

Impacts of Climate Change on Water Resources Planning

Nolan Doesken

State Climatologist, Colorado Climate Center
Atmospheric Science Department
Colorado State University

Presented at Water Conservation Workshop, Pagosa Springs,
Colorado, June 14, 2007



Prepared by Odie Bliss, Wendy Ryan



Should we be concerned about Climate Change?

Before we react too quickly, let's first consider our climate history.



Systematic weather data collection began in the southwest Colorado in the 1880s

(FORM 4.)

WAR DEPARTMENT.
SIGNAL SERVICE, U. S. ARMY.
DIVISION OF TELEGRAMS AND REPORTS FOR THE BENEFIT OF COMMERCE.

METEOROLOGICAL RECORD for the *State of* ending *Nov. 25th 1871 at Denver, Col. Ter.*

| Date of Observation. | Time of Observation. | Height of Barometer. | Height of attached Thermometers. | Reduced Barometer. | THERMOMETER. (OPEN AIR.) | | Direction of wind. | Velocity of wind in miles per hour. | Pressure of wind. Pounds per square foot. | Amount of cloud. | Direction in which upper clouds move. | Rain (or snow) commenced. (Time.) | Rain (or snow) ended. (Time.) | Amount of rain or melted snow. | Shift register from barometer. | REMARKS. |
|--------------------------|----------------------|----------------------|----------------------------------|--------------------|--------------------------|--------------|--------------------|-------------------------------------|---|------------------|---------------------------------------|-----------------------------------|-------------------------------|--------------------------------|--------------------------------|---------------------------|
| | | | | | Dry Bulb. | Wet Bulb. | | | | | | | | | | |
| <i>1871</i> | <i>5:43 a.m.</i> | <i>25.00</i> | <i>57 22</i> | <i>30.07</i> | <i>22 21 26</i> | <i>Calms</i> | <i>0</i> | <i>0</i> | <i>4/4</i> | | | | | | | <i>Light Snow - Cloud</i> |
| <i>Sunday Nov. 19</i> | <i>2:43 p.m.</i> | <i>25.09</i> | <i>63 36</i> | <i>29.97</i> | <i>36 32 44</i> | <i>S</i> | <i>11</i> | <i>.60</i> | <i>0</i> | | | | | | | <i>Clear</i> |
| | <i>4:43 p.m.</i> | <i>25.12</i> | <i>58 14</i> | <i>30.20</i> | <i>14 23 64</i> | <i>S</i> | <i>11</i> | <i>.60</i> | <i>0</i> | | | | | | | <i>Light Snow</i> |
| <i>Monday Nov. 20</i> | <i>5:43 a.m.</i> | <i>25.00</i> | <i>57 22</i> | <i>30.07</i> | <i>22 21 26</i> | <i>Calms</i> | <i>0</i> | <i>0</i> | <i>4/4</i> | | | <i>0.2 m</i> | <i>8.0 m</i> | <i>Blacks</i> | | <i>Light Snow</i> |
| | <i>2:43 p.m.</i> | <i>25.09</i> | <i>63 36</i> | <i>29.97</i> | <i>36 30 46</i> | <i>S</i> | <i>2</i> | <i>.02</i> | <i>0</i> | <i>7 2</i> | | | | | | <i>Clear</i> |
| <i>Tuesday Nov. 21</i> | <i>1:43 p.m.</i> | <i>25.12</i> | <i>58 14</i> | <i>30.20</i> | <i>14 12 64</i> | <i>S</i> | <i>11</i> | <i>.60</i> | <i>0</i> | | | | | | | <i>Stratus</i> |
| | <i>2:43 p.m.</i> | <i>24.99</i> | <i>50 21</i> | <i>30.07</i> | <i>21 19 57</i> | <i>S</i> | <i>13</i> | <i>.84</i> | <i>1/4</i> | <i>24</i> | | | | | | <i>Stratus</i> |
| <i>Wednesday Nov. 22</i> | <i>2:43 p.m.</i> | <i>24.88</i> | <i>56 43</i> | <i>29.67</i> | <i>43 34 28</i> | <i>NW</i> | <i>10</i> | <i>1.62</i> | <i>4/4</i> | <i>10 3</i> | | | | | | <i>Stratus</i> |
| | <i>4:43 p.m.</i> | <i>24.88</i> | <i>58 39</i> | <i>29.70</i> | <i>39 34 53</i> | <i>NW</i> | <i>2</i> | <i>.02</i> | <i>4/4</i> | <i>34 3</i> | | | | | | <i>Stratus</i> |
| <i>Thursday Nov. 23</i> | <i>5:43 a.m.</i> | <i>24.70</i> | <i>55 31</i> | <i>29.59</i> | <i>34 29 79</i> | <i>S.W.</i> | <i>4</i> | <i>.08</i> | <i>4/4</i> | <i>9 7</i> | | | | | | <i>Stratus</i> |
| | <i>1:43 p.m.</i> | <i>24.57</i> | <i>62 35</i> | <i>29.30</i> | <i>35 32 70</i> | <i>W</i> | <i>3</i> | <i>.02</i> | <i>4/4</i> | <i>32.3</i> | | <i>3 p.m.</i> | | | | <i>Light Snow</i> |
| <i>Friday Nov. 24</i> | <i>4:43 p.m.</i> | <i>24.71</i> | <i>61 31</i> | <i>29.59</i> | <i>31 30 89</i> | <i>S</i> | <i>10</i> | <i>.50</i> | <i>4/4</i> | <i>9 0</i> | | <i>10.30 a.m.</i> | | <i>.26</i> | | <i>Stratus</i> |
| | <i>5:43 a.m.</i> | <i>24.54</i> | <i>55 25</i> | <i>29.47</i> | <i>25 24 87</i> | <i>S</i> | <i>6</i> | <i>.18</i> | <i>4/4</i> | <i>30</i> | | | | | | <i>Light Snow</i> |
| <i>Saturday Nov. 25</i> | <i>2:43 p.m.</i> | <i>24.31</i> | <i>63 34</i> | <i>29.06</i> | <i>34 33 89</i> | <i>N.W.</i> | <i>5</i> | <i>.12</i> | <i>4/4</i> | <i>30</i> | | | | | | <i>Light Snow</i> |
| | <i>4:43 p.m.</i> | <i>24.20</i> | <i>60 31</i> | <i>28.97</i> | <i>31 30 89</i> | <i>S</i> | <i>9</i> | <i>.40</i> | <i>3/4</i> | <i>S.F.</i> | | | | | | <i>" "</i> |
| <i>Sunday Nov. 26</i> | <i>5:43 a.m.</i> | <i>24.36</i> | <i>56 32</i> | <i>29.17</i> | <i>32 32 100</i> | <i>S.W.</i> | <i>4</i> | <i>.08</i> | <i>4/4</i> | <i>10 1</i> | | | <i>8 a.m.</i> | <i>.21</i> | | <i>Cloudy</i> |
| | <i>2:43 p.m.</i> | <i>24.37</i> | <i>70 42</i> | <i>29.04</i> | <i>42 37 58</i> | <i>S.E.</i> | <i>2</i> | <i>.02</i> | <i>4/4</i> | <i>33.7</i> | | | | | | <i>Light Snow</i> |
| <i>Monday Nov. 27</i> | <i>4:43 p.m.</i> | <i>24.38</i> | <i>65 27</i> | <i>29.23</i> | <i>27 27 100</i> | <i>N.W.</i> | <i>2</i> | <i>.02</i> | <i>4/4</i> | | | | | | | <i>Fog</i> |
| | <i>5:43 a.m.</i> | <i>24.37</i> | <i>58 32</i> | <i>29.17</i> | <i>32 28 64</i> | <i>SW</i> | <i>7</i> | <i>.24</i> | <i>1/4</i> | <i>9 8</i> | | | | | | <i>Stratus</i> |
| <i>Tuesday Nov. 28</i> | <i>2:43 p.m.</i> | <i>24.42</i> | <i>70 49</i> | <i>29.03</i> | <i>49 39 31</i> | <i>S.E.</i> | <i>2</i> | <i>.02</i> | <i>4/4</i> | <i>32.7</i> | | | | | | <i>Stratus</i> |
| | <i>4:43 p.m.</i> | <i>24.60</i> | <i>68 17</i> | <i>29.60</i> | <i>17 15 75</i> | <i>N.E.</i> | <i>18</i> | <i>1.62</i> | <i>3/4</i> | | | | | | | <i>Light Snow</i> |

2381 Denver November 19-25, 1871

Henry J. Fenton, Observer

In the 1880s the Colorado legislature approved and funded the “Colorado Meteorological Association” to better monitor and document the climatic resources of our young state.

BULLETIN
OF THE
Colorado Meteorological Association.

3.

JUNE, 1886.

Weather records extending through the month of June have been received from nineteen stations, the positions of which will be found upon the hectographed sketch accompanying the bulletin for May. They include all stations whence statistics for that bulletin were derived, with the exception of the ranch near Sanborn, where observations had to be suspended on June 16th. The new stations with their altitudes and the names of observers are as follows:

| | | |
|---------------------|------|----------------------|
| Hugo | 5068 | I. B. Perkins, M. D. |
| Idaho Springs | 7500 | Ignatius Zeller. |
| Pandora | 8700 | C. Laforge. |

THE WEATHER OF JUNE, 1886.

The weather of the month may be described under three periods, the first extending from June 1st to 9th, the second including the week from the 10th to the 16th inclusive, and the third comprising the remainder of the month. During the first period, there was first a barometric rise lasting from two to four days at different stations, then a decline of no great magnitude, and finally a rise to a second maximum which terminated the period. The weather was in general cool, and showers were frequent. The first and second days were dates of the most important rainfall of the month, which appears to have been confined to the eastern slope of the continental divide.

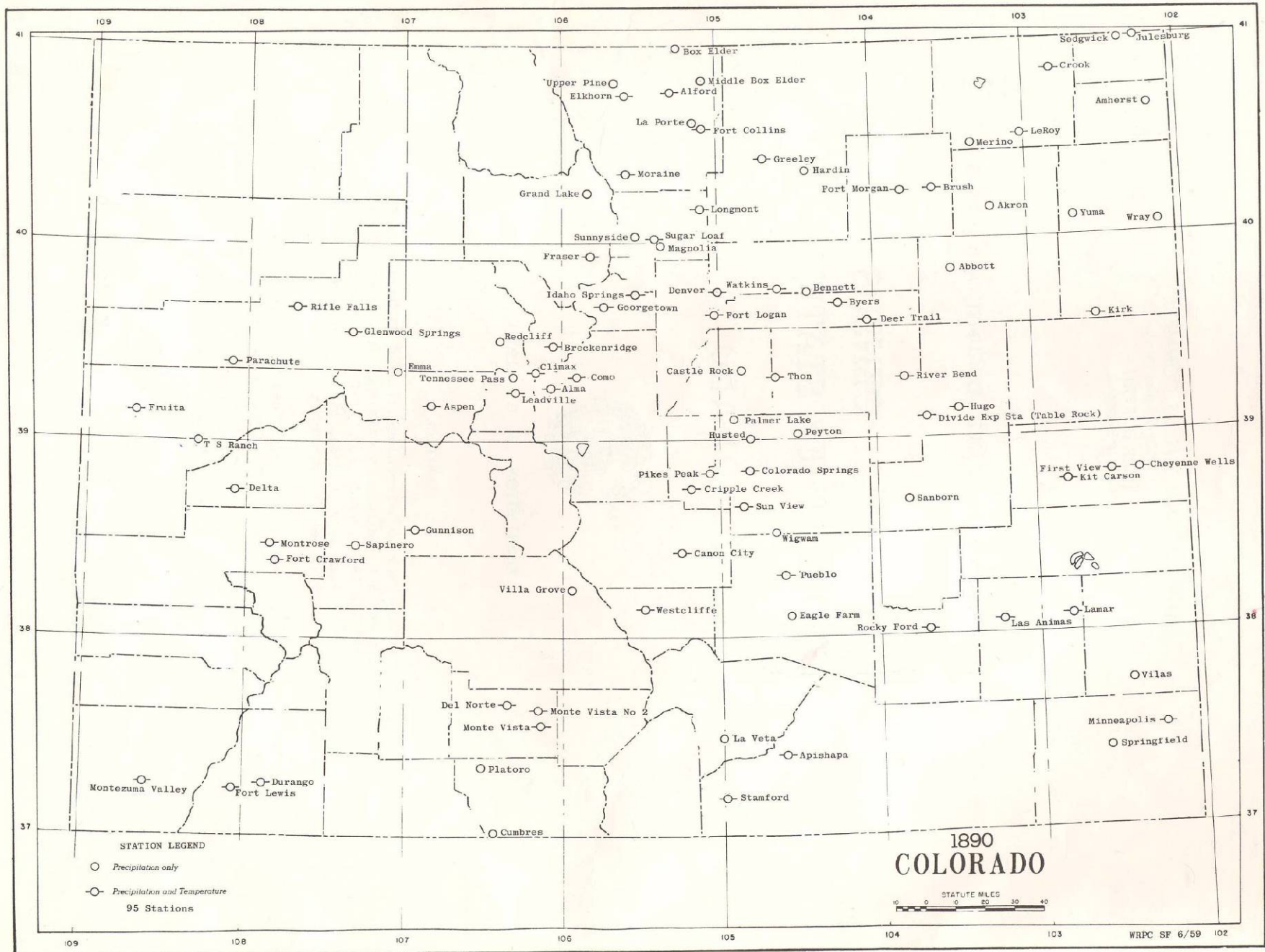
During the second period the barometer descended to the monthly minimum on the 12th, and rose during the four days following. There was no rainfall reported from the western slope, and only local and moderate showers on the eastern side. The 13th and adjacent days were remarkably clear. The temperature of the week was high, declining near the close.


The weather of the third period was quite local in character. The oscillations of the barometer were slight, the lowest daily mean, on the 24th, being generally higher by more than two tenths of an inch than that of the 12th. The precipitation was all or almost all in the form of thunder-showers of small area. Some of these, in the north and northeast of the state were accompanied by violent hail, doing damage to crops which was then estimated to reach a quarter of a million dollars. The temperature was moderate at the beginning of the period, but exhibited a decided increase toward the end of the month.

In 1890 the USDA took over the responsibilities of climate monitoring on a national level, and the first civilian weather service was formed – the U.S. Weather Bureau



Colorado Weather Stations in 1890

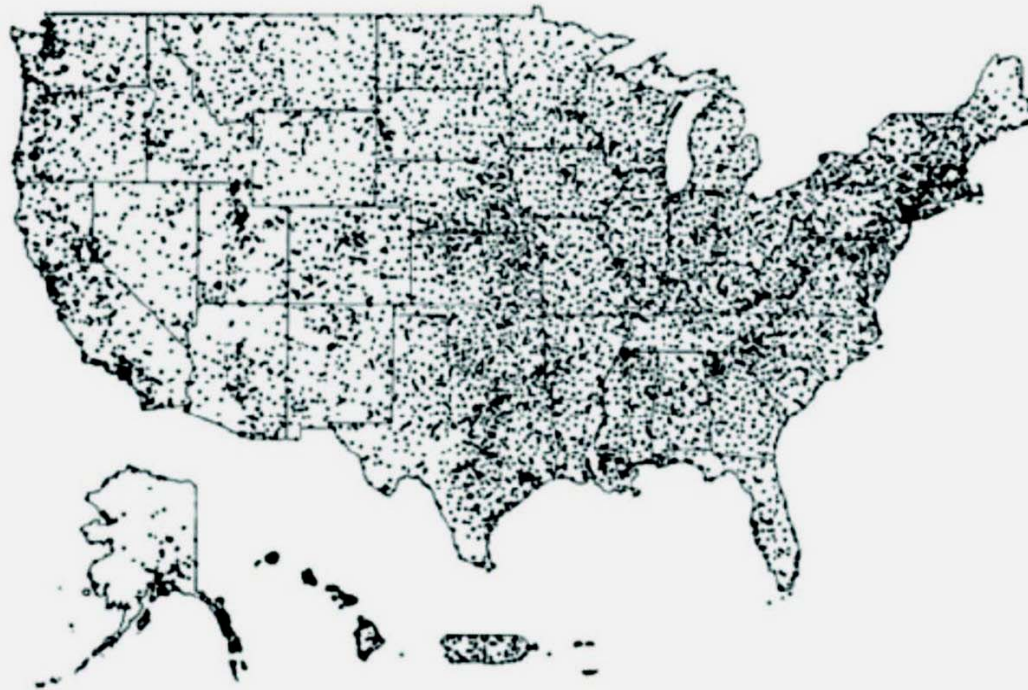




Since then, the U.S. Weather Bureau/National Weather Service has faithfully maintained an oft taken for granted network of weather stations in Colorado and across the country – the Cooperative Observer Network

Photo by Christopher Davey

The NWS stations remain the backbone network for long-term climate monitoring



From Kelly Redmond, WRCC

Approximately 5000 daily max/min temperature stations, 8000 daily precipitation stations, 3000 automated hourly precipitation stations.

In recent years, many other organizations have gotten involved in weather measurements

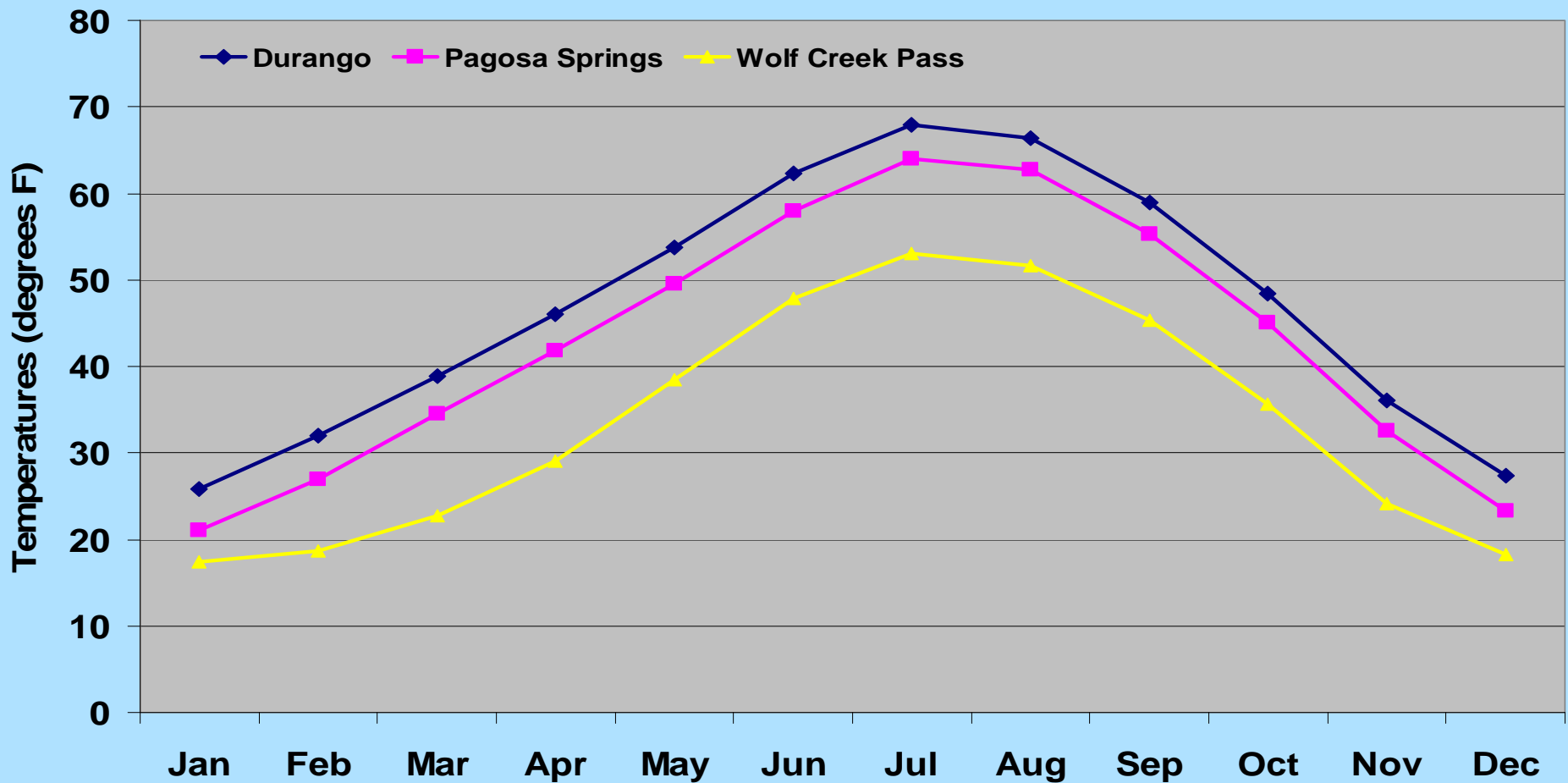


**What have we learned
from nearly 120 years of
continuous climate
monitoring?**

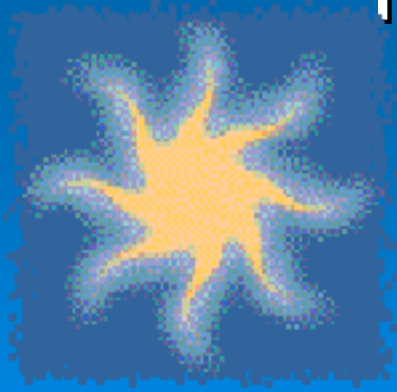


Winters are consistently colder than summers – ☺

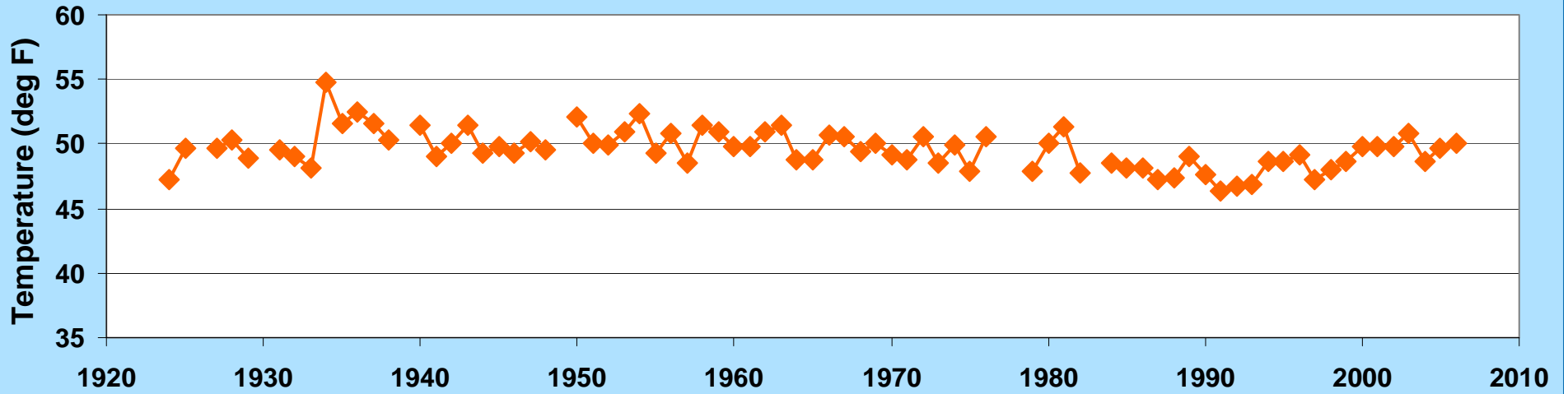
Average Monthly Temperatures (1971-2000) for Selected Stations



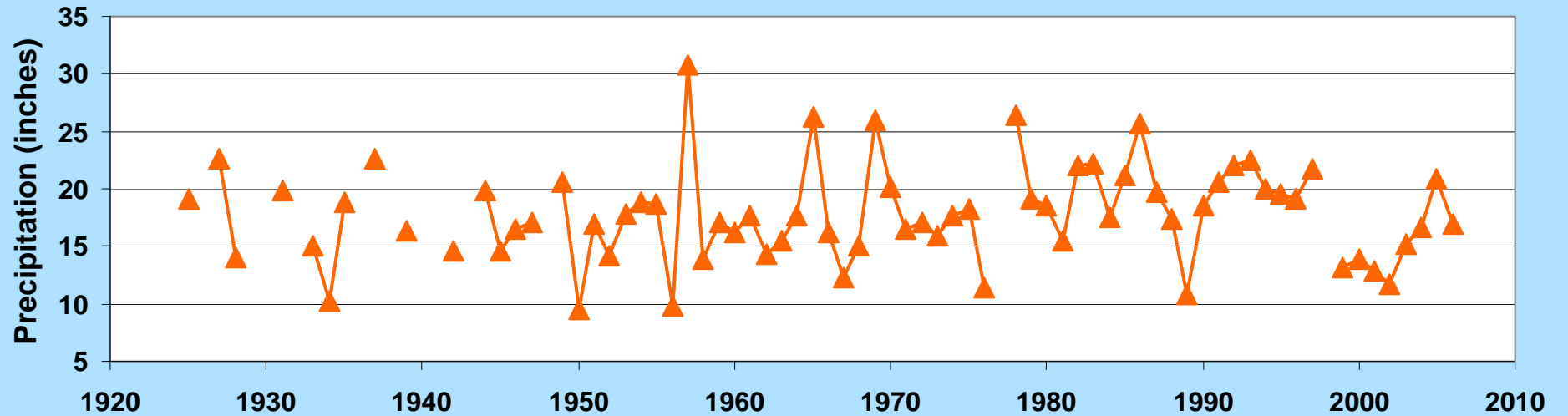
Temperatures are far more stable than precipitation. In fact most other climatic elements (humidity, wind, sunshine and cloudiness, evaporation, etc.) are much more consistent from one year to the next than precipitation.



Mesa Verde Mean Temperatures

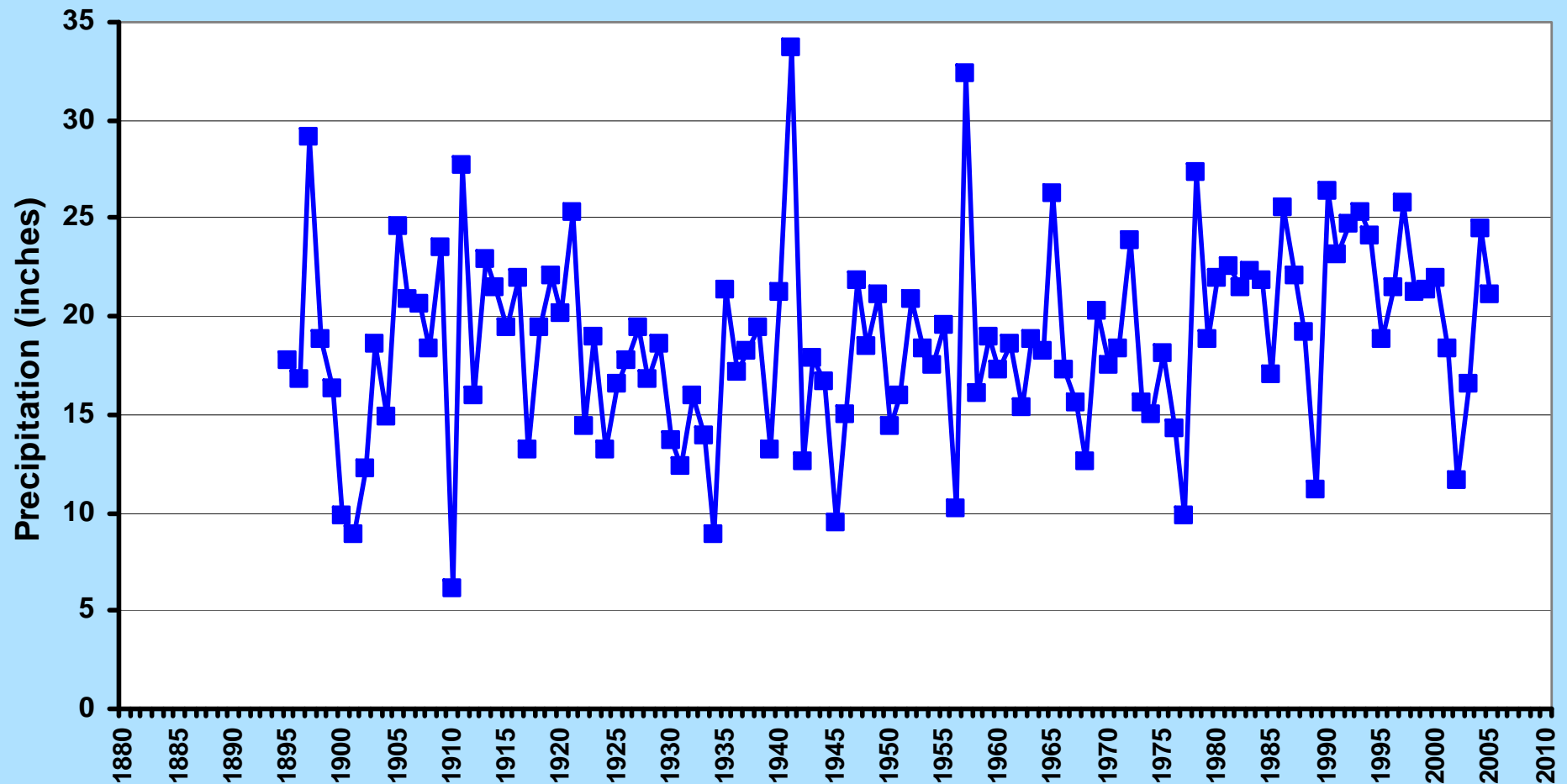


Mesa Verde Annual Precipitation Totals

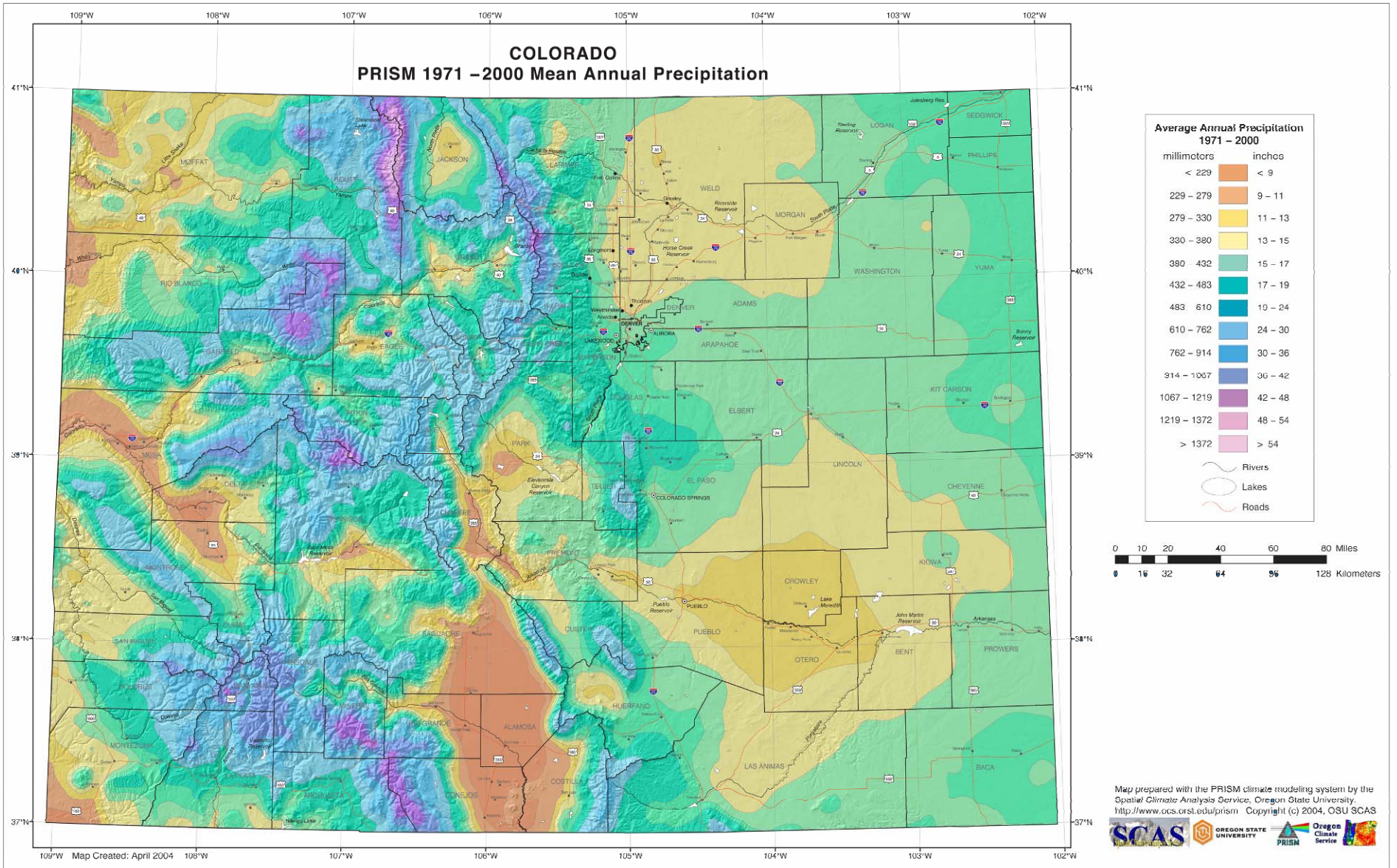


Precipitation varies by as much as 400% from a very dry year to a very wet year

Durango Annual Precipitation

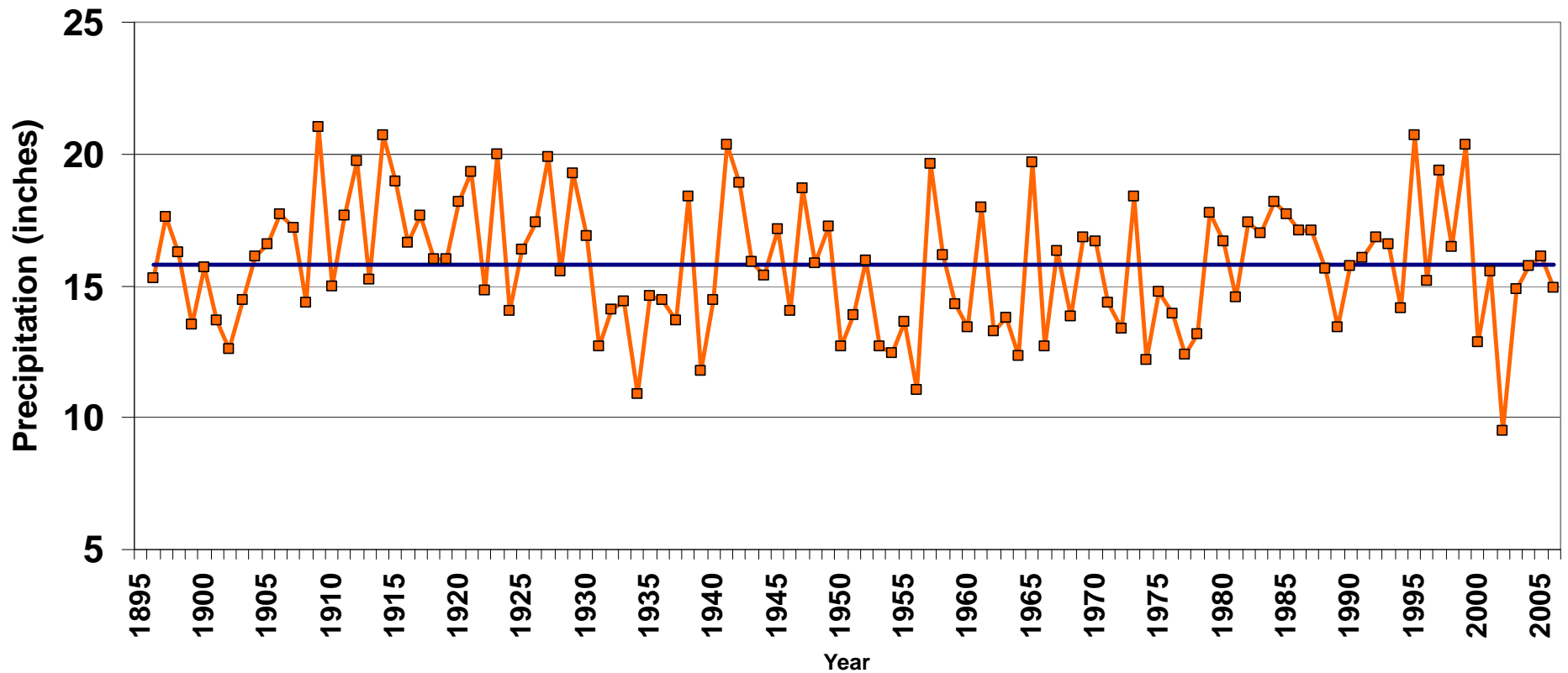


Colorado Average Annual Precipitation



Colorado Statewide Water Year Precipitation

Colorado Statewide Water Year (Oct-Sep) Precipitation
from 1896 - 2006



Drought Visits Our Area Regularly

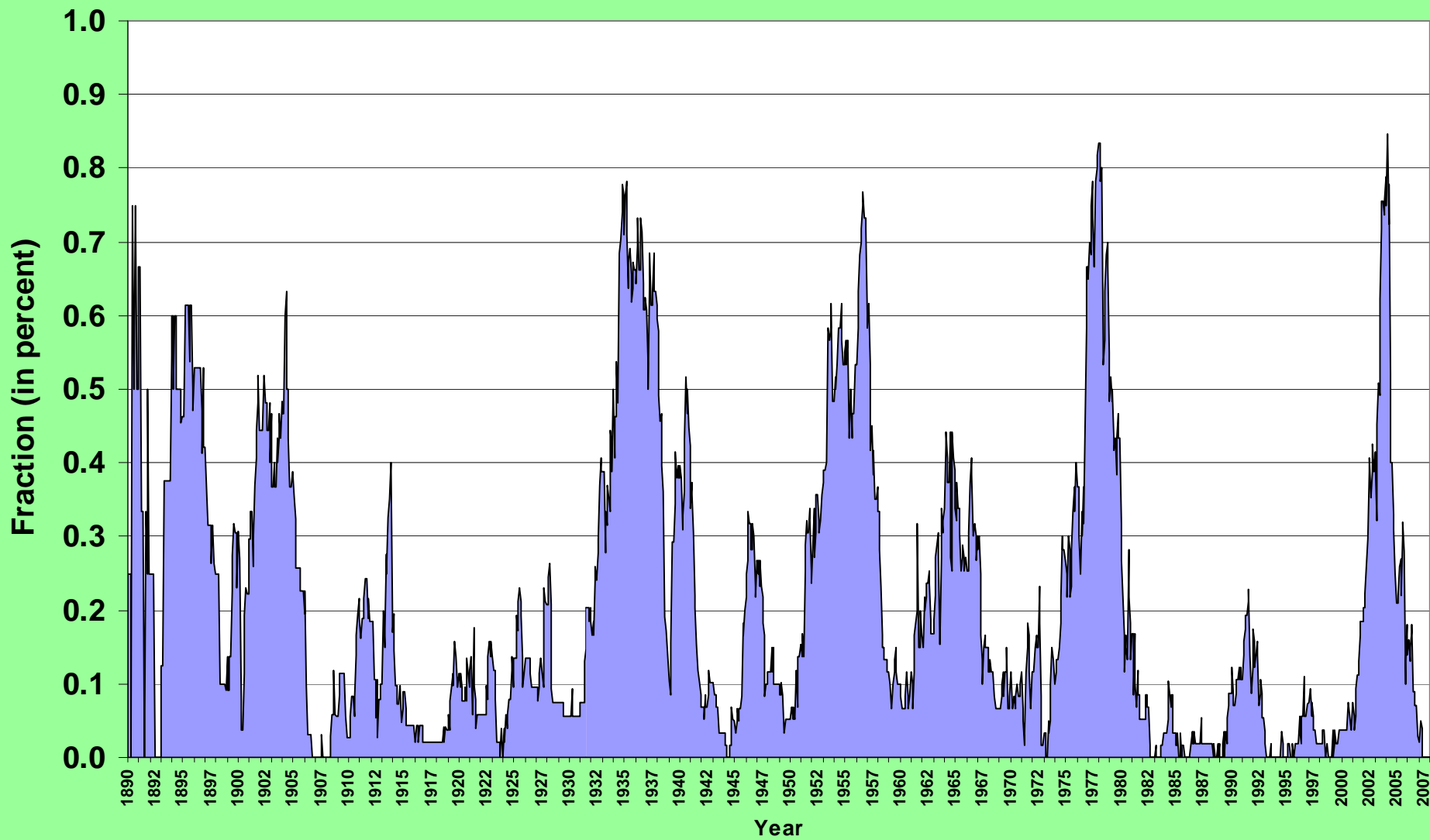


Photo by NRCS

Fraction of Colorado in Drought

Based on 48 month SPI


(1890 - Apr 2007)



Confidently detecting climatic trends is much more challenging and difficult than determining spatial patterns, seasonal cycles, or year-to-year variations



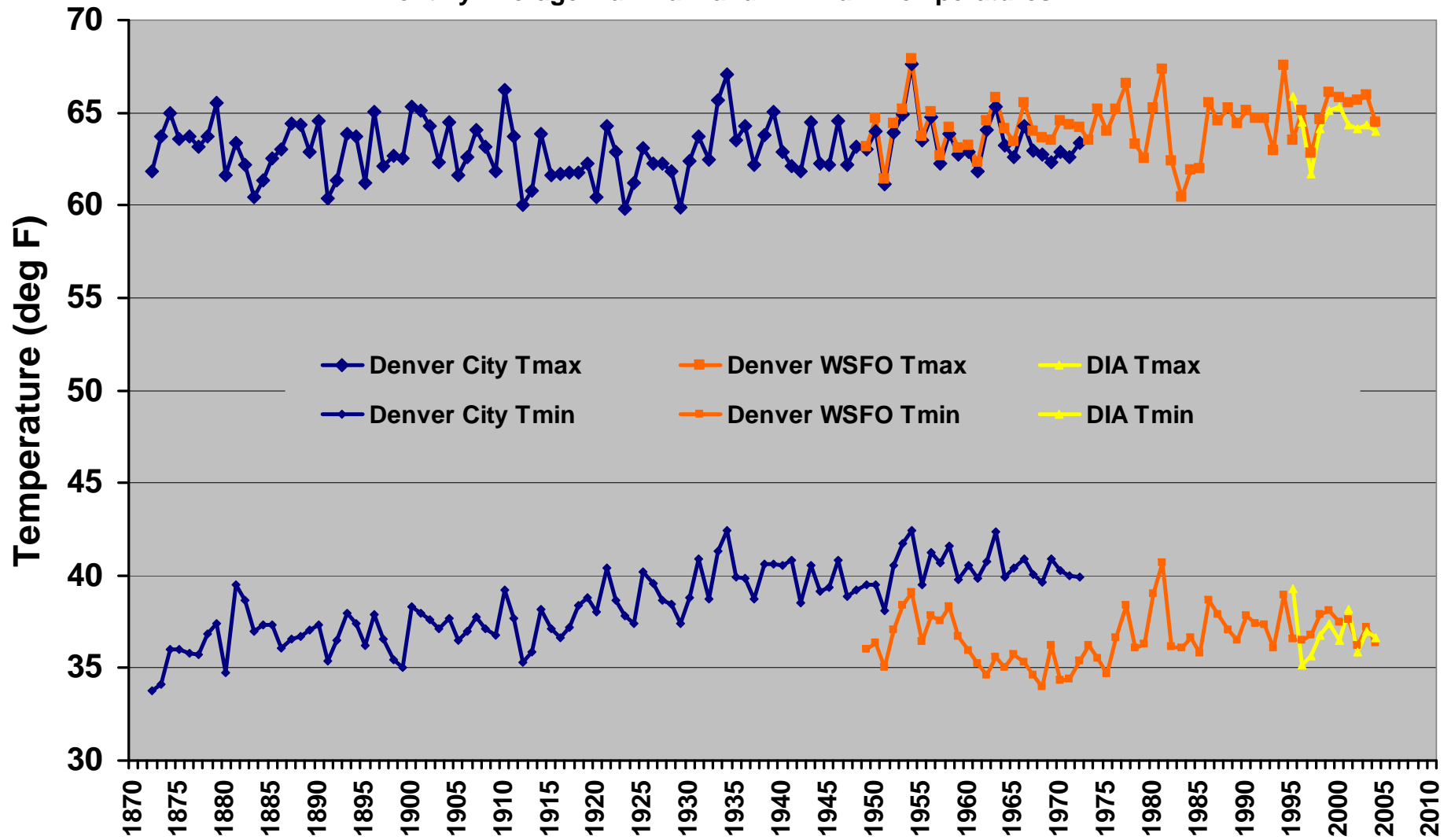
We can find many frustrating limitations to our climate records:

- Changing instrumentation
 - Aging weather observers
 - Changing environments around our weather stations
 - Changing weather station locations
 - Automation, etc.
- 

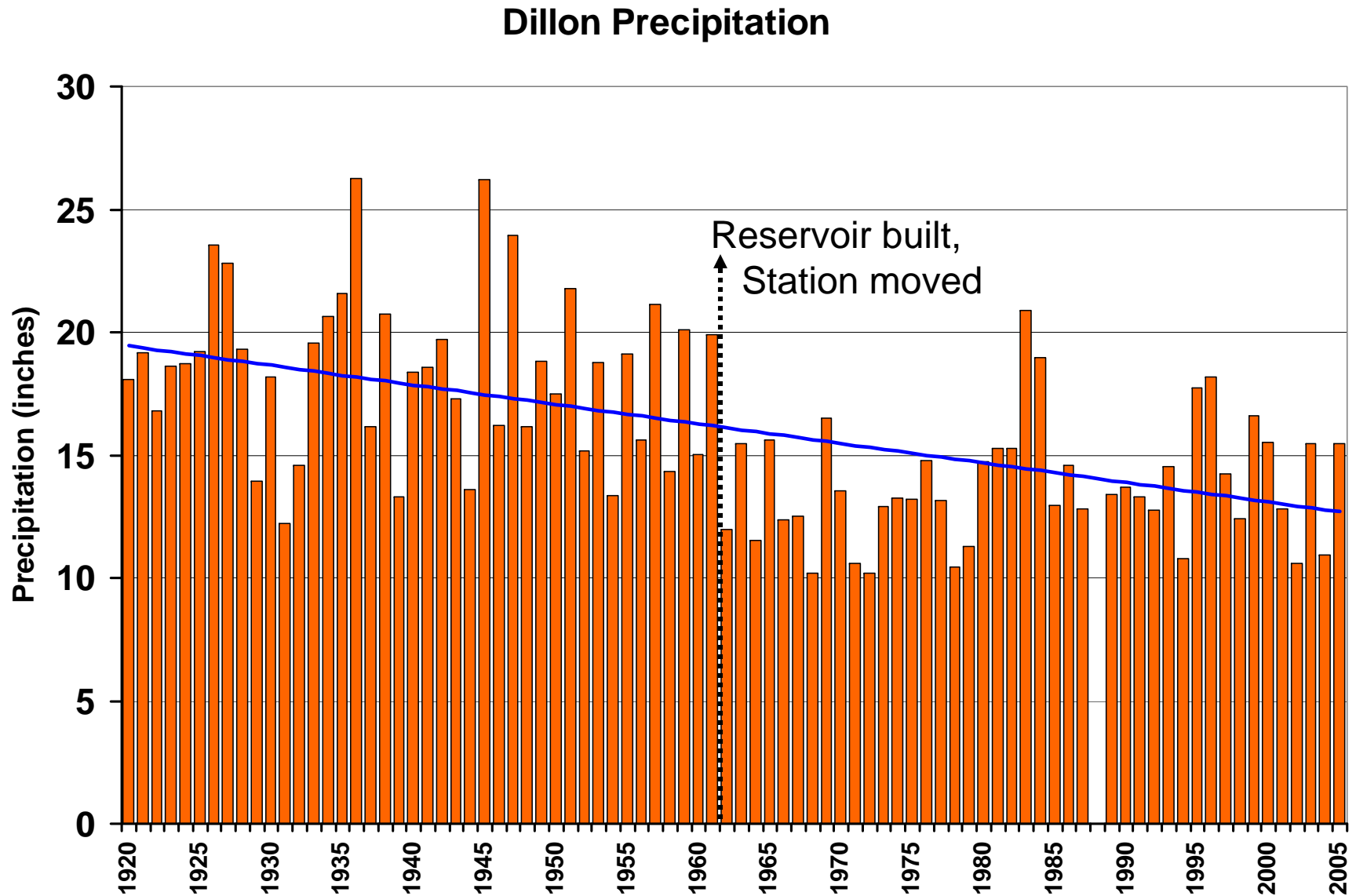
Denver All Stations

Denver (all 3 stations)

Monthly Average Maximum and Minimum Temperatures

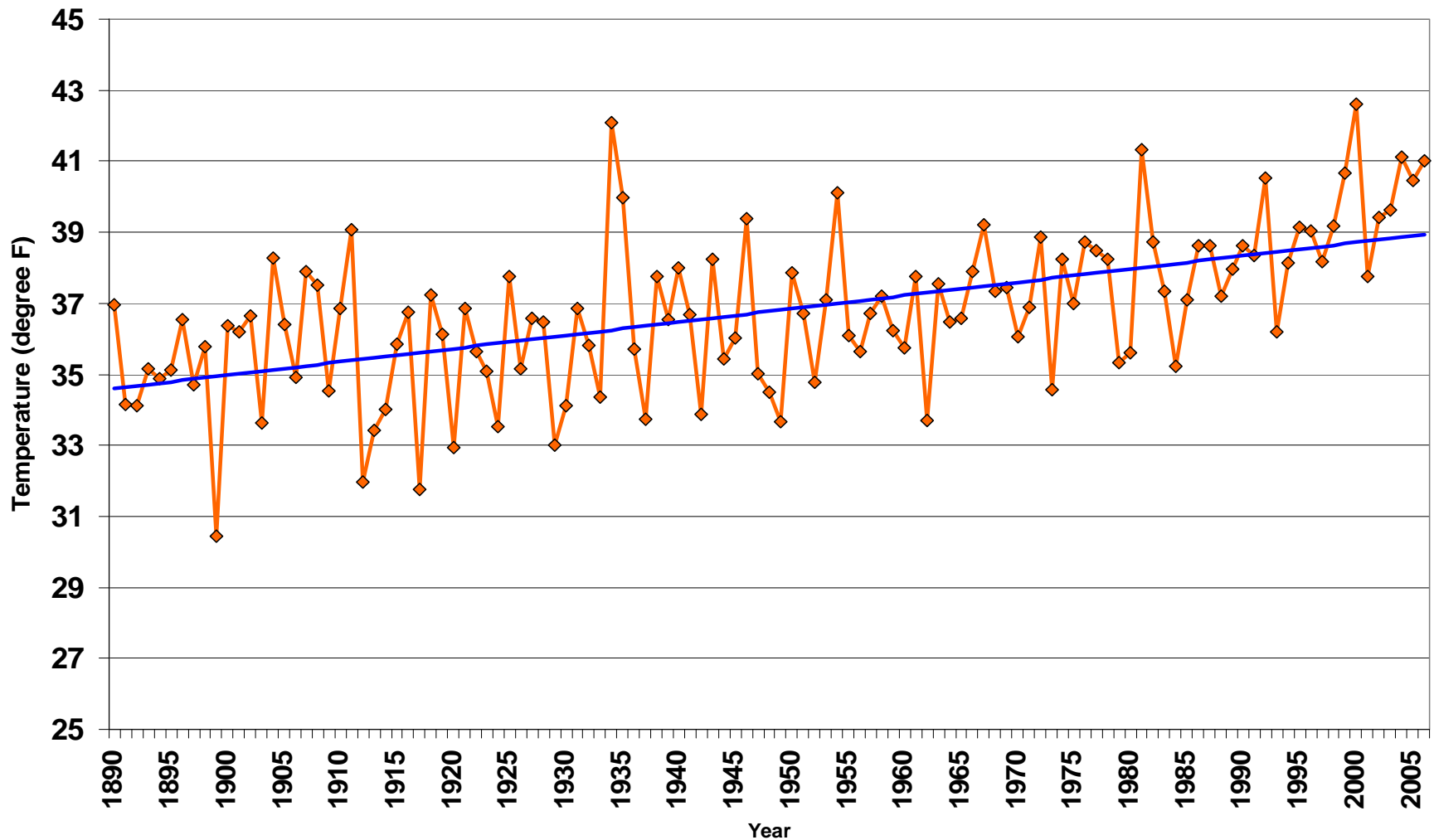


Dillon Annual Precipitation



Fort Collins Winter Temperatures

Fort Collins Water Year Average Temperatures
for Winter (Oct-Apr)

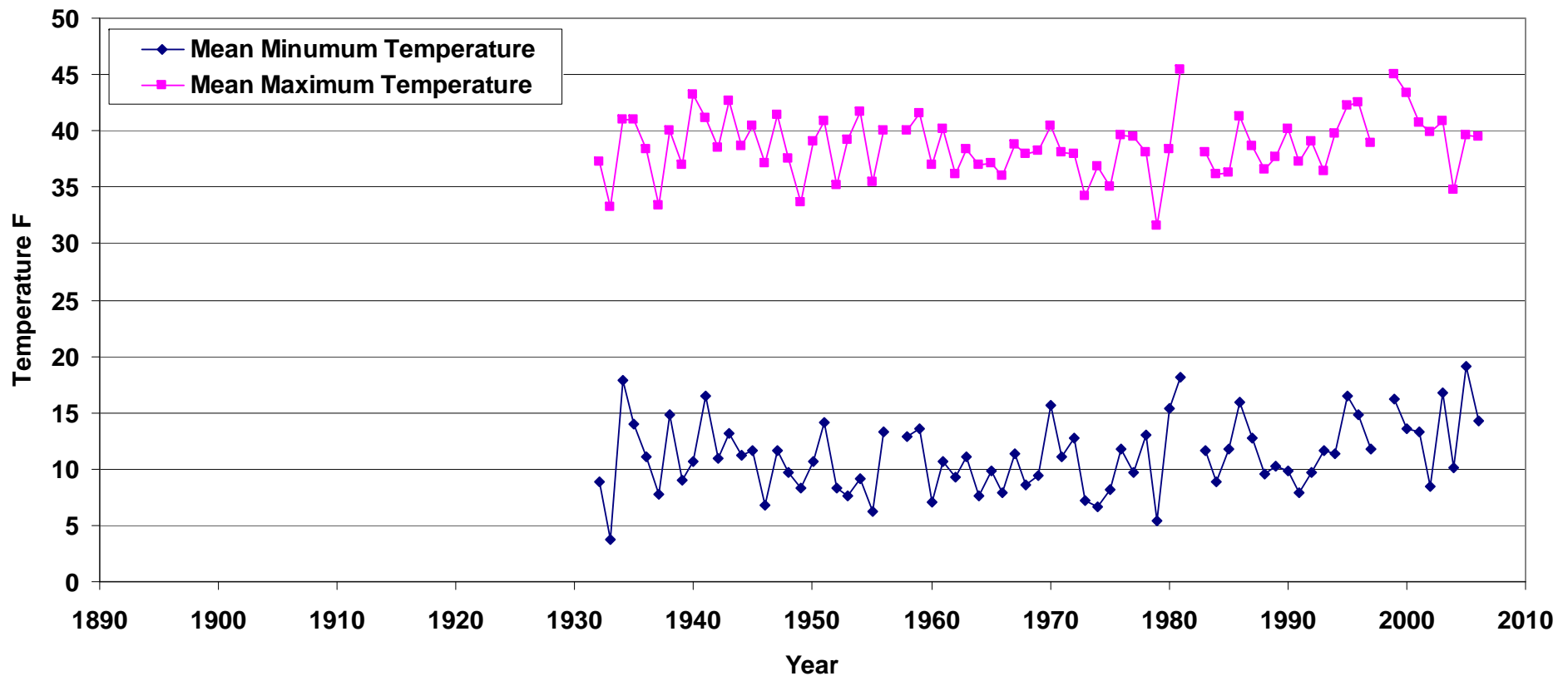


Still, our climate records are more complete, consistent, and widespread than nearly all other forms of long-term environmental monitoring (i.e. we shouldn't whine).

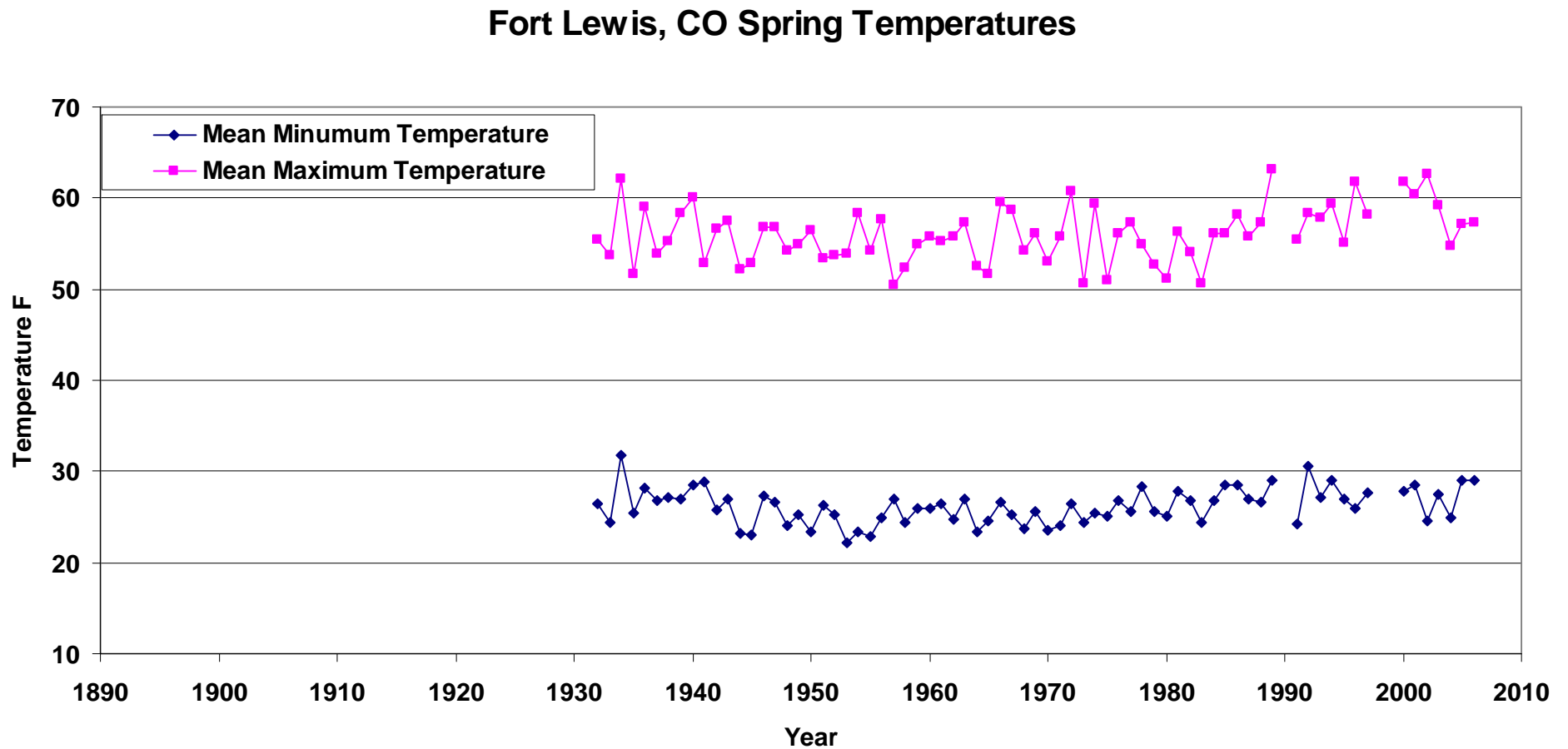


Fort Lewis Winter Temperatures

Fort Lewis, CO Winter Temperatures

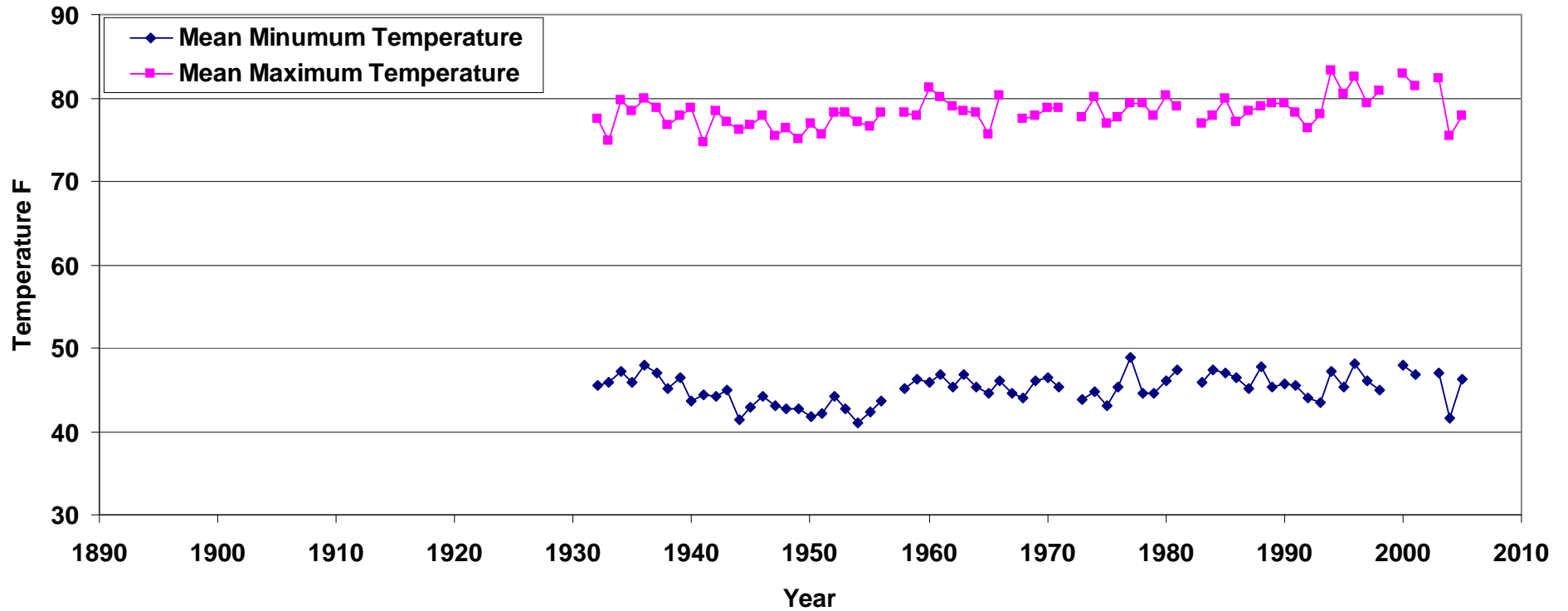


Fort Lewis Spring Temperatures

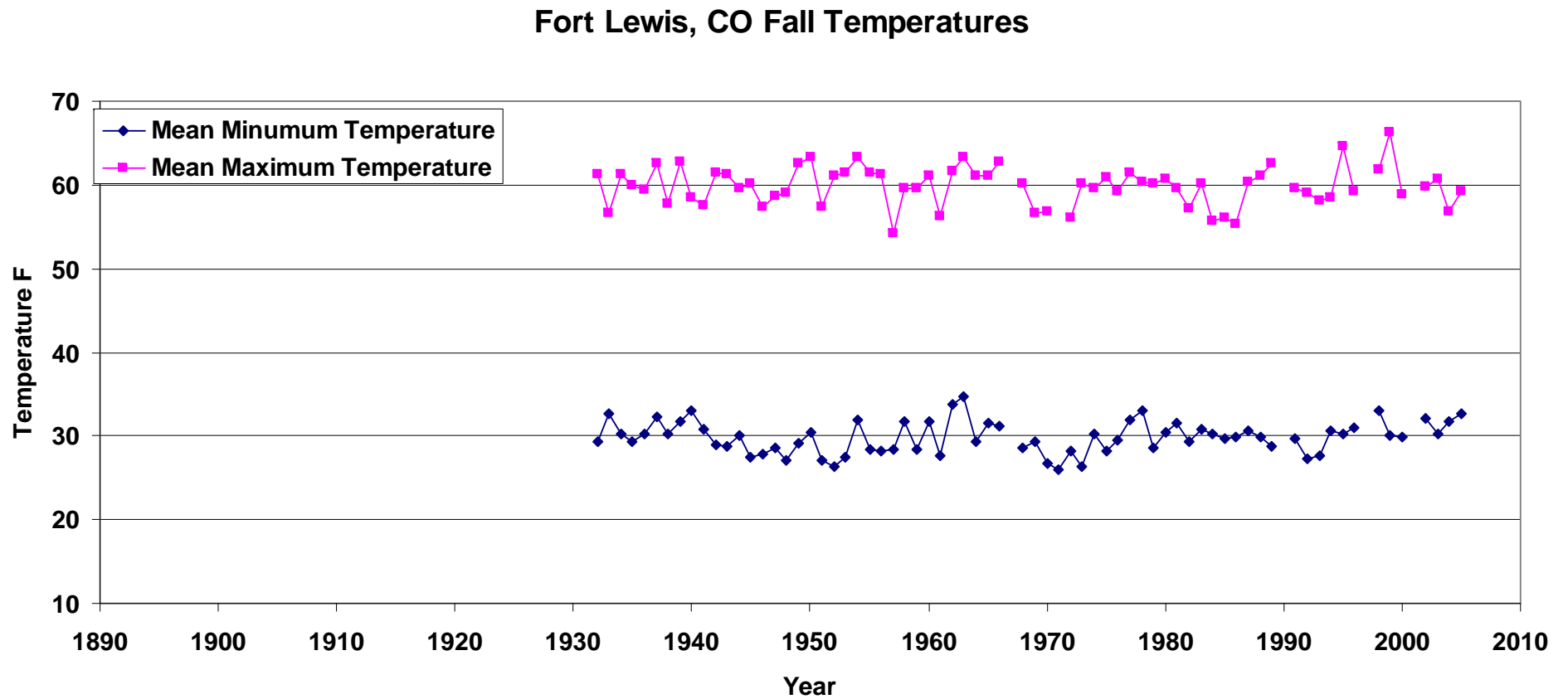



Fort Lewis Summer Temperatures

Fort Lewis, CO Summer Temperatures



Fort Lewis Fall Temperatures



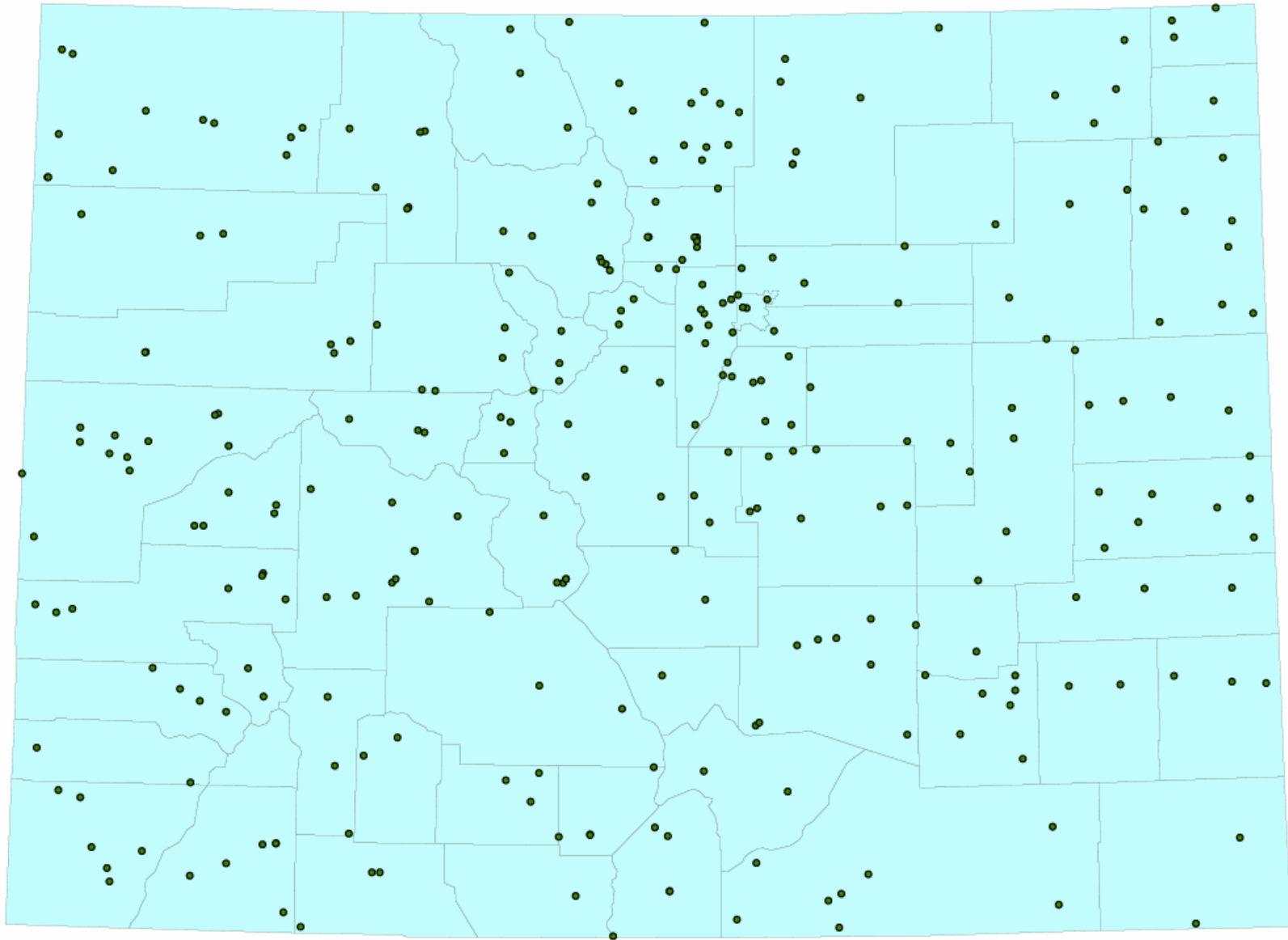


Recently, upward trends in seasonal temperatures have become noticeable in parts of Colorado

That may be significant for water users/planners whether or not precipitation is changing

Colorado Cooperative Stations

COLORADO

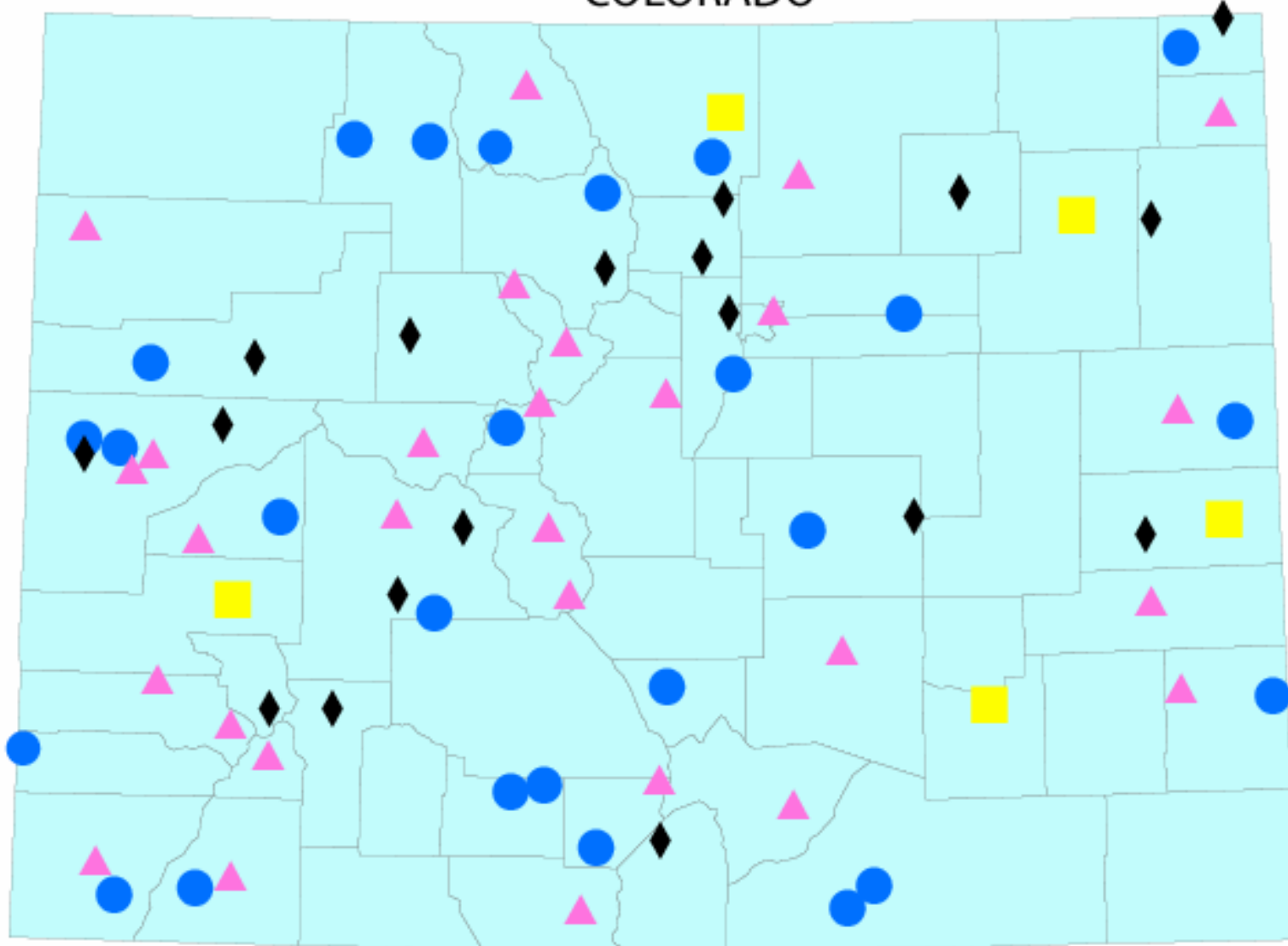


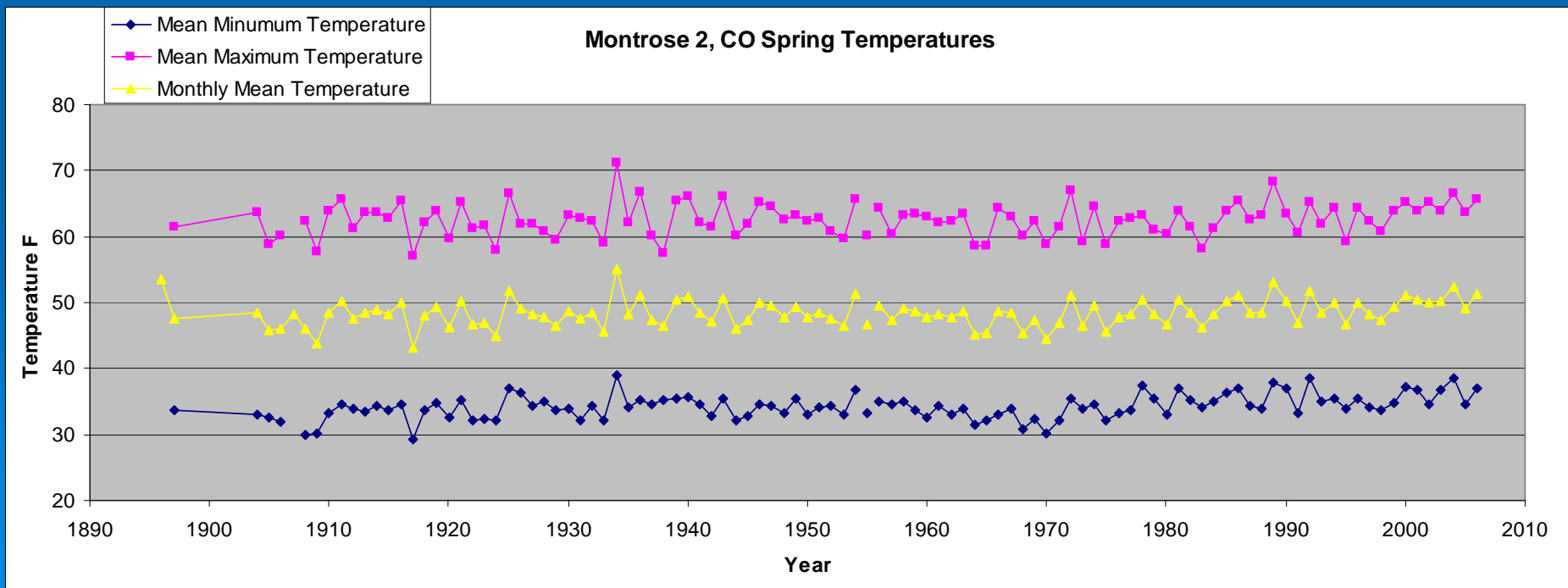
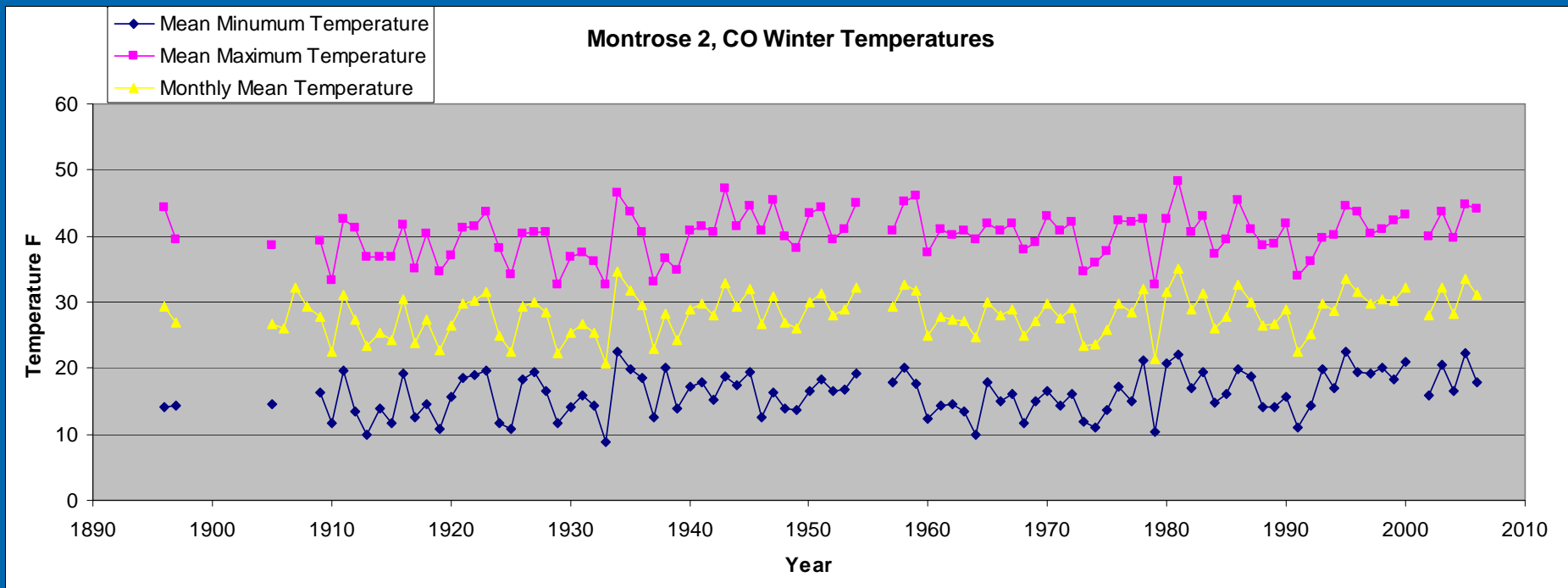
Long-Term Analysis Stations

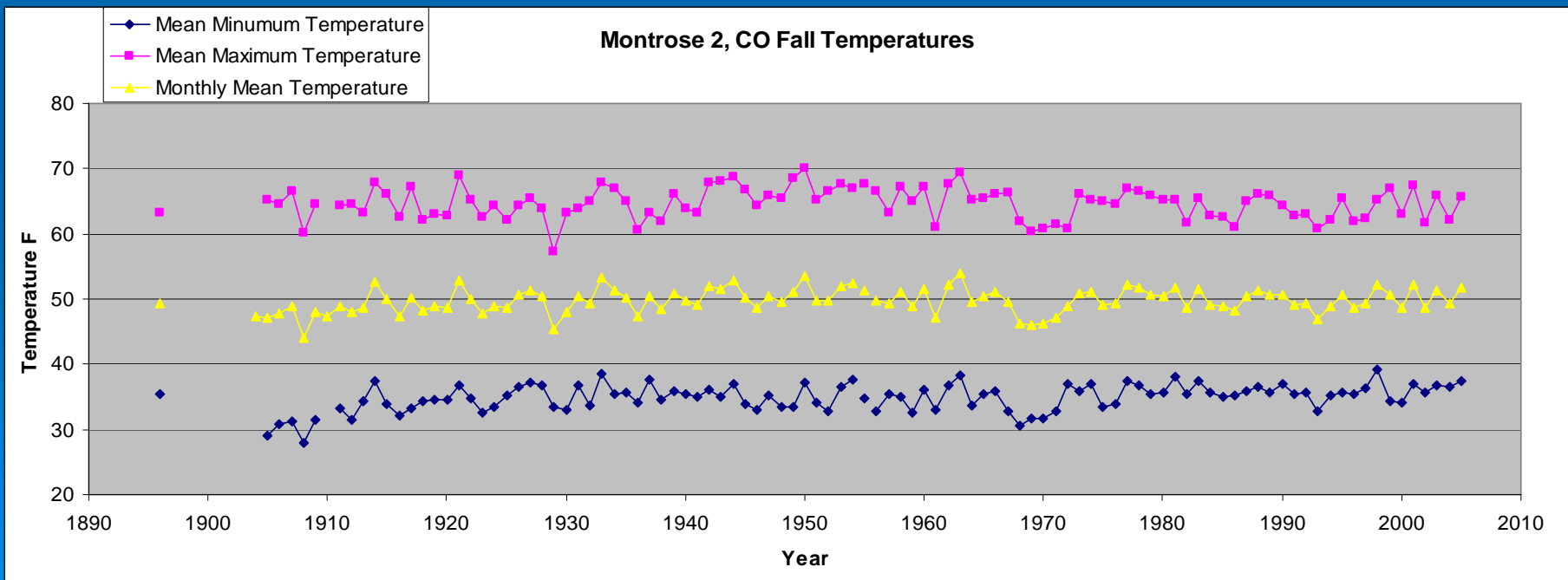
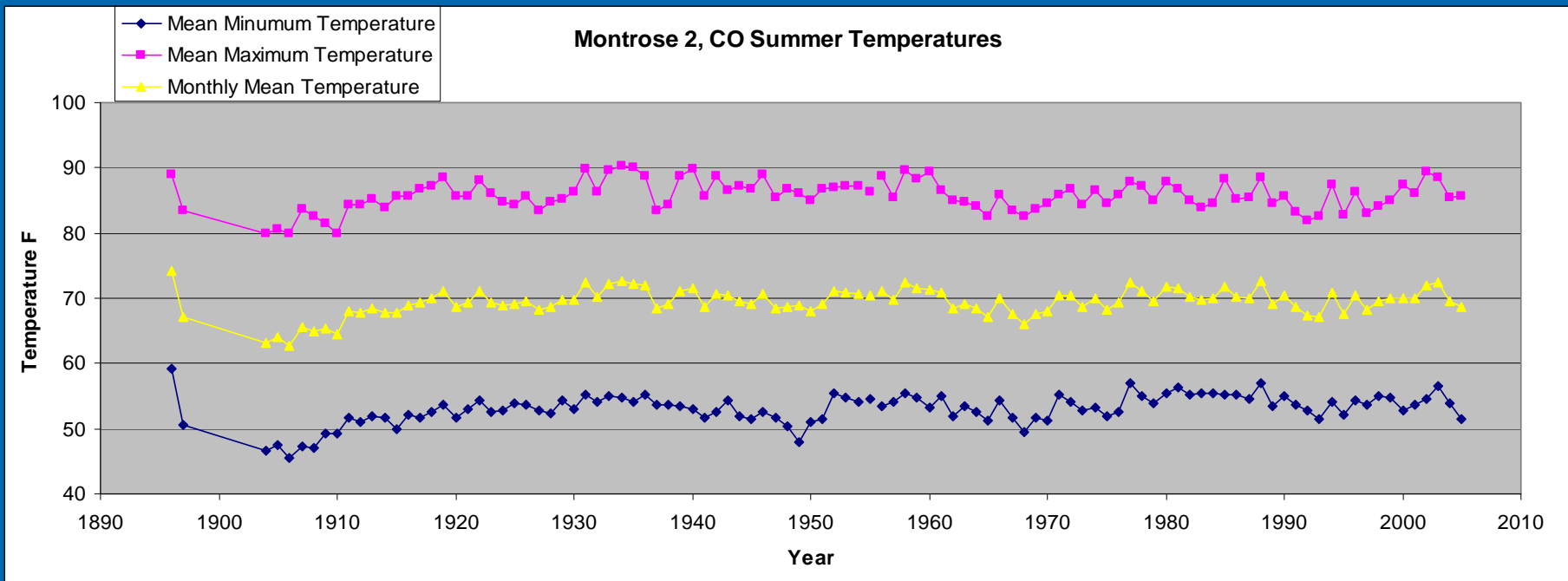
COLORADO

Legend

- ▲ Good
- ◆ Useful
- Better
- Best







With even the best
stations, there is
uncertainty

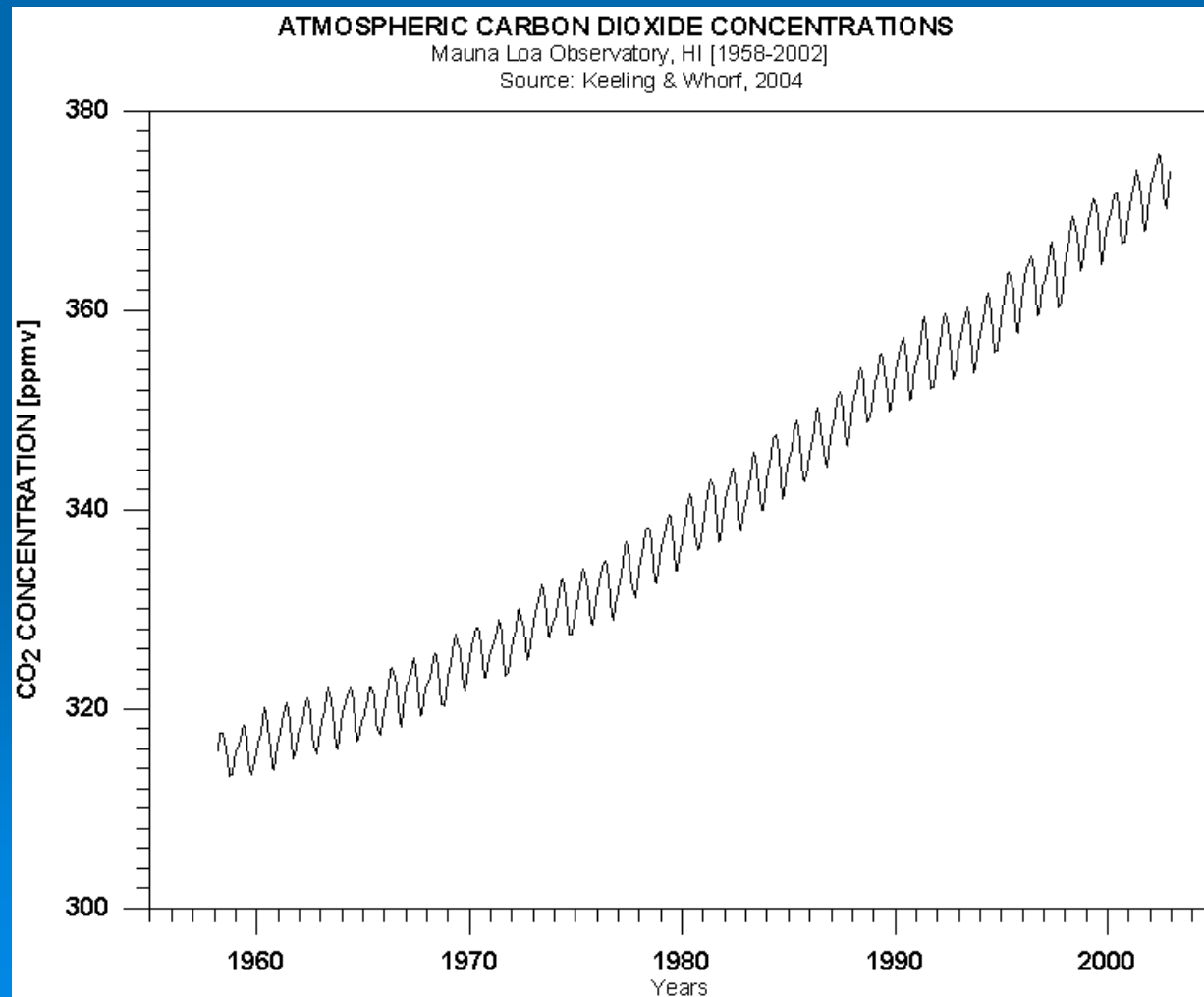


Should water resource planners be concerned about Climate Change?

- The trends so far are subtle, but soon that may not be the case.

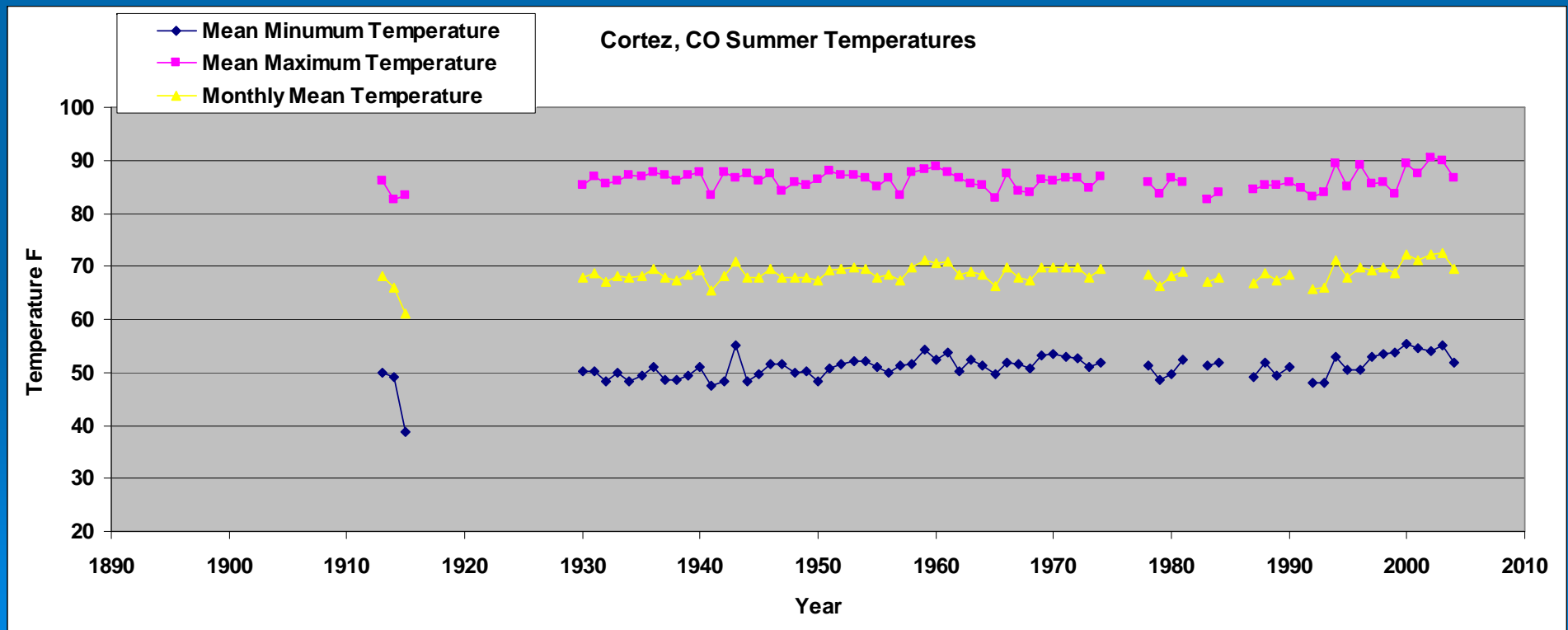


If climate is changing (man caused or otherwise), it will still be a long time before we can tell if our precipitation patterns are changing.



Temperature Trends are Easier to Detect

Cortez Summer Temperatures

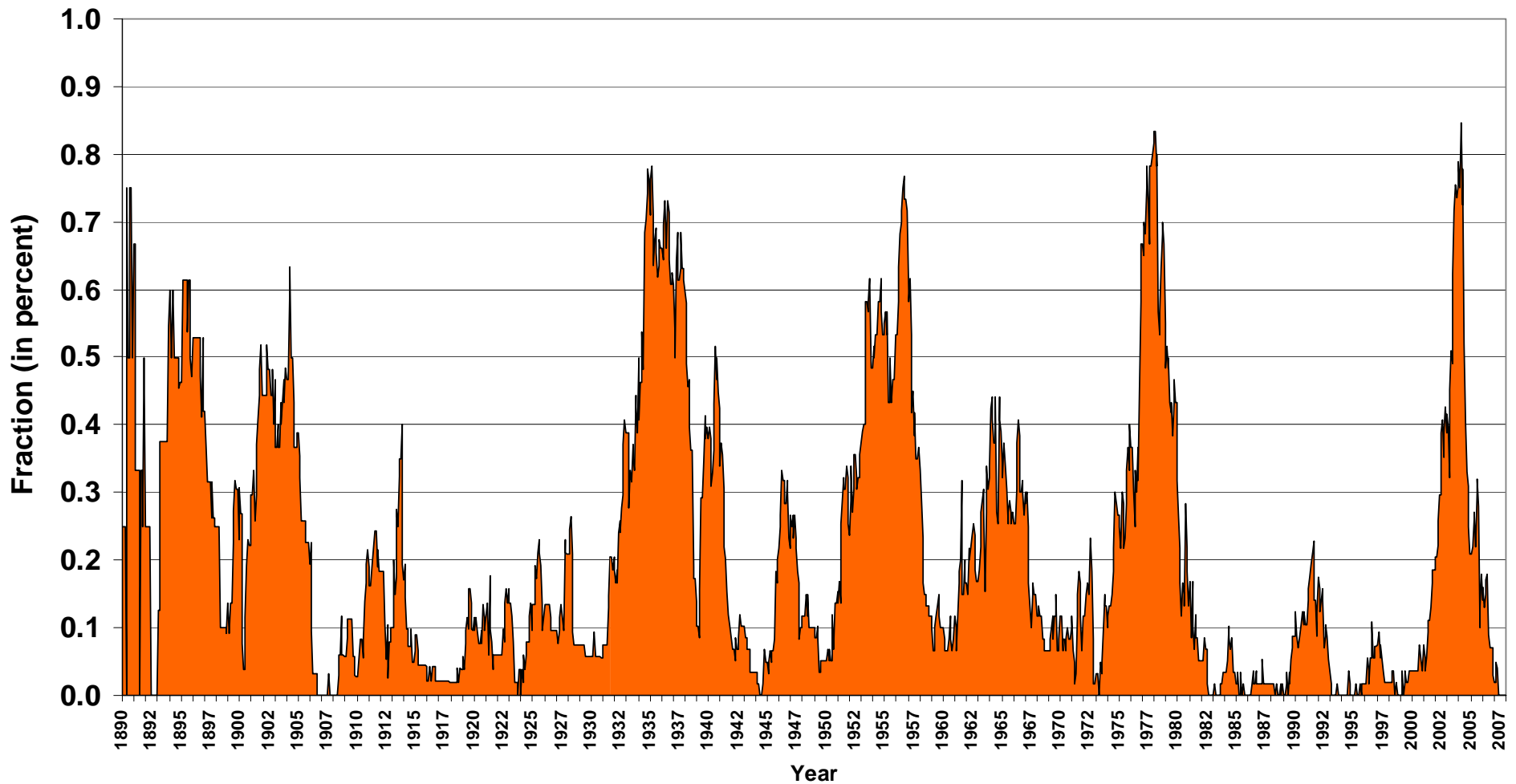


What should we do??



Always plan for drought!

Fraction of Colorado in Drought
Based on 48 month SPI
(1890 - Apr 2007)



And have your rain gauge ready

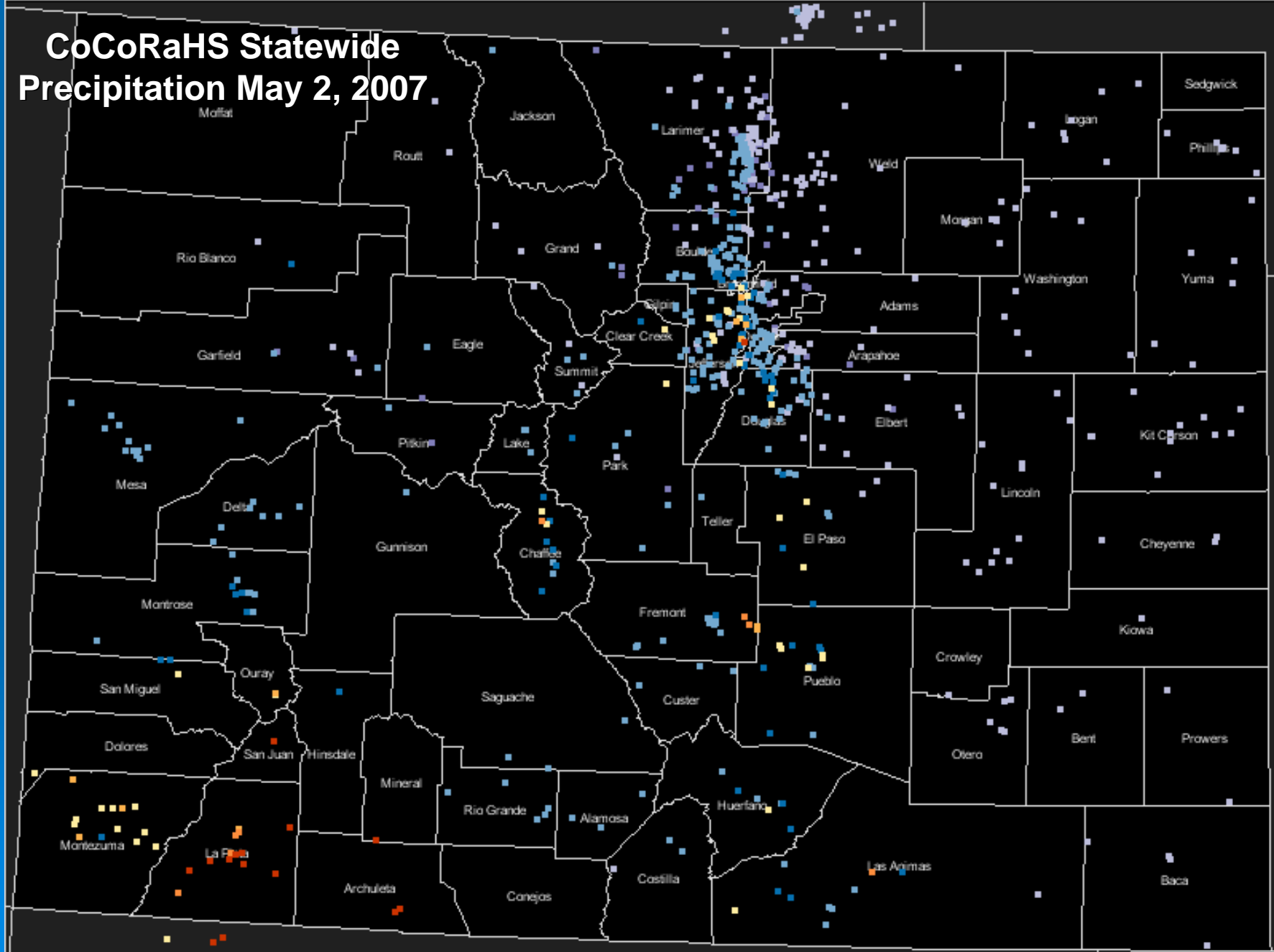


Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am

Colorado 5/2/2007



CoCoRaHS Statewide Precipitation May 2, 2007



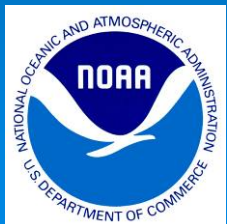
Archuleta County Volunteers Needed!!



For information, visit the CoCoRaHS Web Site



<http://www.cocorahs.org>



Support for this project provided by
NSF Informal Science Education Program,
NOAA Environmental Literacy Program
and
many local charter sponsors.

Colorado Climate Center

Data and Power Point Presentations available for downloading

<http://ccc.atmos.colostate.edu>

Colorado
State
University
Knowledge to Go Places

