Assessing Climate Change in Alabama Using Climate Normals

Jonathan Herbert
Physical and Earth Sciences
Jacksonville State University
Jacksonville, AL 36265
E-mail: jherbert@jsu.edu

Jeffrey A. D. Caudill
Physical and Earth Sciences
Jacksonville State University
Jacksonville, AL 36265
E-mail: Jadcaudill@gmail.com

Abstract

This paper uses climate normals to assess historic changes in temperature and precipitation in Alabama. Changes in temperature and precipitation are calculated between climate normals periods at 18 weather stations across the state and for the state as a whole. The earliest climate normals period for which data are available is 1931-60 and the most recent is 1981-2010. Results show that Alabama has gotten cooler and wetter over the whole period of record, particularly in the fall and winter. However, changes between climate normals periods show these trends are reversing.

Key Words: climate change, climate normals, temperature, precipitation, Alabama.

Introduction

Climate change is a global and regional issue. Recent evidence suggests that human induced changes in greenhouse gas concentrations in the atmosphere have contributed to the recent rise in global average temperature, as well as other changes in the climate system. Global temperature increased by approximately 0.7°C (1.3°F) over the twentieth century. It is projected by climate models to continue to rise, between 1.1 and 6.4°C (2.0 and 9.7°F) by the end of this century, depending on the greenhouse gas scenario and climate model. Precipitation also changed over the twentieth century, increasing in some regions and decreasing in others. Climate models predict that precipitation will decrease in subtropical regions and increase in subpolar regions (Solomon et al. 2007).

Global temperatures are recorded at thousands of weather stations worldwide and also by ships at sea. Various global time series have been calculated, but all show similar trends. There have been temporal and spatial variations in the warming. Temperatures stayed relatively stable at the end of the nineteenth century, before warming from 1900 to 1940, cooling between 1940 and 1970, then warm-
ing again from 1970s to the end of the century. Land areas warmed more than oceans and the Northern Hemisphere more than the Southern (Trenberth et al. 2007).

In the United States, climate has also changed. The country has warmed at a similar rate to the Earth as a whole, although the warming has varied in different parts of the country and in different seasons. In general, the warming has been greatest in the western half of the country and Northeast and during the winter half of the year. Changes in precipitation are much more complex than those in temperature. However, there is evidence that there have been increases in both intense precipitation and droughts, especially in the last few decades (Groisman et al. 2004, Groisman and Knight 2007, Lu, Lund, and Seymour 2005).

The Southeast did not see a statistically significant change in temperature over the twentieth century, although temperatures have increased in the region. Seasonally, winters have warmed the most. Again, precipitation did not show any statistically significant changes. Most seasons have become drier, with the exception of fall, which has become wetter. Temperatures are projected to rise in the Southeast anywhere between 2.5 and 5.0°C (4.5 and 9.0°F) by the end of this century. This may lead to an increase in the number of hot days and the heat index. Predictions of precipitation are less certain but are likely to lead to more droughts and water issues. There are also the possibilities of more coastal hazards such as more intense tropical cyclones in the future (Karl, Mellilo, and Peterson 2009).

It is important to study climate change regionally, at various spatial scales. Different patterns of climate change may exist at these different scales. Much past research, however, documents historic climate change and provides model projections of future changes at large regional scales, whether continental (Trenberth et al. 2007) or sub-national (Karl, Mellilo, and Peterson 2009). Even reports which do focus specifically on state-level climate change (Twilley et al. 2001, Wetzel and Twilley 2001) do not contain detailed historic temperature and precipitation data, or provide climate change information for different places within a state. This is partially related to climate model resolution, although those resolutions are improving all the time. This study provides a detailed study of historic climate change based on weather station data and analyzes historic trends at those locations.

**DATA AND METHODS**

Most climate changes analysis is carried out on global-scale gridded datasets, such as those used in the Intergovernmental Panel on Climate Change reports (Brohan et al. 2006, Hansen et al. 2001, Smith and Reynolds 2005). These data sets are based on station observations on land and at sea. Weather observations began as early as the 1600s in the United States, but the modern record goes back about 150 years, to the mid-1800s, when agencies such as the United States Weather Bureau began to organize networks of volunteer observers and provide them with standardized equipment (Fiebrich 2009). These datasets have been corrected for problems such as changes in sea surface temperature measuring techniques, thermometer exposure, and urbanization (Jones and Wigley 2010).

Individual station data can be averaged at the regional or state level by using climate divisions. Each state is divided into up to ten divisions, varying with the size of the state. Climate divisions are geographic regions consisting of several counties with similar topography and climatic conditions and are often used to produce area-weighted averages. Even if weather stations are unevenly spread throughout an area, averaging variables such as temperature or precipitation over climate divisions, then producing an area-weighted average of the climate division values, produces a more accurate estimation for the state as a whole (Guttman and Quayle 1996).

This study assesses climate change in the state of Alabama using climate normals data.
We use all available historic climate normals. Climate normals are monthly averages of temperature and precipitation, calculated over thirty year intervals. The normals analyzed here are from the 1931-60, 1941-70, 1951-80, 1961-1990, and 1971-2000 time periods.

Recent climate normals for the state, for the periods 1971-2000 and 1981-2010, are available online in digital format. These data have been checked for inconsistencies, such as those caused by changing location, instrumentation, and time of observation and those inconsistencies have been corrected using various techniques (National Climatic Data Center 2011a). Climate normals for previous time periods are archived and available as paper copies. We obtained all the available historic normals for Alabama, from the earliest available time period 1931-60 to 1961-90. (National Climatic Data Center 1962, 1972, 1982, 1992).

For this set of climate normals, from 1931-60 to 1981-2010, there are 18 weather stations that have data for both temperature and precipitation in all time periods. We use these stations for consistency. They are located throughout the state, although areas in the northwest and southeast are not as well represented as other parts of the state. The location of these weather stations is shown in Figure 1.

For each weather station, the changes in annual and seasonal average temperature and precipitation values were calculated between normals periods by simply subtracting the earlier value from the later one. This gives temperature and precipitation changes between 1931-60 and 1941-70, 1941-70 and 1951-80, 1951-80 and 1961-90, 1961-90 and 1971-2000, and 1971-2000 and 1981-2000.

In addition, area-weighted state averages were calculated for temperature and precipitation. This was done using the technique of Guttman and Quayle (1996), based the areas of the eight climate divisions in Alabama, also shown in figure 1. These divisions are the Northern Valley (1), Appalachian Mountain (2), Upper Plains (3), Eastern Valley (4), Piedmont Plateau (5), Prairie (6), Coastal Plain (7), and Gulf (8). Temperature and precipitation values were first averaged for all stations within a given climate division, then these values were combined in a weighted average, based on the area of each division according to the National Climatic Data Center (2011b).

Given the consistent set of stations and the nature of climate normals, this approach should give a robust measure of annual and seasonal climate change in Alabama since the early part of the twentieth century. Any changes in temperature or precipitation over these normals periods should represent long term changes in the climate.

RESULTS

The annual average temperature in Alabama based on the 1981-2010 time period was 17.4°C (63.3°F). The seasonal averages for winter, spring, summer, and fall were 8.1, 17.2, 26.2, and 18.1 °C (46.6, 62.9, 79.1, and 64.5°F) respectively (Table 1). The
Table 1. Seasonal and annual average temperature change in Alabama, based on an area-weighted average of the stations in this study. Changes are shown between normals periods (1931-60/1941-70 etc.) as well as the cumulative change for the whole period of study (1931-60/1981-10). Temperatures are in degrees Celsius.

<table>
<thead>
<tr>
<th></th>
<th>Winter (Dec-Feb)</th>
<th>Spring (Mar-May)</th>
<th>Summer (Jun-Aug)</th>
<th>Fall (Sep-Nov)</th>
<th>Annual (Jan-Dec)</th>
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<tr>
<td>1931-60 / 1941-70</td>
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Table 2. Seasonal and annual average precipitation change in Alabama, based on an area-weighted average of the stations in this study. Changes are shown between normals periods (1931-60/1941-70 etc.) as well as the cumulative change for the whole period of study (1931-60/1981-10). Precipitation is in centimeters.

<table>
<thead>
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<th></th>
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<th>Spring (Mar-May)</th>
<th>Summer (Jun-Aug)</th>
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Figure 2. Average annual temperature change between the 1931-60 and 1981-2010 normals periods by station. Temperatures are in degrees Celsius.

The table shows that annual temperatures in the state have cooled when the whole period of analysis, based on the difference between the 1981-2010 and 1931-1960 normals periods. Seasonally this is also true. Every season has cooled on this time scale, especially winter and spring.

There was, of course, a lot of variation between stations. The temperature changes for the whole period of record are shown by station in Figures 2 and 3. The annual map shows that temperatures consistently decreased, particularly in the central and southern part of the state. Every station showed cooling or no change. Seasonally, the pattern is also similar, but there is more variation. All stations show cooling in winter, all other seasons show both warming and cooling.

The annual average precipitation in Alabama based on the 1981-2010 time period was 143.5 cm (56.5 in). The seasonal averages for winter, spring, summer, and fall were 38.6, 36.3, 37.1, and 31.5 cm (15.2, 14.3, 14.6, and 12.4 in) respectively. Precipitation results are given in Table 2. Again, looking at the whole period of record, comparing the 1981-2010 and 1931-1960 normals periods, various changes are apparent. Precipitation has increased, mostly in fall and winter.

Again, mapping the precipitation changes by station in Figures 2 and 3 shows the spatial nature of these changes. The annual map shows that precipitation consistently increased, particularly in the central and northern parts of the state. Seasonally, there is again more variation, but the winter and spring show the most consistent increases in precipitation at most stations.

The above analysis only considers changes over the whole period of analysis, between the first and last normals periods, or the overall trends in temperature and precipitation. Analyzing all the normals periods, however, allows us to give a more detailed picture of change over time. In particular, it is interesting to note that changes in both temperature and precipitation have reversed, compared to the overall trend, when the differences between the two most recent normals periods are considered.

The statewide annual average temperature decreased over the whole period of analysis by 0.6°C (1.1°F), but increased by 0.2°C (0.4°F) between 1971-2000 and 1981-2010. The same happened with annual average precipitation, which increased by 5.2 cm (2.0 in) over the whole period of analysis, but decreased by 3.4 cm (1.3 in) between 1971-2000 and 1981-2010. Seasonally, these recent precipitation changes seem to be still taking place in the winter half of the year, but temperature changes are taking place more in the summer half of the year.

The results of our study are broadly consistent with other studies already mentioned here. Temperatures across the Southeastern region did not show much change over most of the twentieth century, then started to rise noticeably beginning in the 1970s. Our study shows a twentieth century cooling trend in Alabama, reversing around the 1970s. They also report that the region got wetter over the twentieth century, but drier since the 1970s.
Figure 3. Average seasonal temperature change between the 1931-60 and 1981-2010 normals periods by station. Temperatures are in degrees Celsius.
Our study shows the same for Alabama. Seasonally, however, the temperature and precipitation changes in the Southeast and Alabama do not match. Although the broad pattern of climate change is similar, there are differences at the state level. Greater climate variability at smaller scales is to be expected, with less and less variability as climate patterns are averaged out at larger scales (Karl, Melillo, and Peterson 2009).

Climate models project continued warming across the Southeast, especially in the summer, something evident in the analysis here, between the most recent climate normals periods. Precipitation is harder to project accurately at the regional scale, but most models suggest that the Southeast will become drier in almost all seasons, except in fall. Our recent analysis again broadly agrees, showing winter and fall drying, but summer and fall getting wetter (Karl, Melillo, and Peterson 2009, Twilley et al. 2001).

There are many possible explanations as to why the southeastern United States is one of the few regions worldwide that cooled over the twentieth century. Globally, most of the warming over the last hundred years took place in higher latitudes and land areas of the Northern Hemisphere (Trenberth et al. 2007). The Southeastern region is, of course, relatively low latitude and coastal. The fact that water reacts to changes in temperature more slowly than land may have moderated any global warming influence in the region. Other explanations include the rural nature of the region and activities such as irrigation that may have increased evaporational cooling in many areas (Misra et al. 2012).

The patterns of climate change found in this study fit with the idea that the Southeast cooled over the twentieth century, although they certainly suggest that this pattern is changing. It may be that changes in the general circulation of the atmosphere, related to climate change, are taking place. Changes in the position of the jet stream might be associated with changes from cold to warmer winters and also account for the decrease in winter precipitation seen in the data here. Alternatively, the region may just be reacting more slowly to climate change due to its coastal location and the moderating influence of the Gulf Stream.

**CONCLUSIONS**

This study analyzes changes in temperature and precipitation between each climate normals period from 1931-60 to 1981-2010. The analysis shows that Alabama has had changes in temperature and precipitation over the last 80 years. Annual temperatures have decreased and annual precipitation has increased. Temperature has decreased in every season, whereas precipitation has shown more variability.

Interestingly, both of these trends have now reversed. The most recent climate normals, for 1981-2010 show increases in temperature and decreases in precipitation over those from 1971-2000. Whether this is a temporary change, or a potential global warming signal that might continue in decades to come, is unsure, but it is broadly

![Figure 4. Average annual precipitation change between the 1931-60 and 1981-2010 normals periods by station. Precipitation is in degrees Celsius.](image)
Figure 5. Average seasonal precipitation change between the 1931-60 and 1981-2010 normals periods by station. Precipitation is in degrees Celsius.
consistent with climate model projections. Either way, it is hoped that the climate normals based approach used here proves useful and provides a robust measure of climate change. Analyzing changes between climate normals gives a more detailed picture of climate change through time than simple trends over longer time periods. This study also shows the changing nature of temperature and precipitation trends in Alabama over the last 80 years, when climate normals have been available. Although Alabama, along with much of the southeastern United States, has not shown signs of global warming over much of the twentieth century, the results here suggest that this may now be changing.

REFERENCES


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