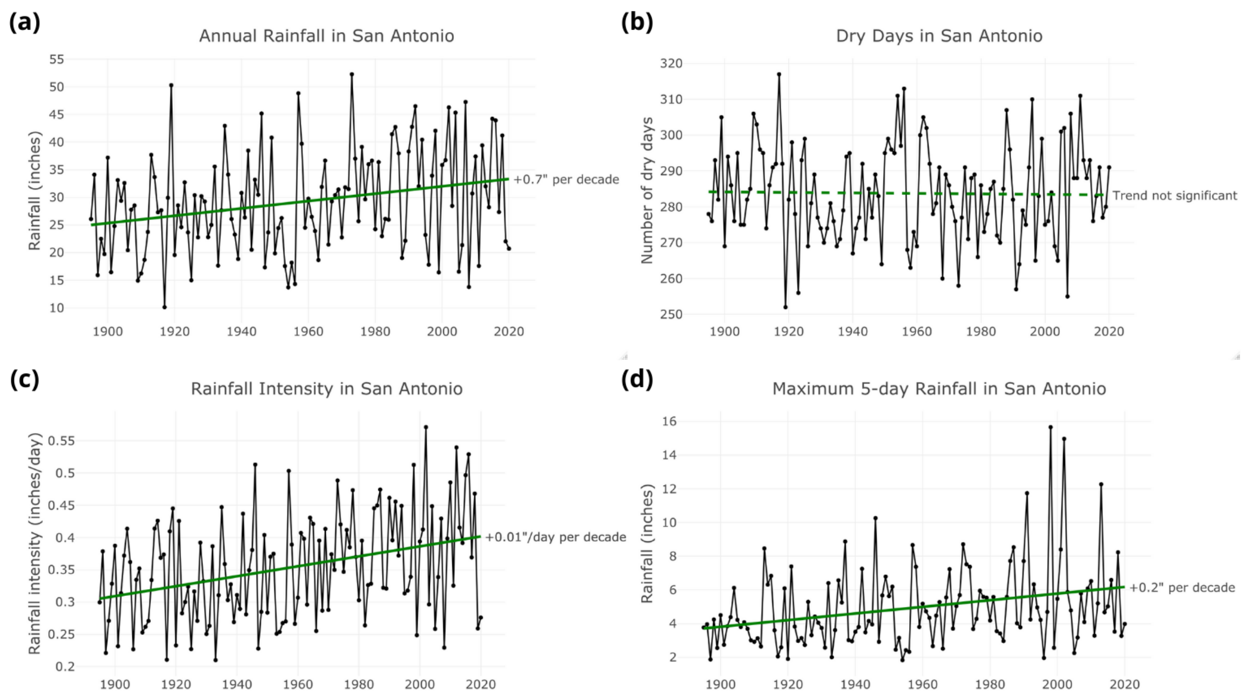


Figure 11. Observed year-to-year values (jagged lines) and long-term trends (straight lines) in (a) annual rainfall, (b) number of dry days per year, (c) rainfall intensity (average rainfall on each day with precipitation), and (d) amount of rain falling during the wettest consecutive 5 days of the year in San Antonio from 1895-2020. Significant trends (p<0.1) have solid lines; trends that are not significant have dashed lines. *Source: K. Hayhoe, updated by SCIPP with data from ThreadEx for the San Antonio area*

What do we expect for the future?

Although the future is uncertain, scientists can break down the uncertainty in future climate change into three specific sources:

1. **Internal (natural) variability of the climate system** is the result of interactions between different components of the climate system, such as the exchange of heat energy between the ocean and the atmosphere. It is most important over the short term (from year to year) and at smaller spatial scales. Beyond these time frames, long-term climate trends become meaningful. In NCA4, we[7] accounted for natural variability by comparing projected climate changes averaged over 30 years in the future (e.g. 2036-2065 and 2070-2099) to historical climate conditions averaged over a similar 30-year period (e.g. 1986-2015).

2. **Scientific uncertainty** arises because scientists' ability to model and predict the response of the climate system to global change is limited and incomplete. To account for scientific uncertainty, in NCA4 we used simulations from a broad range of different climate models, as the average of a large set of simulations is nearly always closer to

[7] I served as a lead author for Chapter 2 in NCA4.

reality than any individual model or sub-set of models.

3. **Scenario uncertainty** is the result of not being able to predict human behavior. Future emissions of heat-trapping gases will be driven by human choices including population, technology, and policy. This uncertainty becomes most important past mid-century. To encompass the range of possible futures, in NCA4 we compared projections of what would be expected under a higher as compared to a lower future scenario.

At the global scale, additional temperature increases between 3.6°F and 9°F are expected by the end of the century, depending on the amount of carbon emissions humans produce[4]. This is expected to be accompanied by increases in extreme heat and heavy precipitation events. For most temperature and some heavy precipitation indicators, a higher emissions scenario is expected to result in greater amounts of change, while lower emissions lead to comparatively smaller amounts of change.

NCA4 projections for the United States show increases in average temperature across the country, with greater increases under a higher as compared to a lower future scenario (Figure 12). By the end of the century, average temperature is projected to increase by an average of 3-4°F under a lower scenario and 6-8°F under a higher scenario across central Texas[8]. NCA4 projections also estimate increases in the frequency of days over 100°F. Across central Texas, there are expected to be between 1 to 3 more months' worth of hot days by the end of the century, depending on the scenario (Figure 13).

[8] In this report, "central Texas" refers to the region encompassing San Antonio and central Texas. It is not possible to be any more specific without generating climate projections for the city.

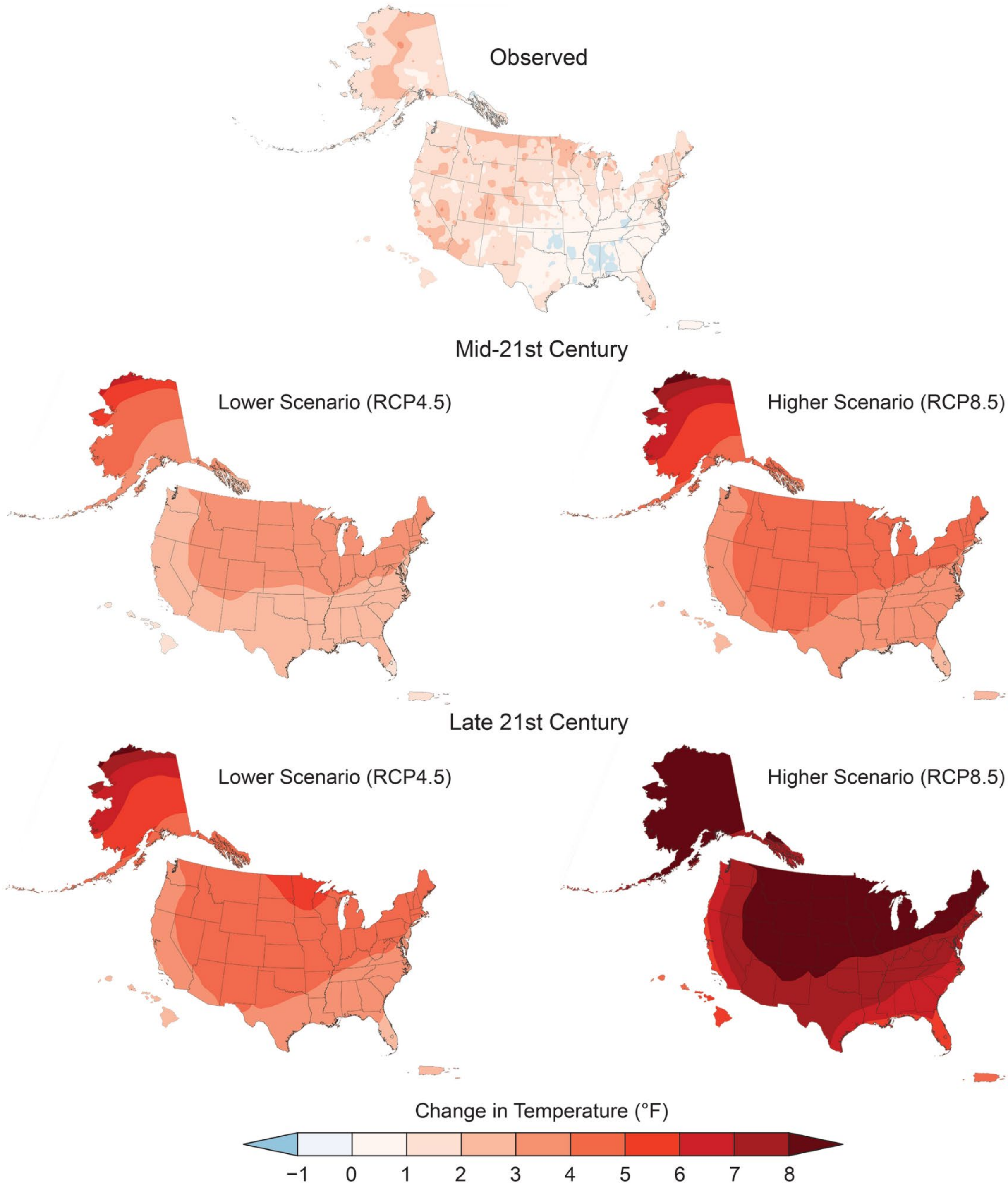


Figure 12. Observed (top) and projected (middle and bottom) change in annual average temperature. Observed temperature is the difference between 1901-1960 and 1986-2015. Projected temperature is shown for the mid-21st century (2036-2065, middle) and late 21st century (2070-2099, bottom) compared to 1986-2015 for both a lower (RCP 4.6) emission scenario and higher (RCP 8.5) emission scenario. Higher temperatures are expected under a higher emission scenario in the late 21st century (bottom right). ***Source:*** ***NCA4***

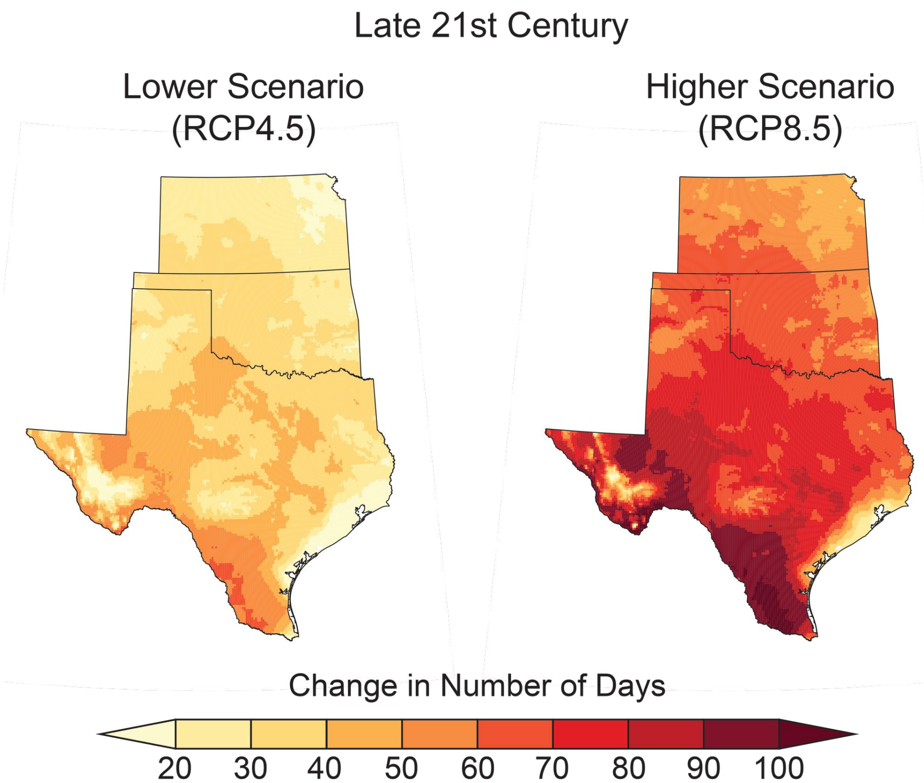


Figure 13. Projected increase in the number of days above 100°F for the late 21st century under a lower (RCP 4.5, left) and higher (RCP 8.5) emission scenario (right). ***Source: NCA4***

In terms of precipitation, global projections as well as projections across North America show a general pattern of "wet regions becoming wetter and dry regions becoming drier." The largest changes in seasonal annual precipitation are projected for winter and spring, when much of Texas, along with the Southwest, is projected to become drier on average (Figure 14, top). NCA4 projections also show an increase in the fraction of the annual precipitation occurring during the heaviest rainfall events by the end of the century in central Texas (Figure 14, bottom). It is not possible to provide any further detail without developing customized projections for San Antonio.

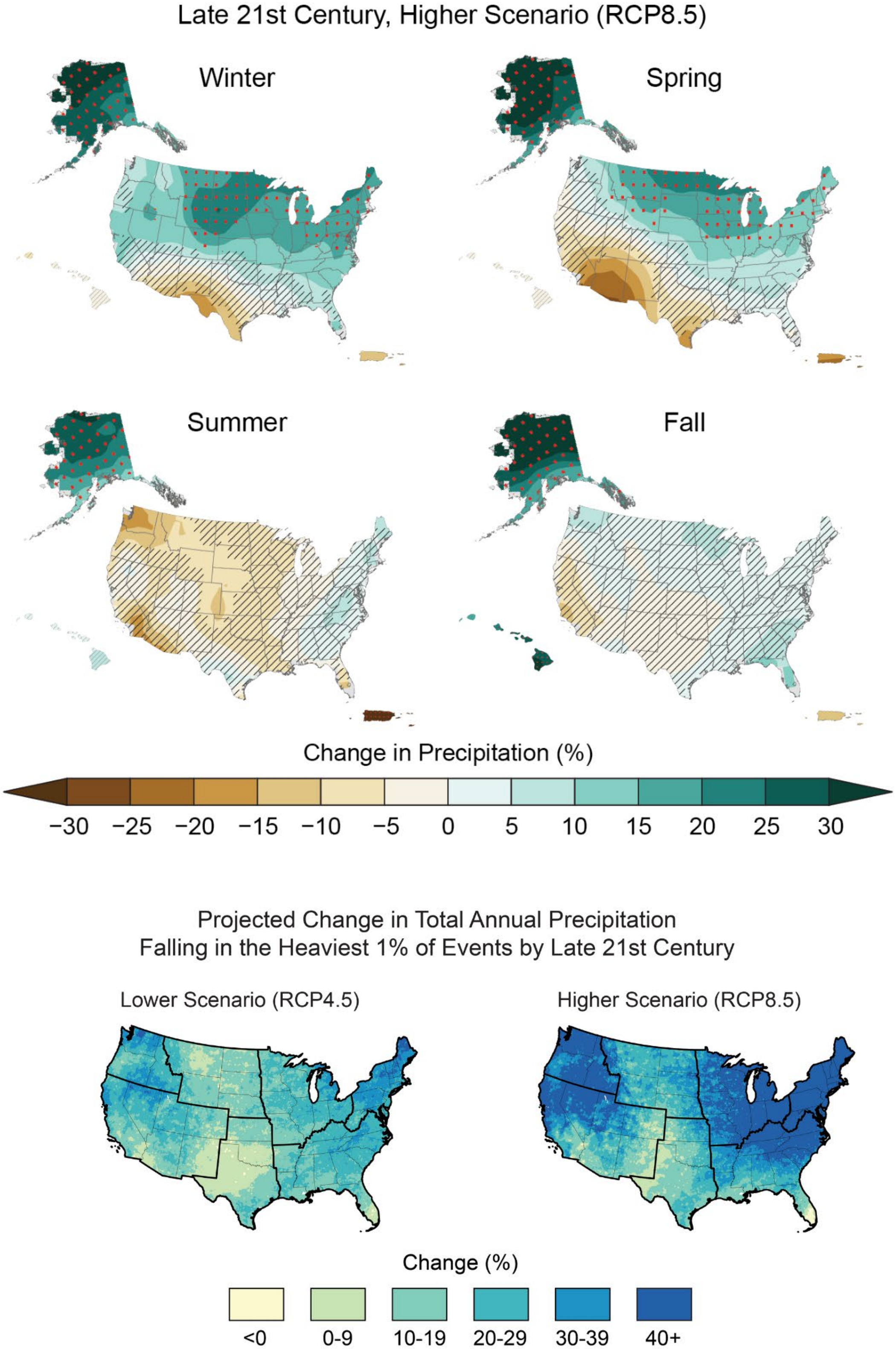


Figure 14. Projected future changes in seasonal average precipitation (top) and in total annual precipitation falling in the heaviest 1% of events (bottom) for the late 21st century (2070–2099)

relative to 1986-2015. Heavy rain projections are shown for a lower emission scenario (RCP 4.5, bottom left) and a higher emission scenario (RCP 8.5, bottom right). ***Source: NCA4***

The 2011 U.S. National Research Council report, Warming World: Impacts by Degree, quantifies some of the impacts that would be expected to increase per degree of global warming. For example, for each degree-Celsius (or 1.8°F) that global temperature increases, we would expect:

- An increase in the amount of rain falling during heavy precipitation events of 3-10%
- A decrease in the amount of streamflow and runoff averaging around 7% across the Texas Gulf region and 12% across the Rio Grande region
- A reduction in the yields of common crops including wheat and maize by 5-15% worldwide
- An increase in the area burned by wildfire in the western United States by 70-400%

Using this same approach of quantifying future impacts by degree, we calculated the risk of future drought conditions, as defined by the seasonal mean Standardized Precipitation Index. As global temperature increases by 1, 2, 3 and 4°C, the risk of dry conditions across much of Texas is projected to increase in spring. In summer, central Texas initially shows little change. By the time the world warms by +3°C, however, dry conditions are projected to become more frequent in summer as well (Figure 15[9]).

[Insert original Figure 15 (previously Figure 13)]

Fig. 15. Projected change in Standardized Precipitation Index for a +1, 2, 3, and 4°C increase in global mean surface temperature (GMST) relative to the historical period 1971–2000. The top row shows projections for spring, while the bottom row shows projections for summer. Green and blue areas are projected to experience wetter conditions while brown areas are projected to experience drier conditions compared to the historical base period. ***Source: Swain & Hayhoe (2014)***

The Bottom Line

For projected changes occurring over *climate timescales* (averaging over 20–30 years or more), based on the observed trends analyzed here and the future projections provided in NCA3 and NCA4, there is:

- *High confidence* that average temperatures will continue to warm, with greater increases under a higher as compared to a lower future scenario.

- *High confidence* that the number of hot days and warm nights occurring on average each year will continue to increase, with greater increases under a higher as compared to a lower future scenario.

[9] Swain, S. and K. Hayhoe. 2014. CMIP5 projected changes in spring and summer drought and wet conditions over North America. Climate Dynamics, 44:2737–2750 (2015). Available from: https://doi.org/10.1007/s00382-014-2255-9.

- *Moderate confidence* that average winter and spring precipitation will decrease over the long term, towards the end of the century, accompanied by increased risk of dry conditions in spring and longer periods of consecutive dry days. Also towards the end of the century, there is some indication these changes may be greater under a higher as compared to a lower future scenario, or under a greater amount of global temperature change as compared to a lesser.

- *Moderate confidence* that the frequency of heavy precipitation and/or average precipitation intensity may increase across some parts of Texas, although projected increases are likely to be small and trends at individual locations, such as San Antonio, will be strongly influenced by local factors.

Statements of confidence simply reflect how certain the science is, in our expert judgment, that these changes will occur. The degree of scientific confidence says nothing about the vulnerability of San Antonio's infrastructure, services, or people to such impacts. In fact, sometimes the greatest vulnerabilities can have the lowest levels of confidence associated with them. For example, the rain event in May 2015 was at least a 1-in-2000 year event, according to early estimates. Vulnerability to this event, in terms of impacts on people, infrastructure, and the economy, was very high. However, this event is exceedingly rare. As such, scientific confidence in how soon and how often this event might recur will be quite low. Low confidence, however, does not mean low impact.

The projections presented in this report provide qualitative guidance regarding the likely direction of future trends in average climate indicators and certain temperature and precipitation extremes. These projections **should not be used to generate specific numbers for the city of San Antonio**, as local and regional factors not included in these projections can modify projected values.

Finally, as discussed above, these projections are **subject to uncertainty** due to natural variability, scientific uncertainty, scenario uncertainty, and the influence of regional land use and topography on local climate. More information on climate science, regional climate change, and the origin of the information presented in this report is available from the linked references highlighted throughout the report.