Investigation C:
CLIMATE AND CLIMATE VARIABILITY FROM THE INSTRUMENTAL RECORD

Driving Questions: What can we determine from the instrumental record regarding the variability of climate? When might that variability infer a change in climate?

Educational Outcomes: Understanding climate and its variability are the first steps in making sense of what factors determine the mean state of the climate system, how it may have changed, and how it might change in the future. This course attempts to cover those key concepts of the boundary conditions that affect Earth's climate state and how the system varies within the limitations imposed by those constraints. We use the record of instrumental observations from the reliable length of readings to define that climate state and to identify its variability. From statistical analysis of the record, we then try to determine if and when a change has occurred or can be expected to occur in that climate state.

After completing this investigation, you should be able to:

- Describe where climate data may be obtained and displayed.
- Show ways the climate record may be analyzed.
- Explain how the climate analysis provides an understanding of climate variability and could lead to objective evidence of climate change (past and present).

In this investigation, we will use temperature records to demonstrate ways in which climatic data acquired by use of reliable instrumentation are employed to examine climate and its variability. We will assess some specific temperature records for the period from 1895 to the present in the climatological division of Nebraska that includes Grand Island, whose local climatic data were referred to in Investigation B.

The temperature data we will analyze are monthly averages from the several sites within climatological division 5 ("central") of Nebraska. A **climatological division** is a region of a state considered to be homogeneous climatologically and containing a reasonable number of observing sites. **Here we will deal only with the July temperature averages;** each value thus being the average of 31 daily averages from approximately ten stations. The data are from NOAA's National Climatic Data Center. These data thus represent the average commonly warmest month's temperature of the area including and surrounding Grand Island, Nebraska for the reliable length of temperature readings there.

In statistics, there are several terms for the most representative or middle value of a series of data (including mean, median, and mode). **Average**, a sometimes vague term, is commonly used to denote the middle value of a set of data determined by dividing the sum of the values by the number of values used in the summation. This definition of average is synonymous with the term **mean**, which statisticians prefer using to precisely define a middle value so calculated. Finally, there is the term “normal” used in climatology. The climatological
standard normal is the average (mean) of the 30 values of the variable within the most recent three decadal climate period, currently 1971-2000. Here we are using the average (mean) temperature for the month of July for each year. That average itself was the average of the daily average temperatures for the 31 days of each July. And each daily average was the average of that day's high and low temperatures.

Figure C1 is the time series graph of July average temperature in degrees Fahrenheit from 1895 to 2008 from NOAA's National Climatic Data Center. The average July temperature of each year is shown by a small green square plotted at the mid-point of that year with the years connected by line segments. The series of red squares making a horizontal line is the average (mean) of these July averages.

Figure C1. Nebraska Central climatological division average July temperatures from 1895 to 2008. [NOAA/NCDC]

1. The average of all the July temperatures, denoted by the line of plotted red squares, is about \([74.5 \, \text{(75.1)} \, 77.2] \) °F.

2. The Local Climatic Data, Annual Summary publication for Grand Island, Nebraska (mentioned in Investigation B) gave the average July temperature for Grand Island in 2005 as 77.4 °F. From Figure C1, the 2005 central climatological division which contains Grand Island had an average July temperature that was \([less \, than \, equal \, to] \)
(greater than) the Grand Island value. The more urban nature of Grand Island compared to the rural area's average probably accounts for this result.

3. The departure of the individual years from the average is the variability. The maximum July average temperature in this series is about 83.6 °F. This occurred in 1934. The minimum July average temperature was 68.1 °F which occurred in 1992. The range is defined as the difference of the maximum and minimum values, and is one simple measure of the variability of data. For the average July temperatures of this period, the range was \((0.7)(8.4)(15.5)(29.3)\) F°.

4. Another issue in a long series of data such as this is the nature of these variations in the data. For example, are there clear cycles of variation? If the values varied in a totally random way, one would expect swings from above to below average and vice versa occurring every year or at least every couple of years. One would not expect consistent runs of above or below average values and certainly not much above or below for extended periods. Using this general context, consider the periods 1902 to 1911, 1929 to 1943, and 1988 to 1997. Do these consecutive-year periods seem to imply total randomness in year-to-year variability? \([\text{Yes}](\text{No})\]

A climate system comprises many interacting processes, some of which serve to maintain certain departures (positive feedbacks) and some to dampen those departures (negative feedbacks.) Evidence exists in the Central Nebraska July temperature for both types of behavior.

The traditionally accepted climate period of the most recent three decades (30 years) of record for climatic values would dictate 1971-2000 as the current climatic normal period. Draw vertical lines on your graph at 1971 and at 2000 to display this span of years. Using the July average temperatures from these years, the following statistics were derived:

- mean: 74.2 °F
- maximum: 79.2 °F
- minimum: 68.1 °F

5. The 1971-2000 July average temperature is [\(\text{less than}(\text{equal to})(\text{greater than})\)] the average of all July temperatures for 1895-2008.

6. The range of July temperatures for 1971-2000 shown in is 11.1 F°. The mean and range for the 1971-2000 period \([\text{are}(\text{are not})]\) equal to those for the 1895-2008 period.

In fact, one could compute the mean for each of the climatic normal periods within the entire length of this temperature record. Those mean values are given below:

- 1901-1930 74.6 °F 1941-1970 75.2 °F
- 1911-1940 76.6 °F 1951-1980 75.2 °F
- 1921-1950 76.4 °F 1961-1990 74.9 °F
- 1931-1960 76.6 °F 1971-2000 74.2 °F
A major concern facing humankind at present is the potential for global warming. This concern comes from the recent worldwide examination of surface temperatures. We can consider these issues from our brief look at the localized summer temperatures of central Nebraska as a data "game". (By no means should this be considered a rigorous climate investigation but only a very limited example of using climate data to answer possible questions.)

7. Let us take "climate change" for our purpose here to imply simply a change of the mean temperature from one climatic normal period to another. Compare the mean of the most recent period, 1971-2000, to those of the preceding periods listed above. The 1971-2000 mean July temperature is \((\text{less than any})(\text{greater than any})\) of the prior climatic periods listed.

8. If merely a change of mean value is considered a different climate regime, has there been a "climate change" in this case? \((\text{Yes})(\text{No})\)

9. Next, consider the magnitude of the difference from the others in the group and also recall the variability displayed in the graph of the total group of temperature values. Given the small difference of the 1971-2000 mean from those others and the overall nature and size of departures over the entire period of record (variance), could one conclusively be sure real change had occurred? \((\text{Yes})(\text{No})\)

10. If we are concerned with "global warming", compare the mean for the 1971-2000 period to those of the other periods listed. The 1971-2000 period mean July temperature is \((\text{the lowest value})(\text{only lower than one or two others})(\text{in the middle of the values})(\text{higher than some others})(\text{the highest value})\).

One caution on these results, while there may be global trends, climate patterns are non-uniform geographically on the regional and local levels. Thus, while some areas may be clearly warming, others may be cooling, with only the overall average showing warmer values.

**Summary:** A number of ways in which recorded temperature values can be analyzed has been shown. Although limited to July data in one climatological division, they are intended as examples of how empirically acquired climatic data can be examined to determine climate variability, which in turn can lead to objective evidence of climate change in the past and present.

However, predicting climate change in the future requires a dynamic approach. As mentioned in Investigation A, while the empirical approach allows us to construct descriptions of climate, the dynamic approach is what enables us to seek explanations for climate. Explanations lead to predictions, including prognostications of change. Considering Earth’s climate system dynamically as a physical system makes it possible to leap-frog into the future via computer models to make potentially useful climate change predictions.
The USGCRP *Global Climate Change Impacts in the United States* report presents climate-change predictions on the regional scale. As an example, the report shows in Figure C2 that climate models predict the Nebraska Central climatological division’s summer temperatures are projected to rise 6°F or more compared to a 1960s and 1970s baseline.

Figure C2. Projected summer temperature change in the Great Plains [USGCRP].