

Taking the Pulse of Colorado's Climate

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Atmospheric Science Department
Colorado State University



Presented 5 August 2011
Colorado State University,
Fort Collins, CO



First -- A short background

- In 1973 the federal government abolished the “State Climatologist” program nationwide leaving Colorado without
- Later that same year, Colorado re-established the State Climate program with support through the Colorado Agricultural Experiment Station at Colorado State University.



Our Mission

- The Colorado Climate Center at CSU provides valuable climate expertise to the residents of the state through its threefold program of:
 - 1) ***Climate Monitoring*** (data acquisition, analysis, and archiving),
 - 2) ***Climate Research***
 - 3) ***Climate Services***. (providing data, analysis, climate education and outreach)

Monitoring our Climate

- Elements: temperature, precipitation, snow, wind, solar, evaporation, soil temperatures, humidity, clouds, etc.



Fort Collins CSU Historic Weather Station
Continuous monitoring since the 1880s

Systematic weather data collection began in Colorado in the 1870s and 1880s

(FORM 4.)

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

METEOROLOGICAL RECORD for the *Month* 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.	Remarks.	
					Dry Bulb.	Wet Bulb.										
<i>1871</i>																
<i>Sunday Nov 19</i>	<i>5:43 a.m.</i>	<i>25.00</i>	<i>57 32</i>	<i>30.07</i>	<i>22 21 46</i>	<i>46</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>4/4</i>					<i>Thin Snow</i>	
	<i>2:43 p.m.</i>	<i>25.09</i>	<i>63 36</i>	<i>29.97</i>	<i>36 35 44</i>	<i>S</i>	<i>2</i>	<i>.02</i>	<i>0</i>						<i>Clear</i>	
<i>Monday Nov 20</i>	<i>5:43 a.m.</i>	<i>25.12</i>	<i>58 14</i>	<i>30.28</i>	<i>14 12 64</i>	<i>S</i>	<i>11</i>	<i>.60</i>	<i>0</i>						<i>Clear</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>72</i>				<i>Light Snow</i>	
<i>Tuesday Nov 21</i>	<i>5:43 a.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>Stratus</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>18</i>	<i>1.62</i>	<i>4/4</i>						<i>Stratus</i>	
<i>Wednesday Nov 22</i>	<i>5:43 a.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>Stratus</i>	
	<i>2:43 p.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>Stratus</i>	
<i>Thursday Nov 23</i>	<i>2:43 p.m.</i>	<i>24.37</i>	<i>62 35</i>	<i>29.50</i>	<i>35 32 70</i>	<i>W</i>	<i>2</i>	<i>.02</i>	<i>4/4</i>						<i>"</i>	
	<i>5:43 a.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>3 P.M.</i>	<i>11 P.M.</i>	<i>.26</i>	<i>Light Snow</i>	
<i>Friday Nov 24</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>Stratus</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>10.30 a.m.</i>			<i>Light Snow</i>	
<i>Saturday Nov 25</i>	<i>5:43 a.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>"</i>	
	<i>2:43 p.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>8 a.m.</i>	<i>.21</i>	<i>Cloudy</i>	
<i>Sunday Nov 26</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>W</i>	<i>2</i>	<i>.02</i>	<i>2/4</i>						<i>Fog</i>	
	<i>5:43 a.m.</i>	<i>24.37</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>Monday Nov 27</i>	<i>2:43 p.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>Stratus</i>	
	<i>5:43 a.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>2/4</i>						<i>Stratus</i>	
<i>Tuesday Nov 28</i>	<i>9:43 a.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 scud fl</i>	

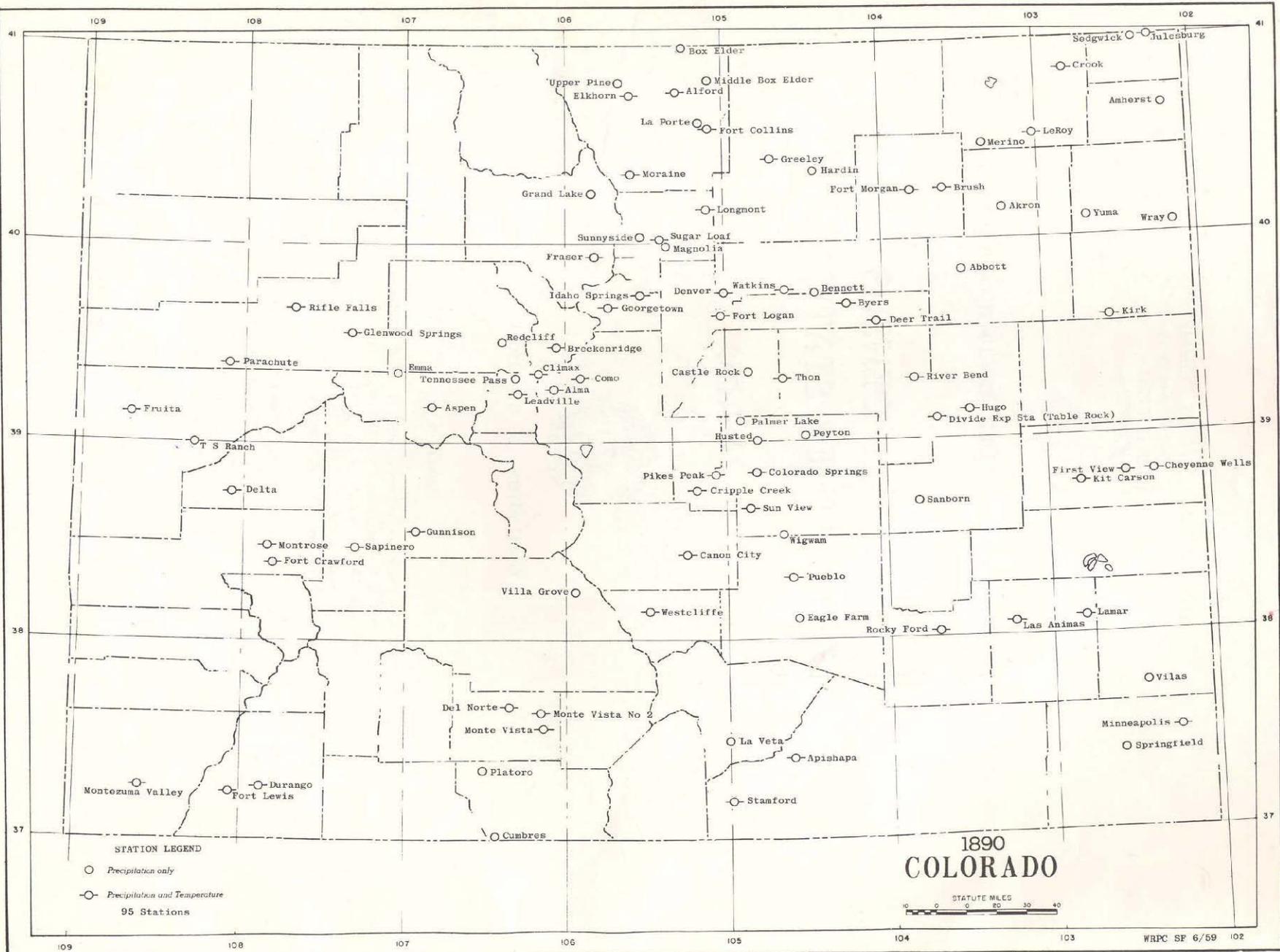
2391

Denver November 19-25, 1871 *Henry Finlow, Observer*

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



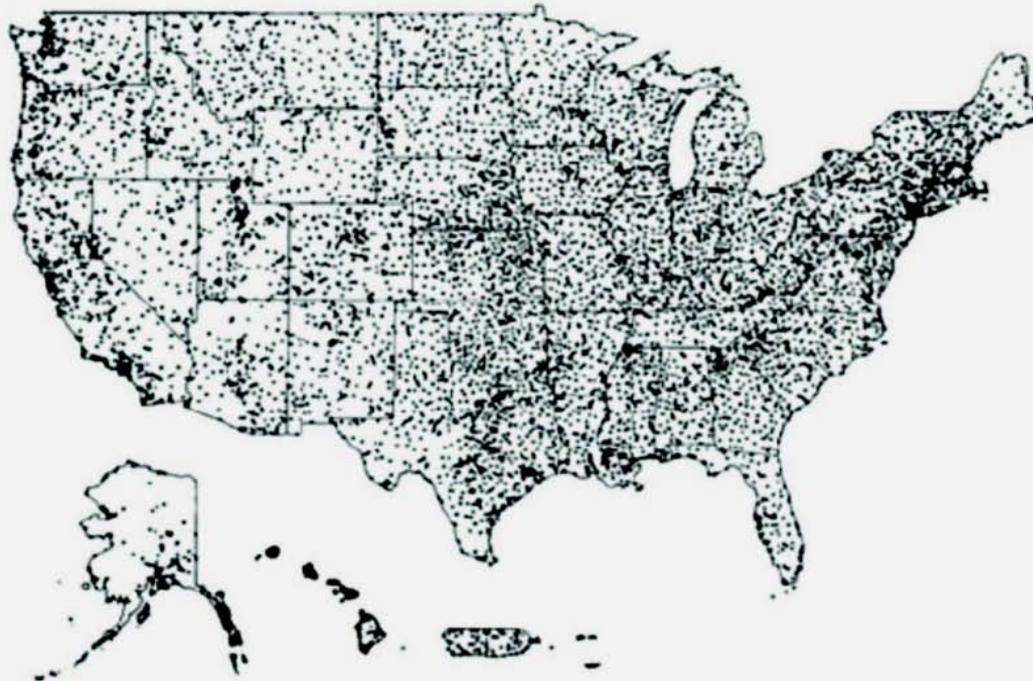
Colorado Weather Stations in 1890





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

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

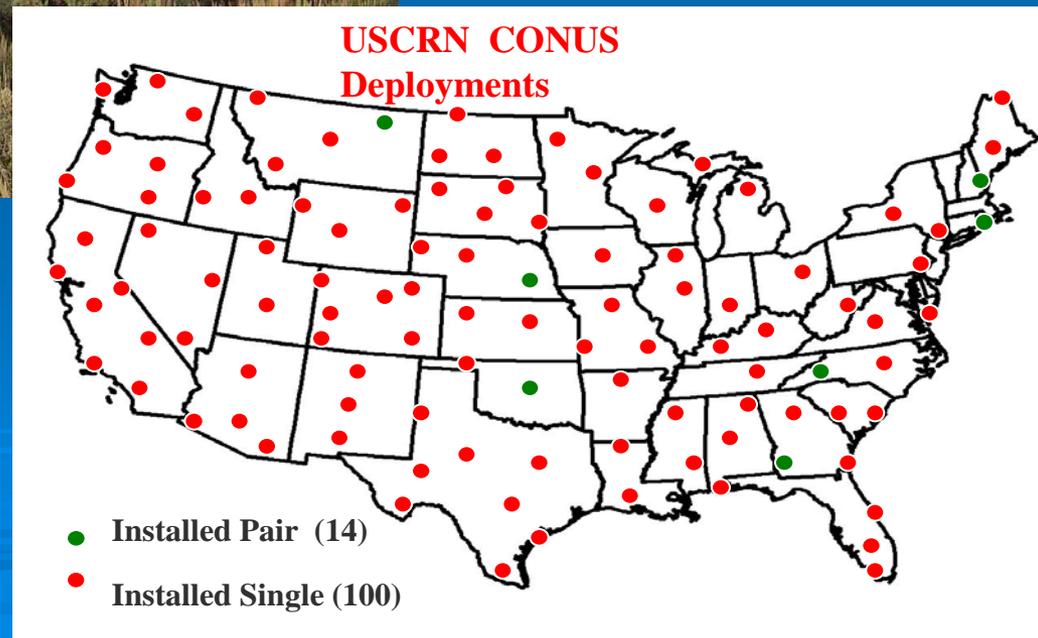


From Kelly Redmond, WRCC

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

U.S. Climate Reference Network (CRN)

- New observing networks have been added specifically to help track national climate trends



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



We Have a Fascinating Climate

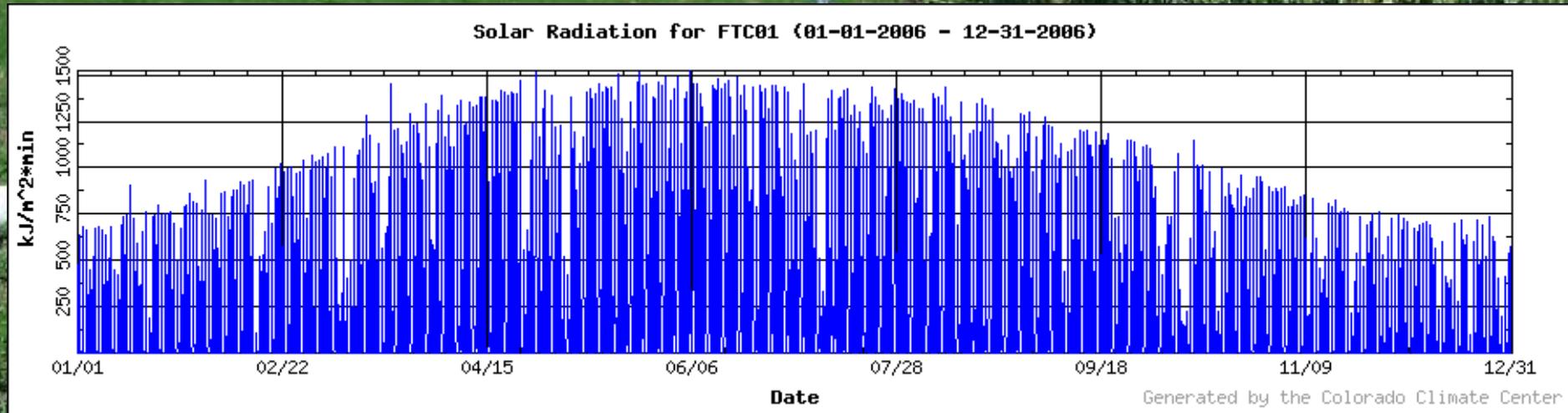
- High elevation (highest state in the Union – by far)
- Mid-Latitude location (lively seasonal changes)
- Interior Continental Location far from atmospheric moisture sources
- Complex Mountain topography

The Result?



Generous sunshine and low humidity much of the time

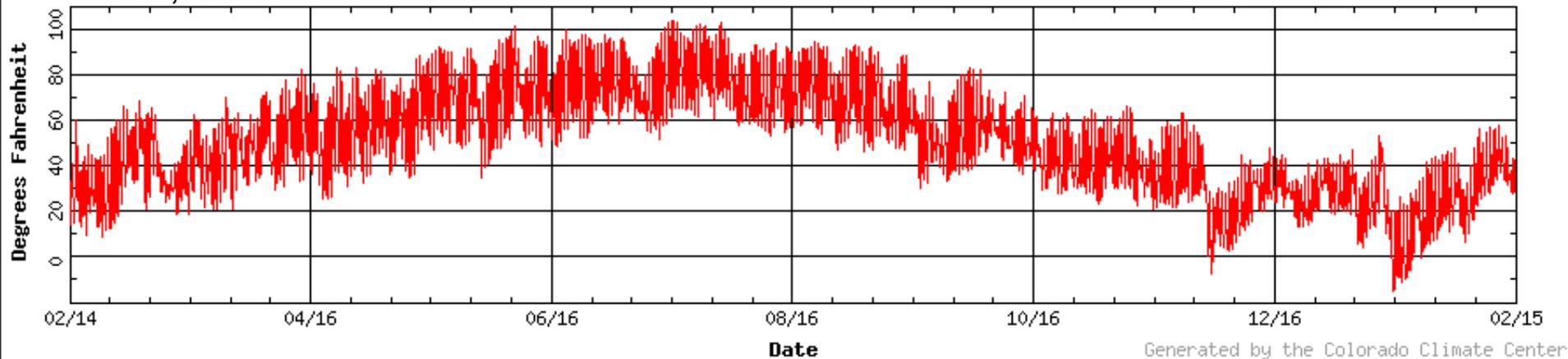
people like it here



Large Seasonal Temperature Variations

Fruita, Colo.

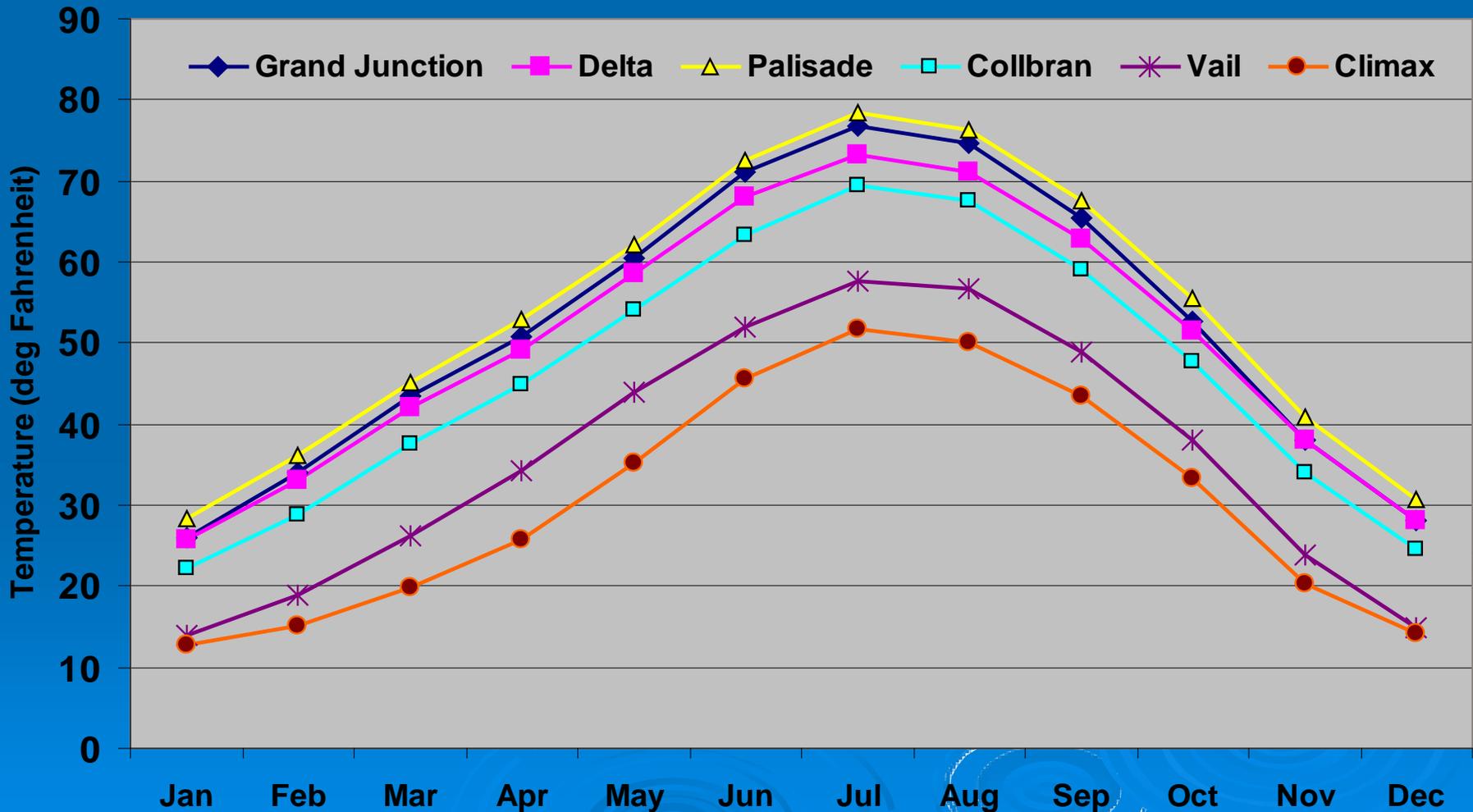
Temperature for FRT02 (02-14-2006 - 02-15-2007)



Generated by the Colorado Climate Center

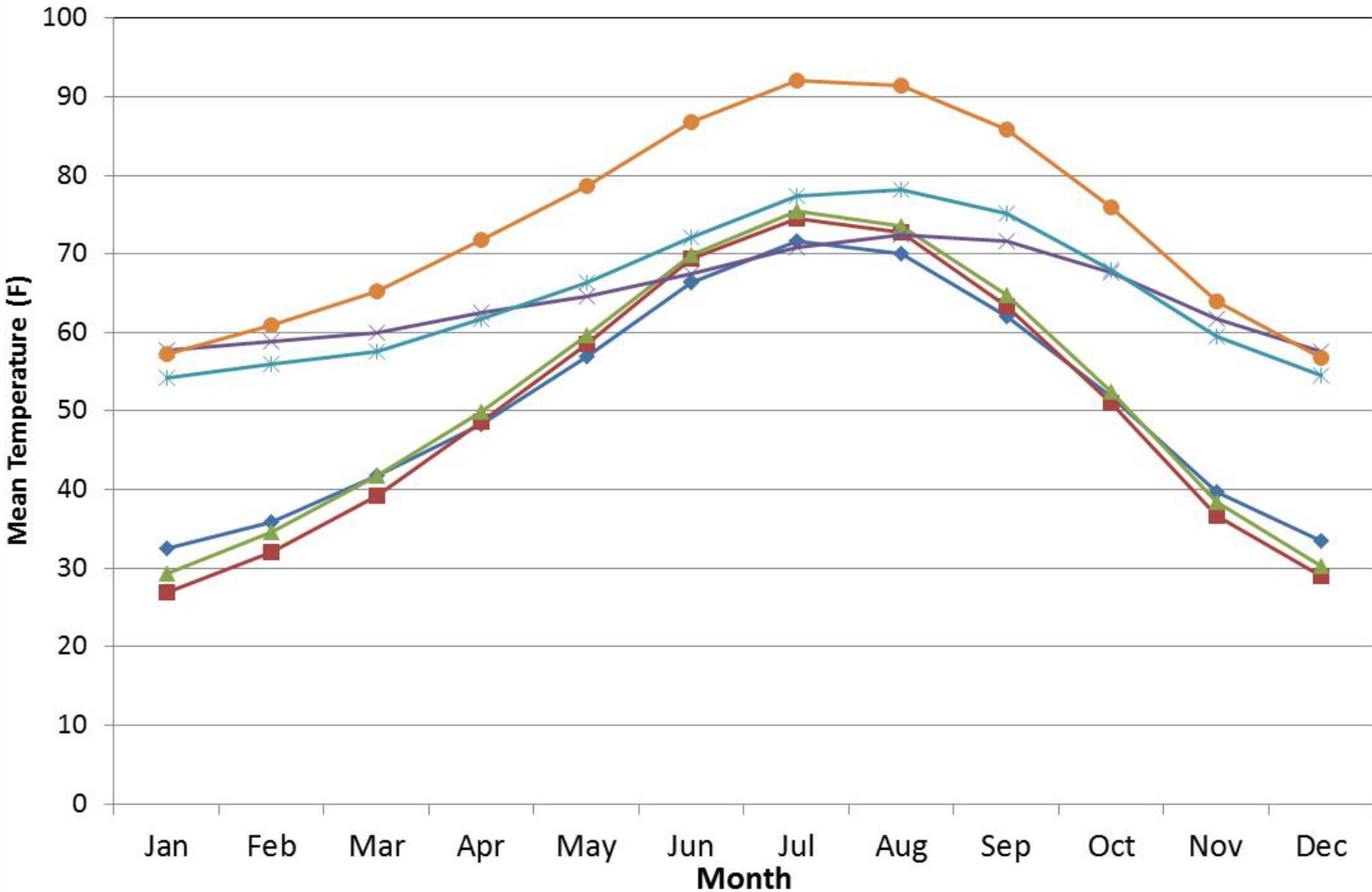
Winters are consistently colder than summers – ☺

Average Monthly Temperature (9171-2000) for Selected Station



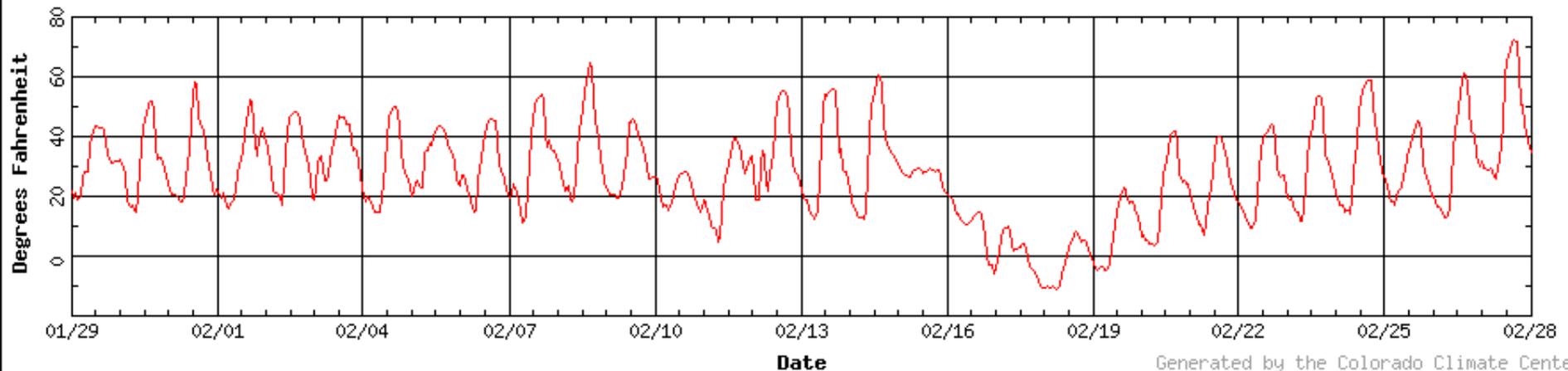
Average Monthly Temperatures (F) for selected sites in CO and CA

BOULDER HOLYOKE PUEBLO AP SAN DIEGO LINDBERGH AP RIVERSIDE CITRUS EXP ST PALM SPRINGS

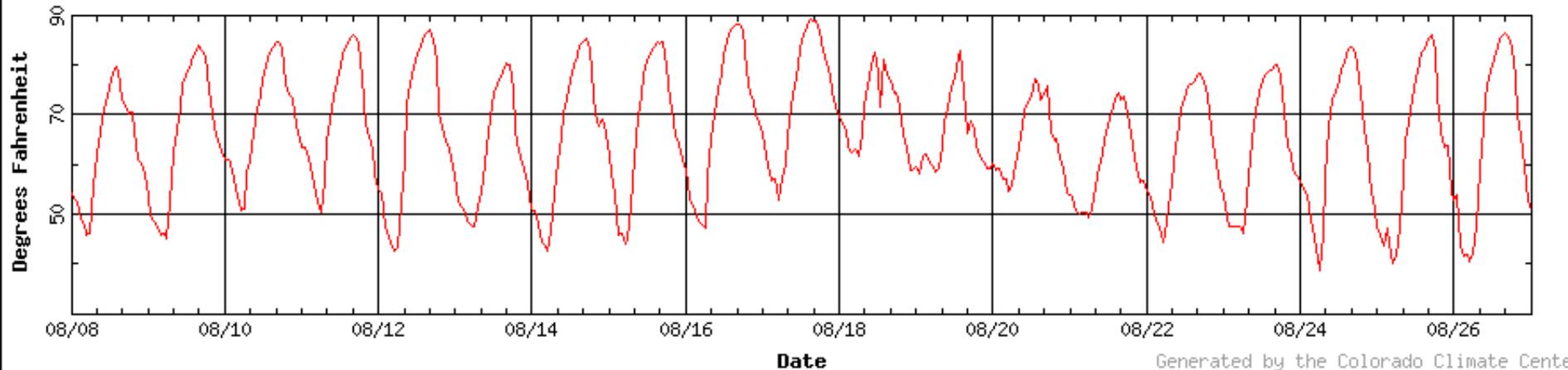


Large diurnal temperature ranges and rapid changes

Temperature for KSY01 (01-29-2006 - 02-28-2006)

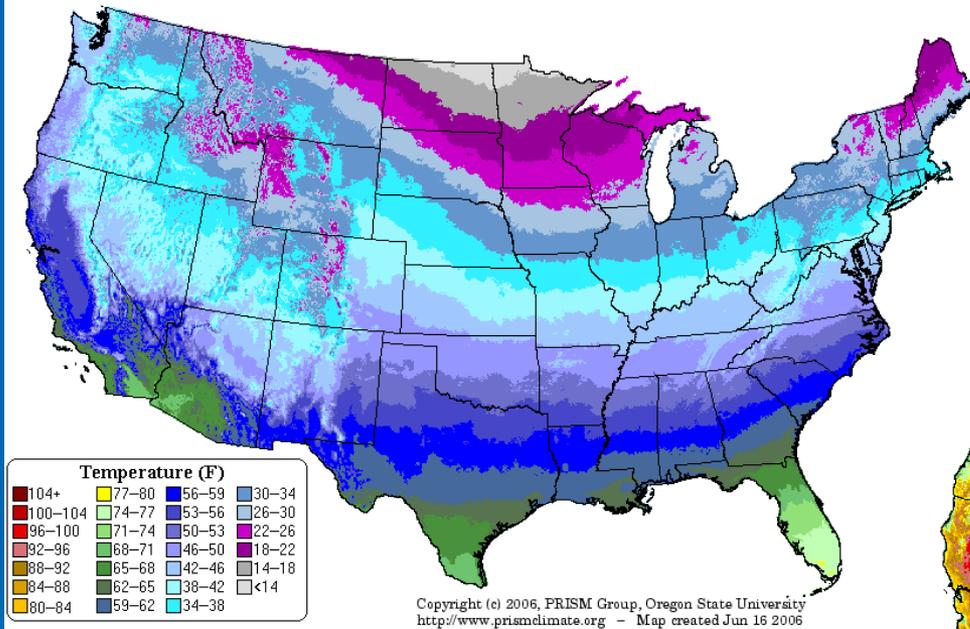


Temperature for BLA01 (08-08-2002 - 08-27-2002)

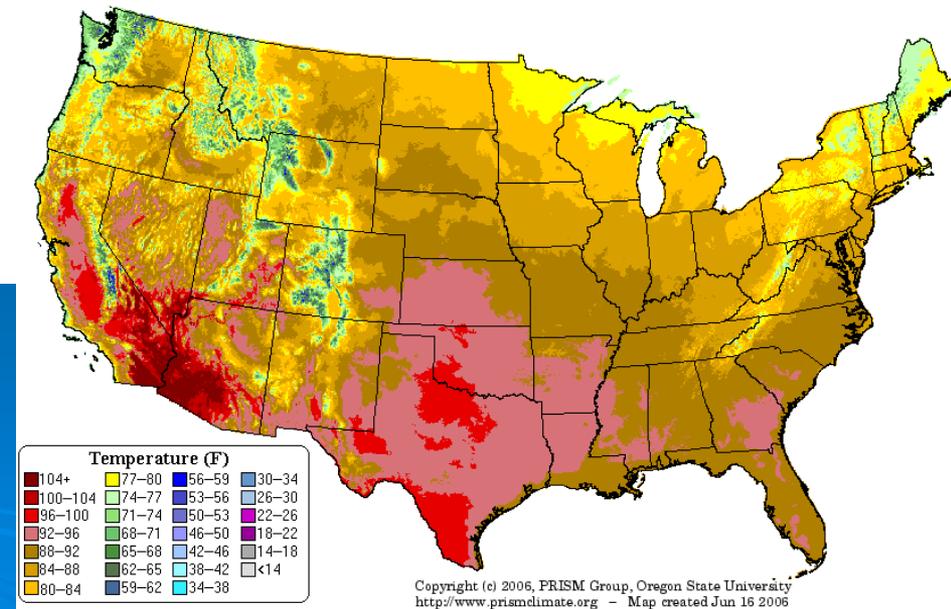


Complex local variations due to elevation and topography

Maximum Temperature: January Climatology (1971–2000)



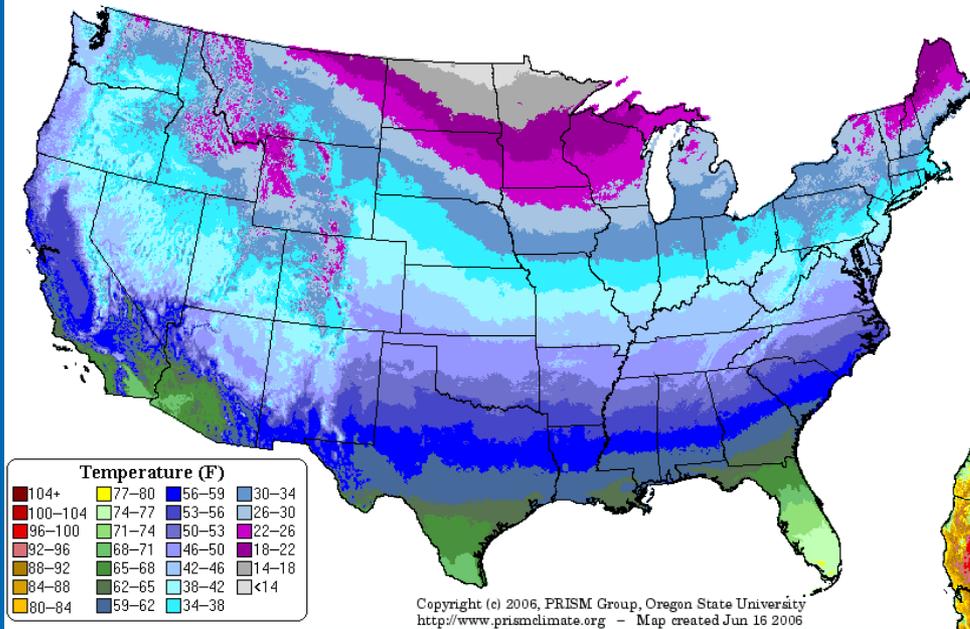
Maximum Temperature: July Climatology (1971–2000)



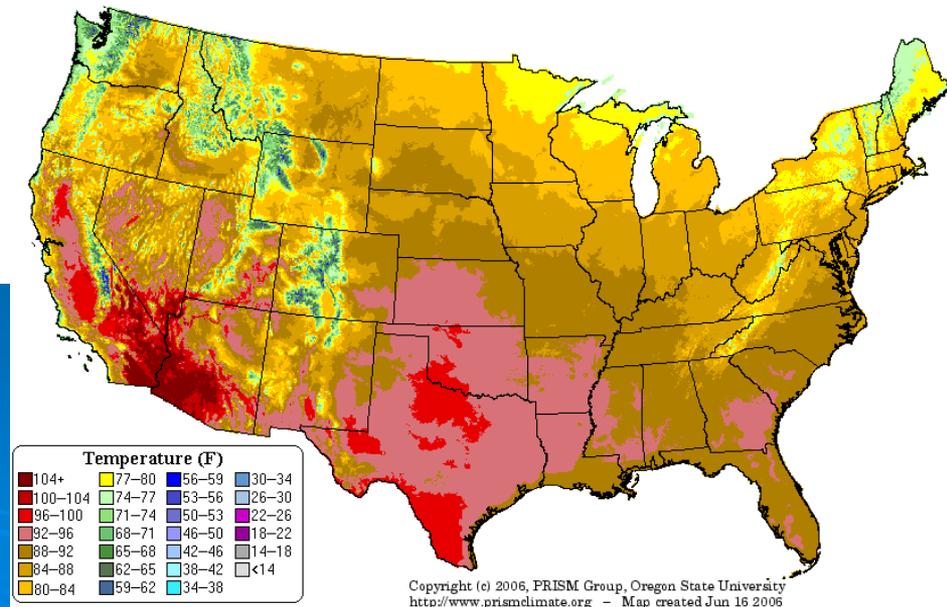
For example, variations within Rocky Mountain National Park – Totally different climate west of the Continental Divide than east even at the same elevation

Average Maximum Temperature

Maximum Temperature: January Climatology (1971-2000)

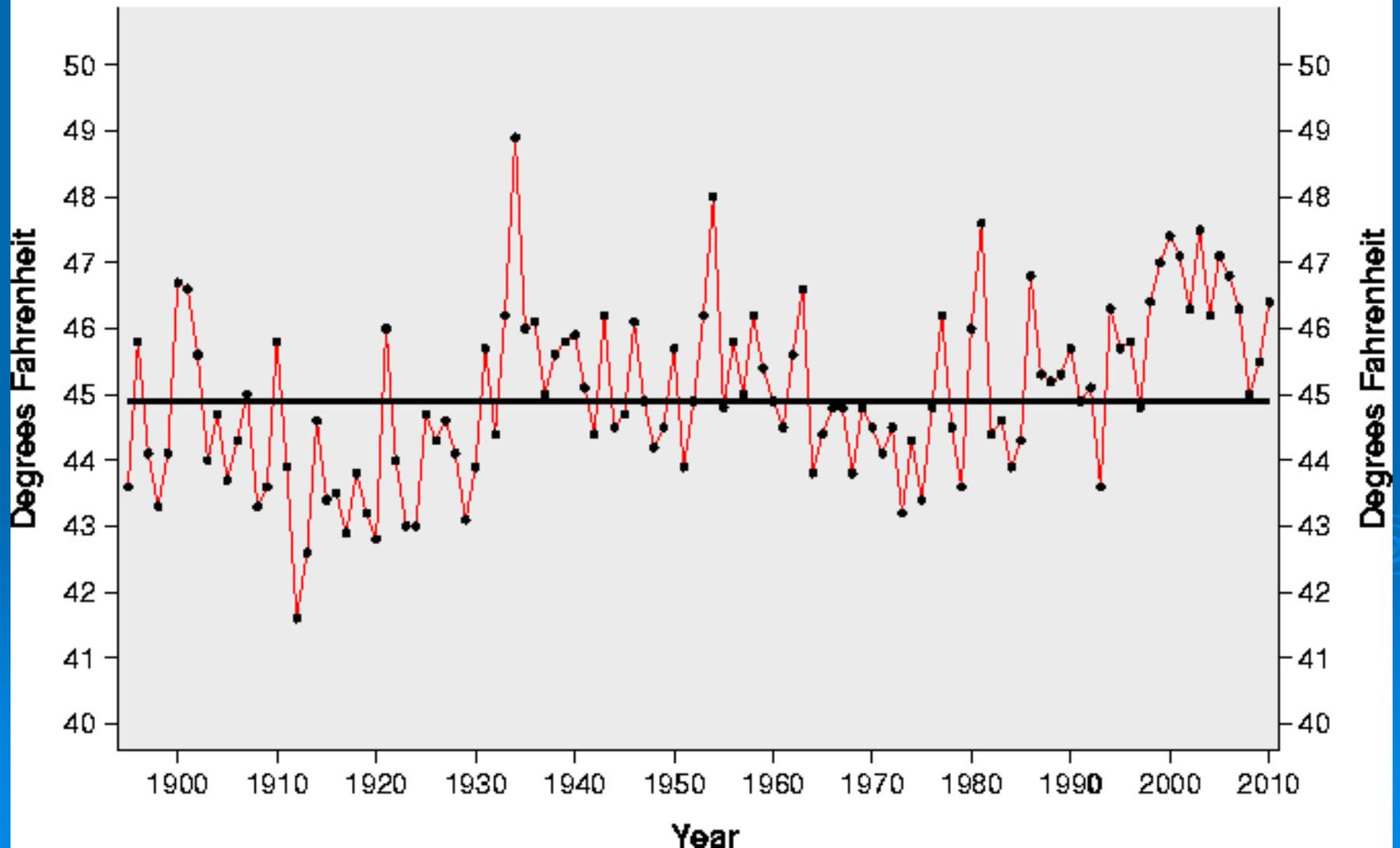


Maximum Temperature: July Climatology (1971-2000)



Relatively Large Year to Year Variations (“Interannual Variability”)

Colorado Statewide Mean Annual Temperature (1895-2010)



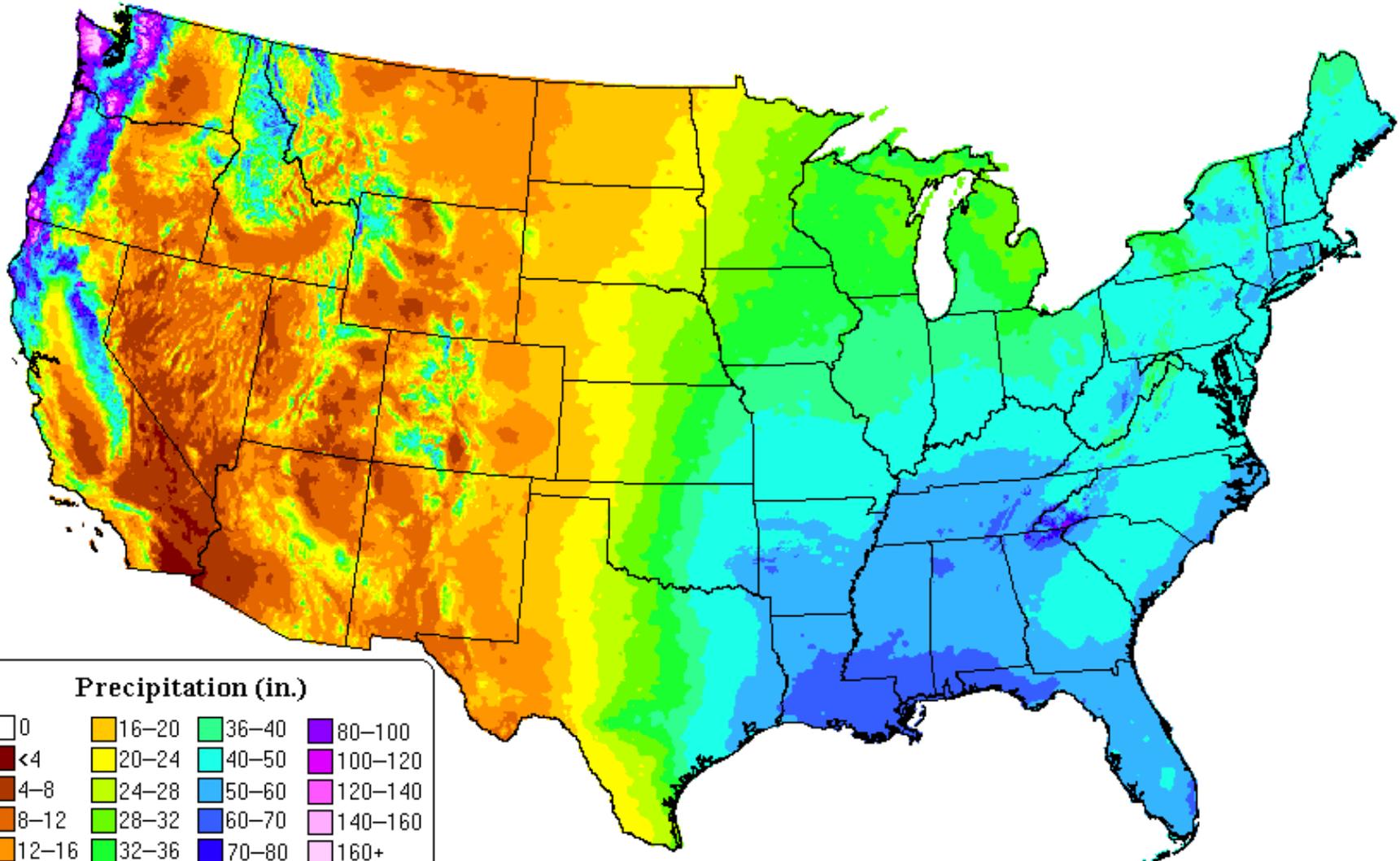
**Frequent but highly variable
precipitation
(for every “upslope,”
there’s a “downslope”)**



Photo by Wendy Ryan

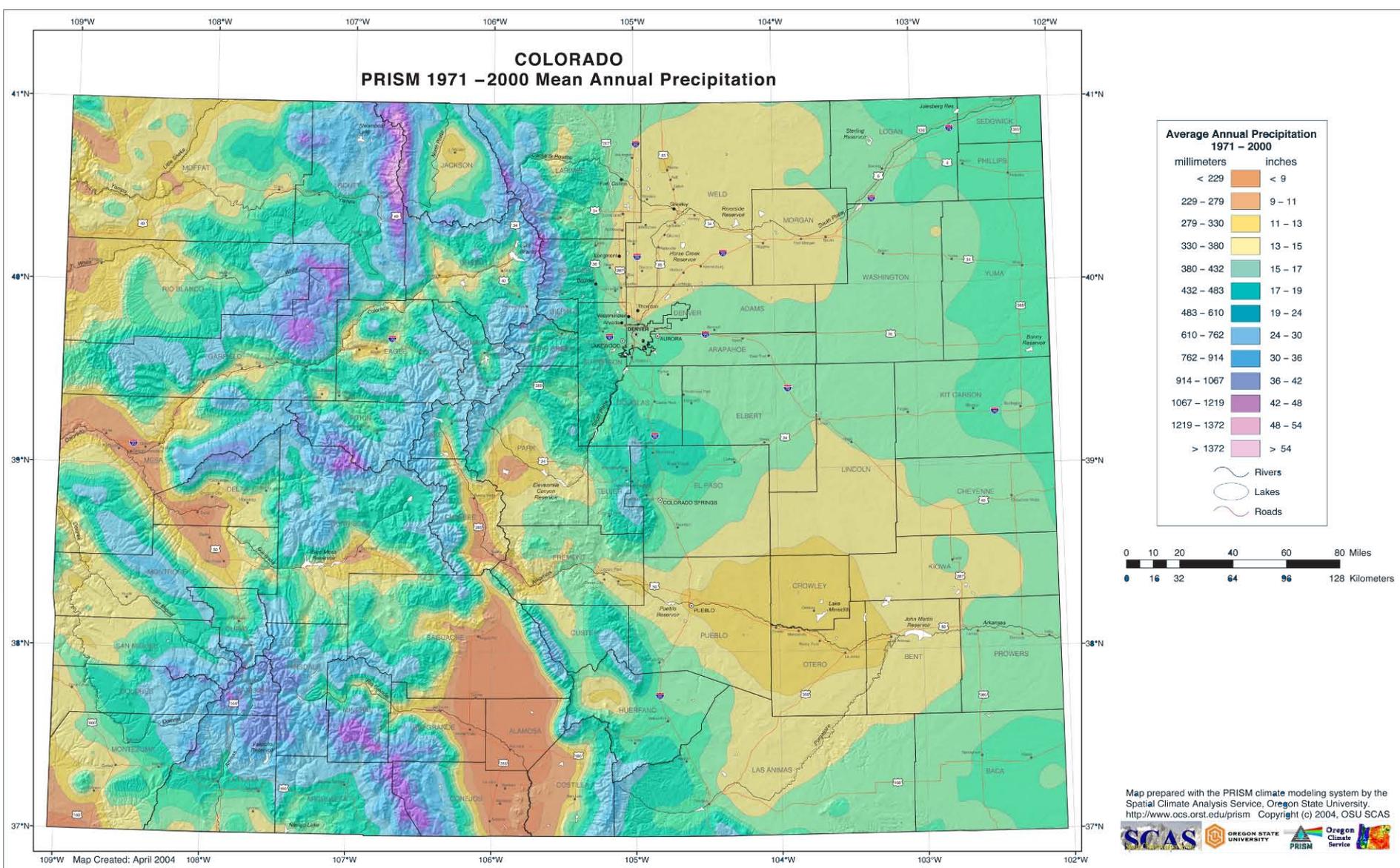
Where we fit in the national picture

Precipitation: Annual Climatology (1971–2000)



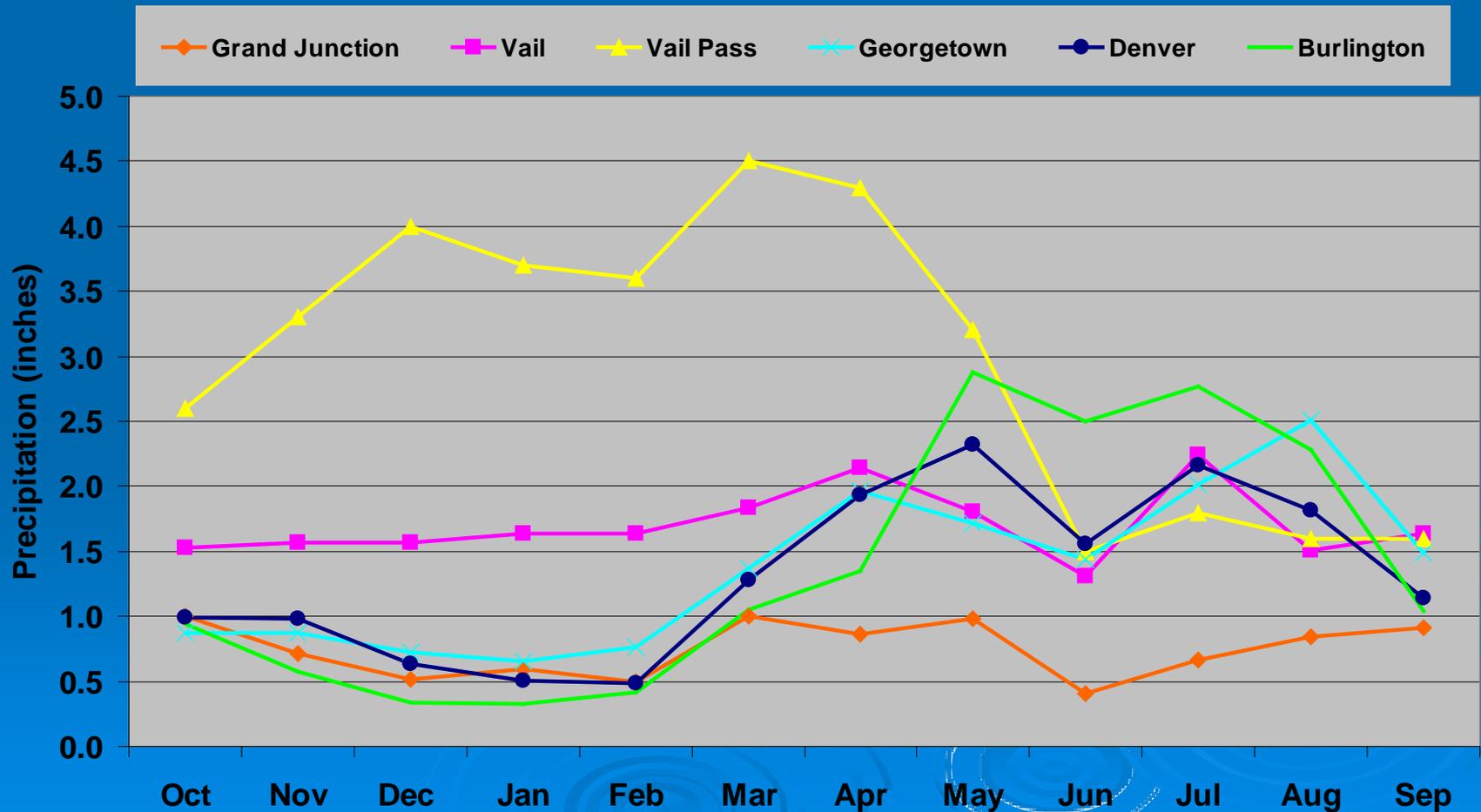
Copyright (c) 2006, PRISM Group, Oregon State University
<http://www.prismclimate.org> - Map created Jun 16 2006

Colorado Average Annual Precipitation



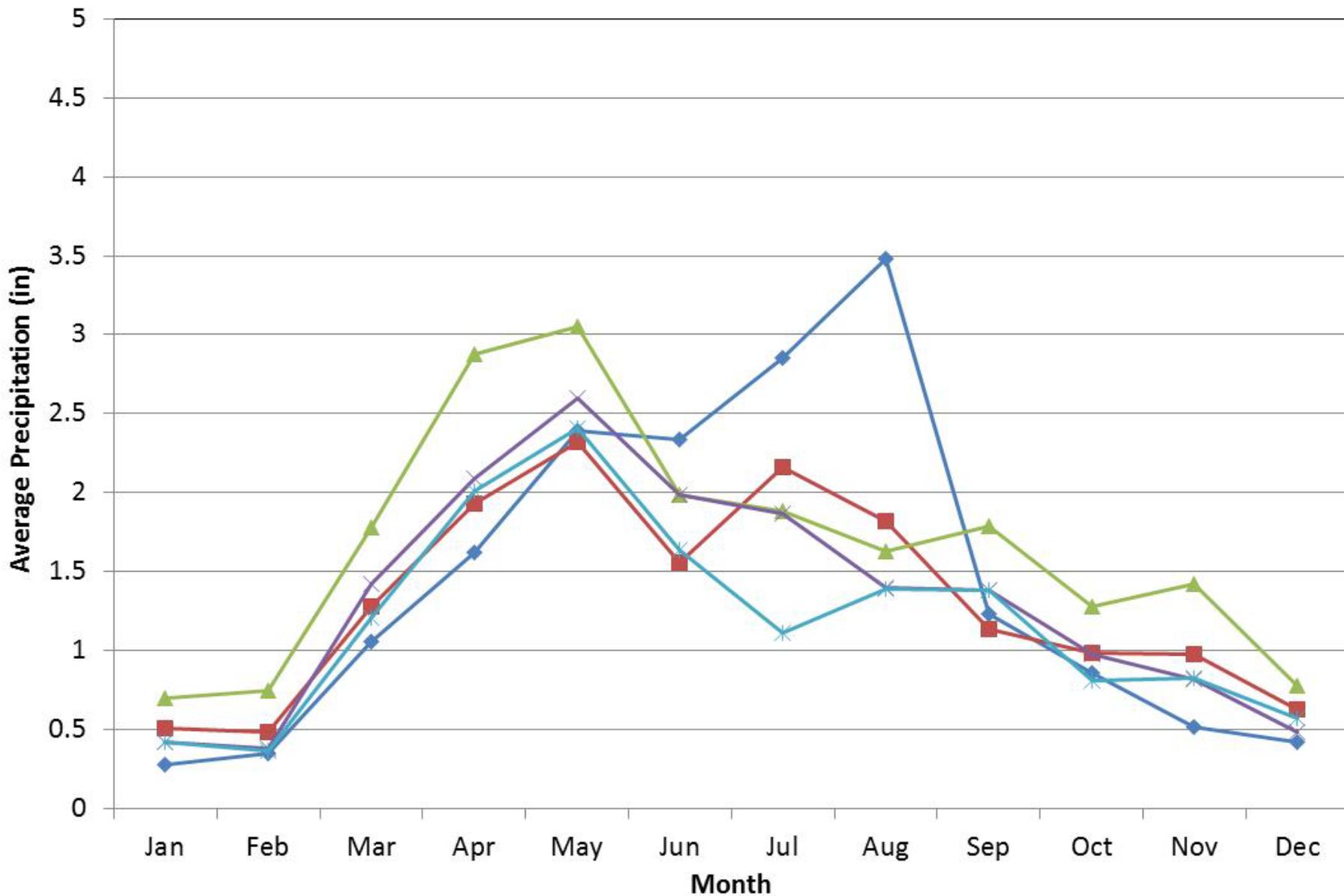
Highly seasonal precipitation patterns with considerable geographic diversity in “seasonality”

Water Year Average Precipitation for Selected Stations

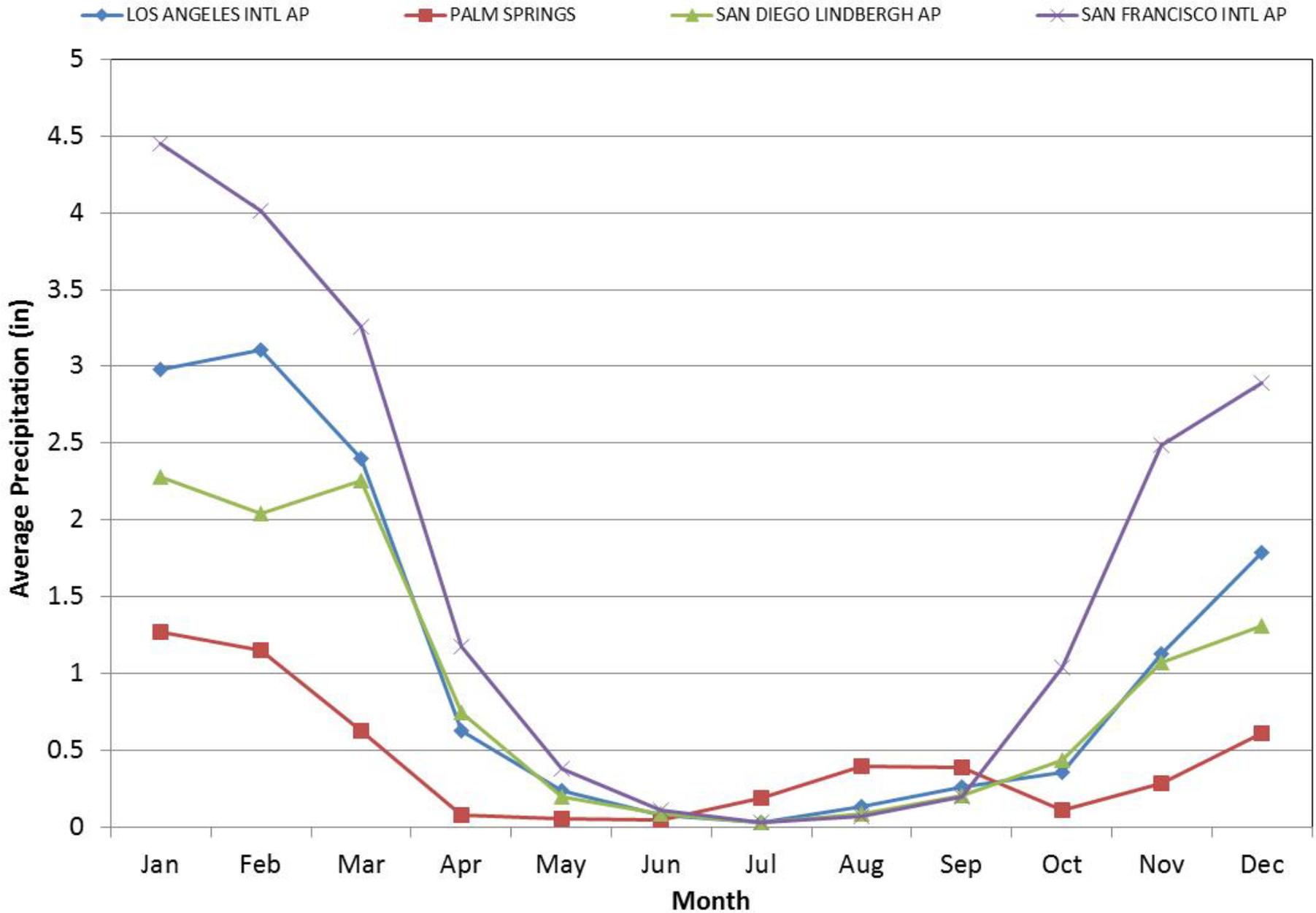


Average Monthly Precipitation (in) for selected Colorado Stations

COLORADO SPRINGS MNPLA DENVER STAPELTON BOULDER FORT COLLINS LONGMONT 2 ESE



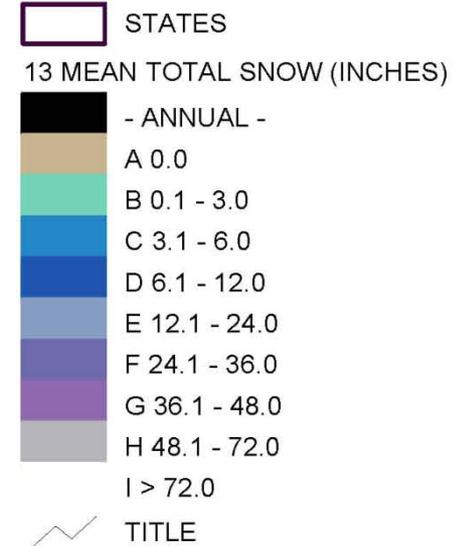
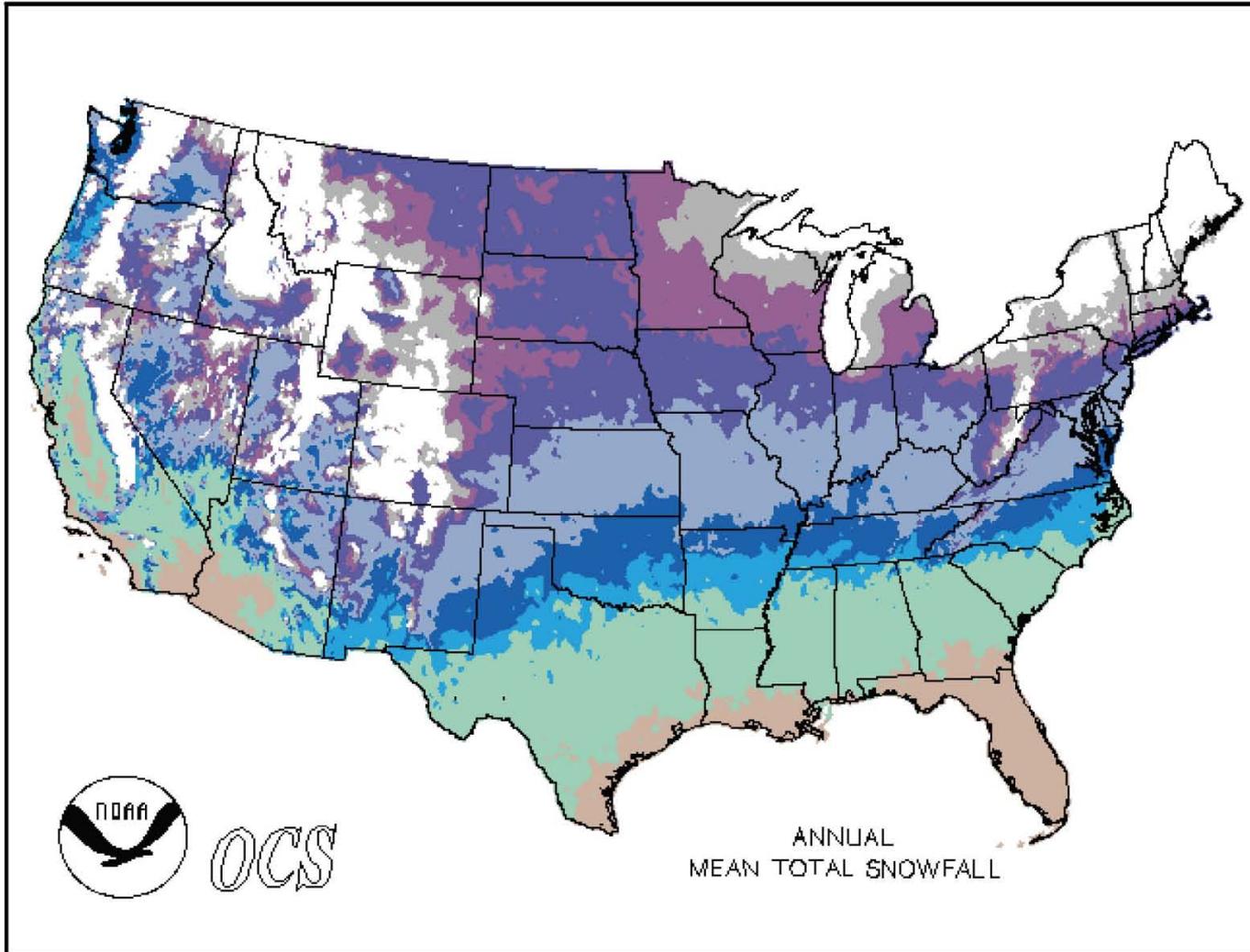
Average Monthly Precipitation (in) for selected California Stations



**Lots of Snow,
sometimes and some places**



National Annual Average Snowfall



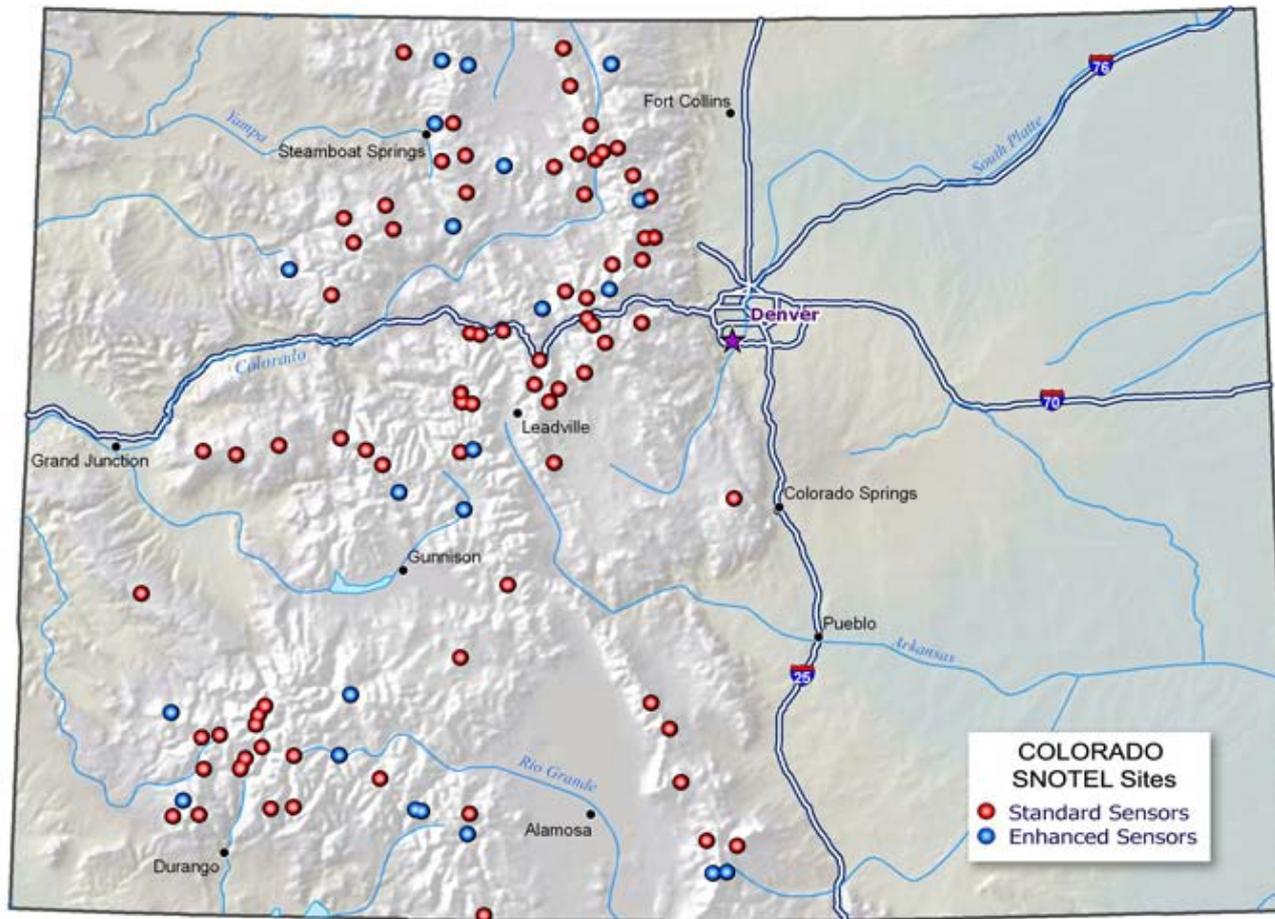
**Considering our
Latitude (40 N)
Colorado is one
of the snowiest
areas of the
world --
because of our
high elevation**



SNOTEL -- Tracking Colorado's High-elevation Snowpack

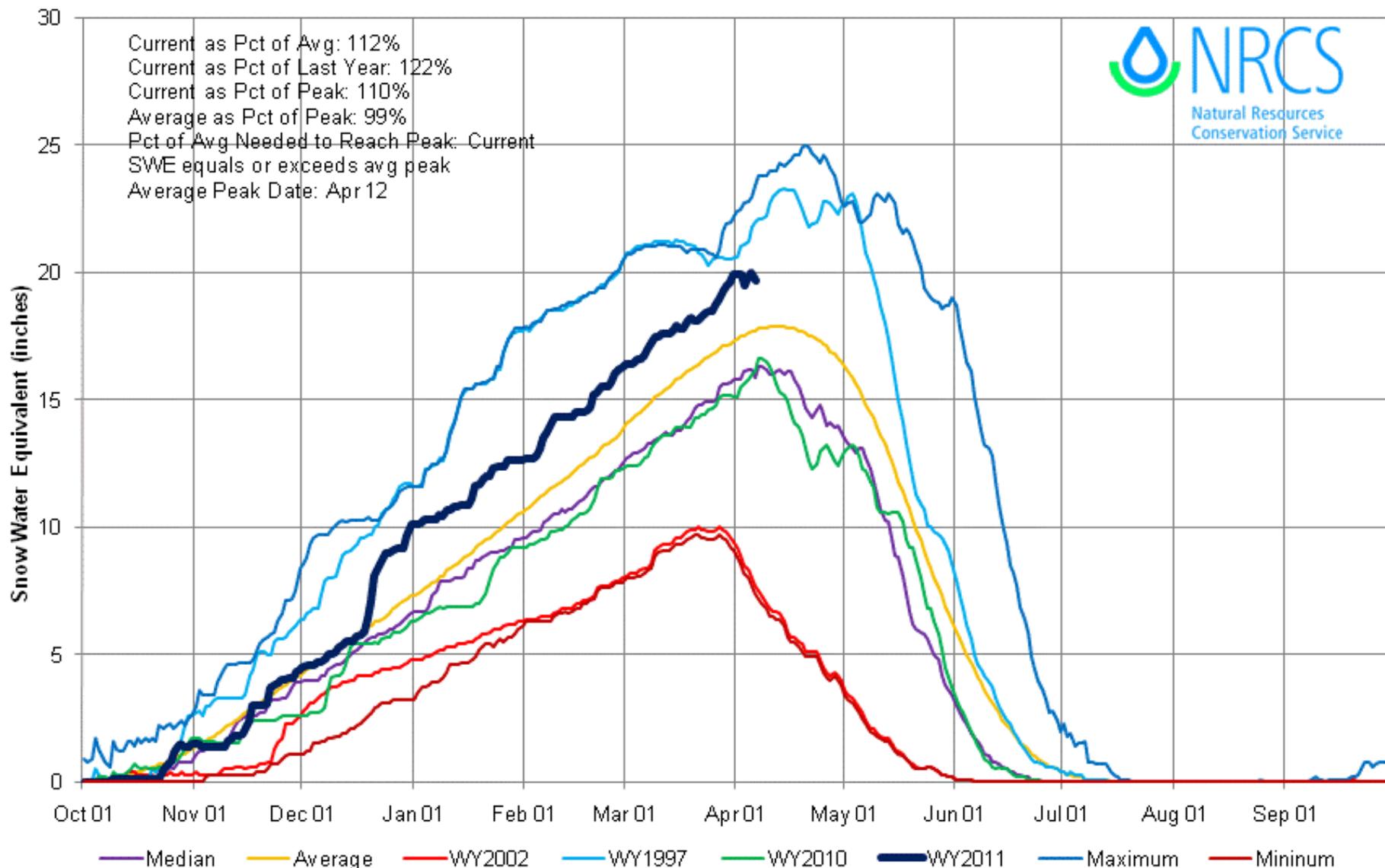
USDA – Natural Resources Conservation Service Snow Survey

<http://www.co.nrcs.usda.gov/snow/>



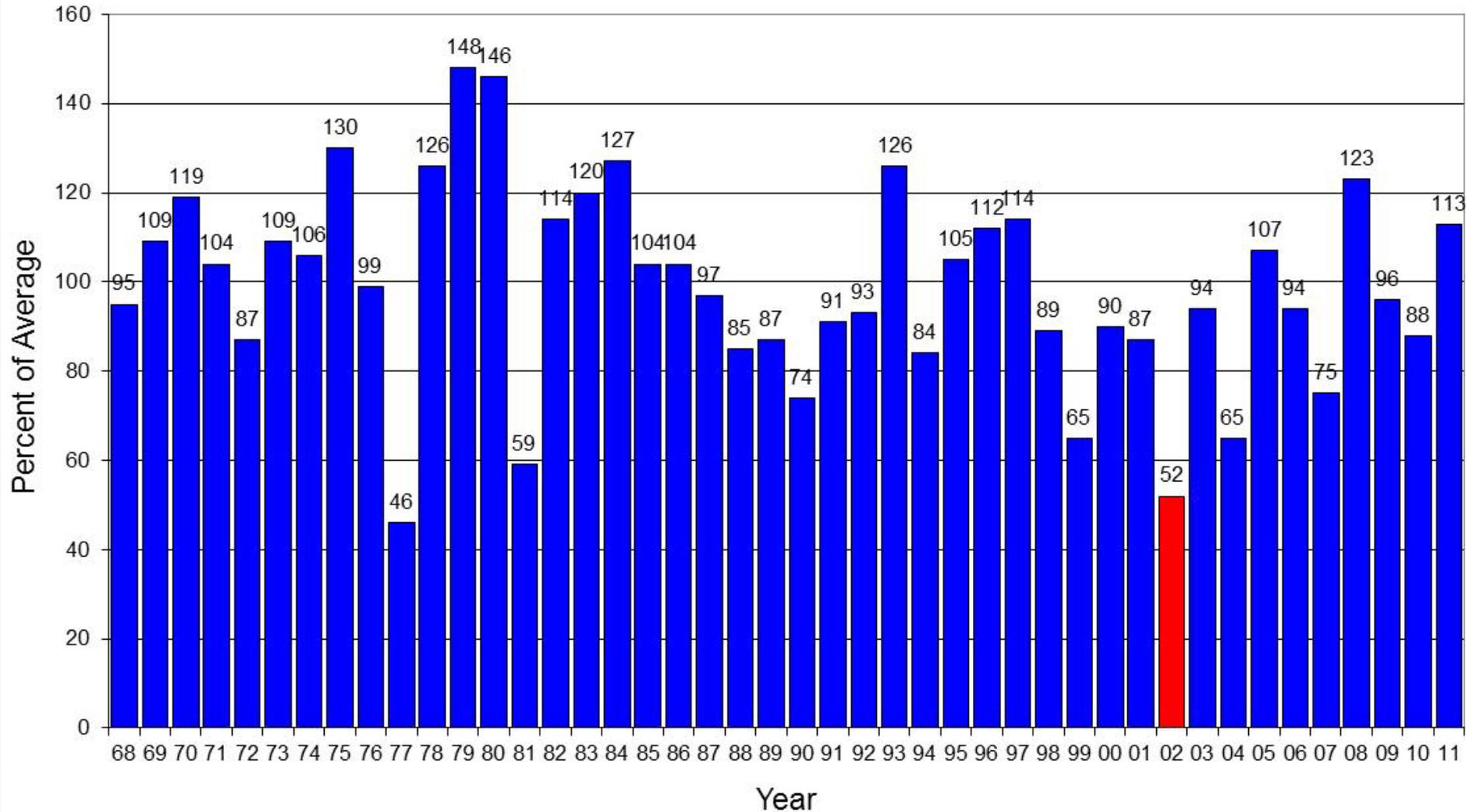
Colorado Statewide High/Low Snowpack Summary

Based on Provisional SNOTEL data as of Apr 06, 2011



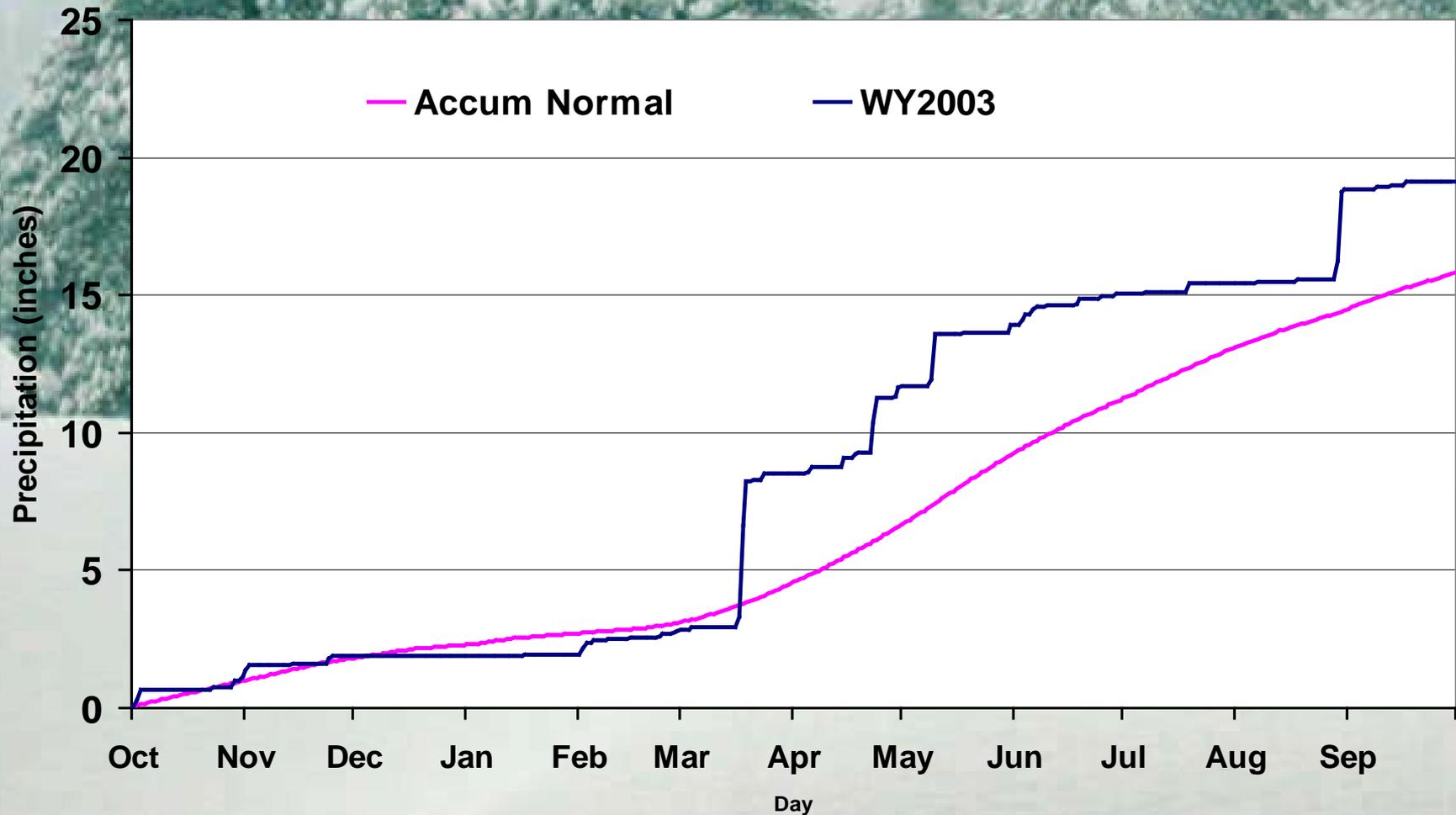
Colorado Statewide April 1 Snowpack

Time Series of April 1 Snowpack – Tracking Variability and Trends



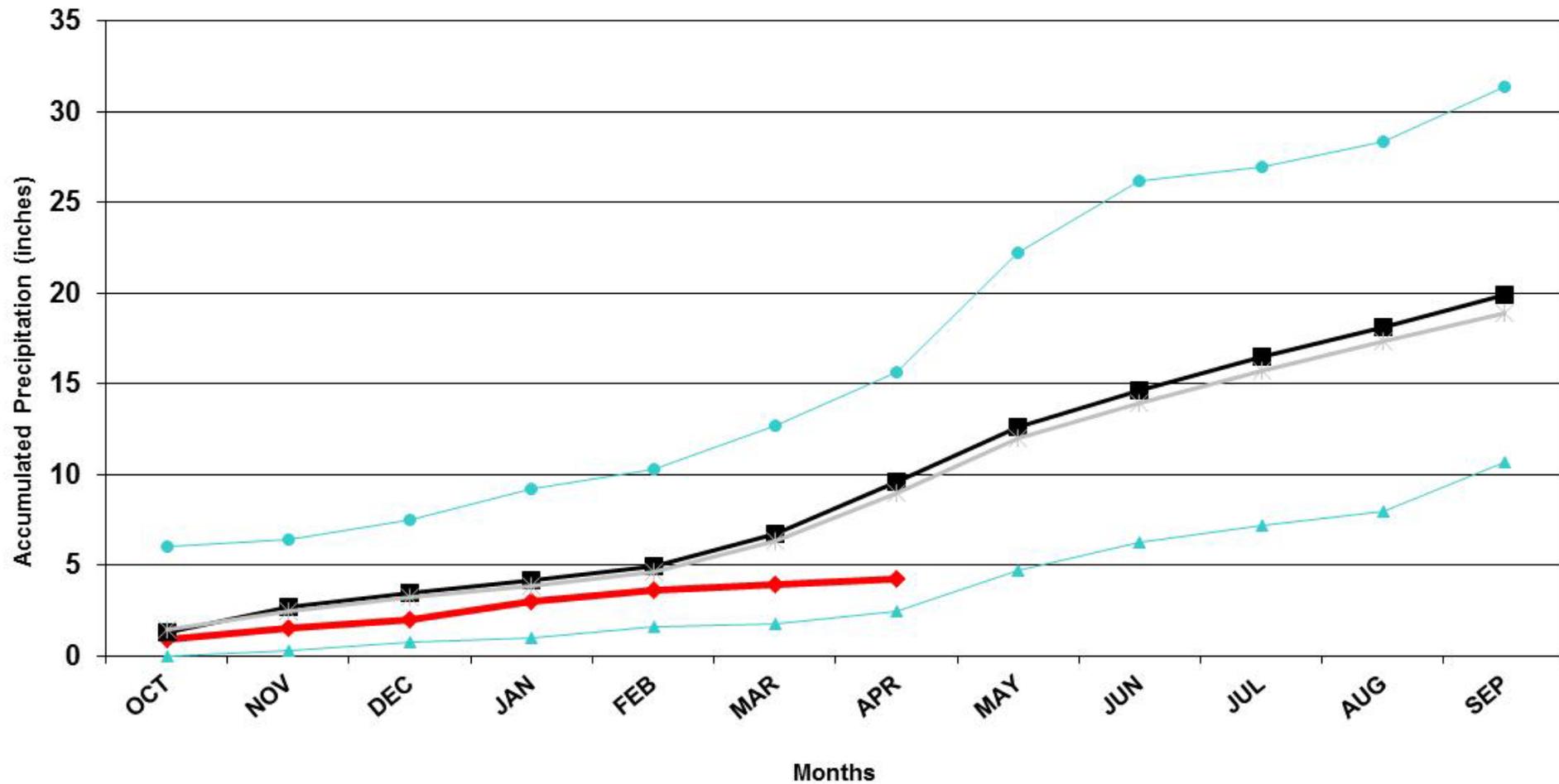
A few storms contribute a large fraction of the annual precipitation in many years

Fort Collins Daily Accumulated Precipitation



Boulder 2011 Water Year

2011 Water Year 30 Year Averages-1971-2000 Period of Record Average - 1894-2009 Max Precip Min Precip

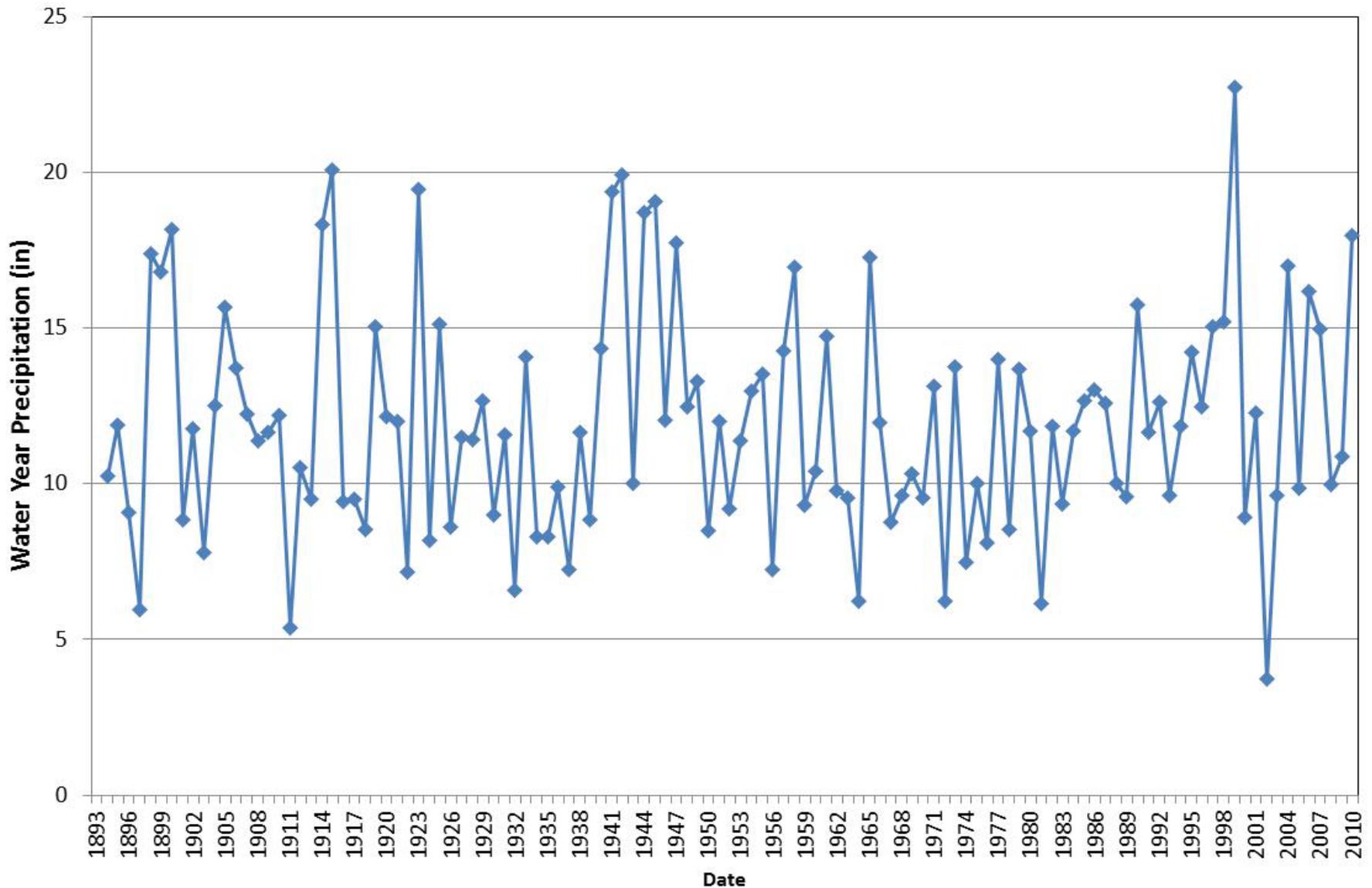


Large Year-to-Year Variations in Precipitation



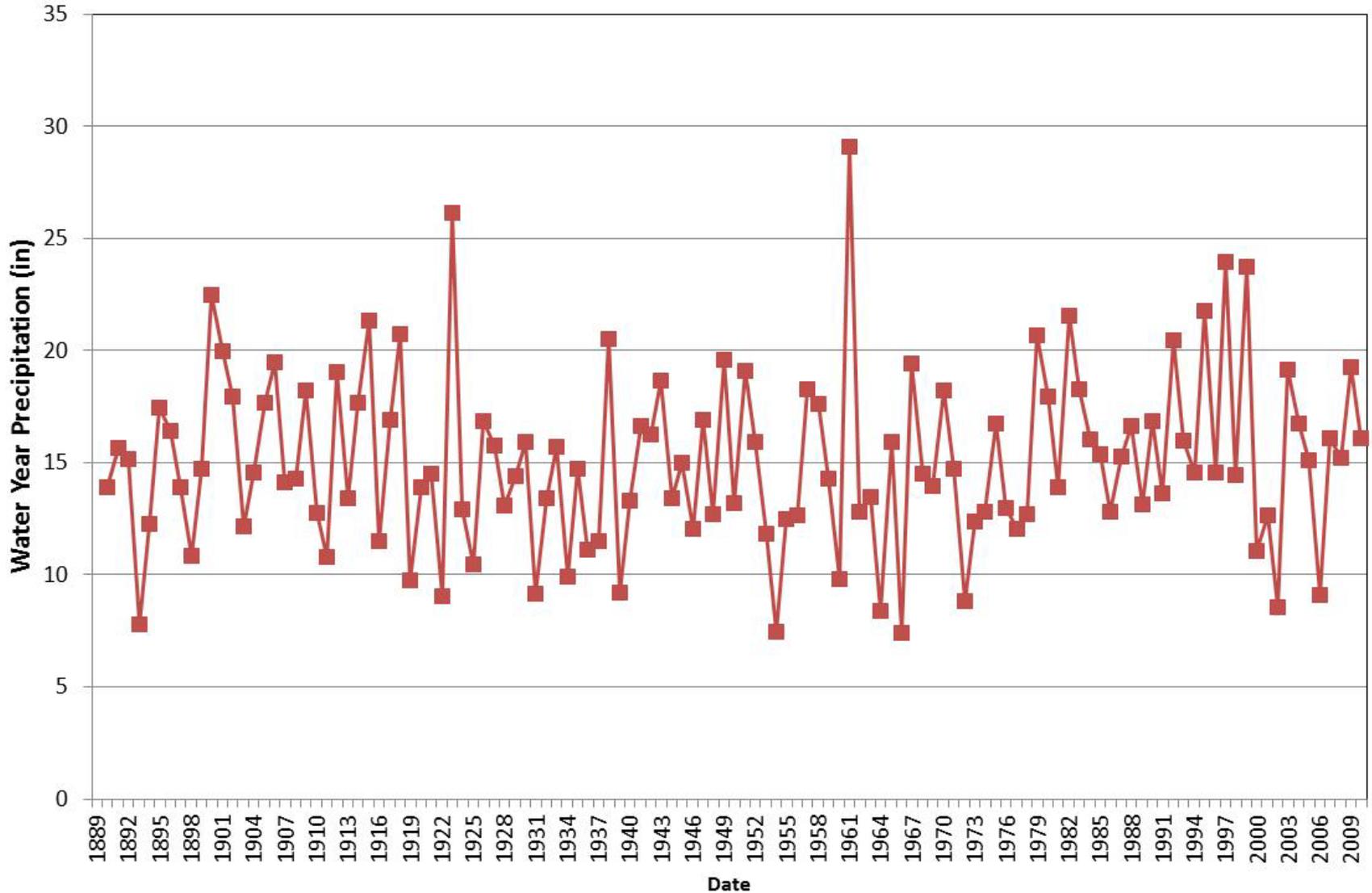
Rocky Ford Precipitation

Rocky Ford Water Year Precipitation (in) 1894-2010



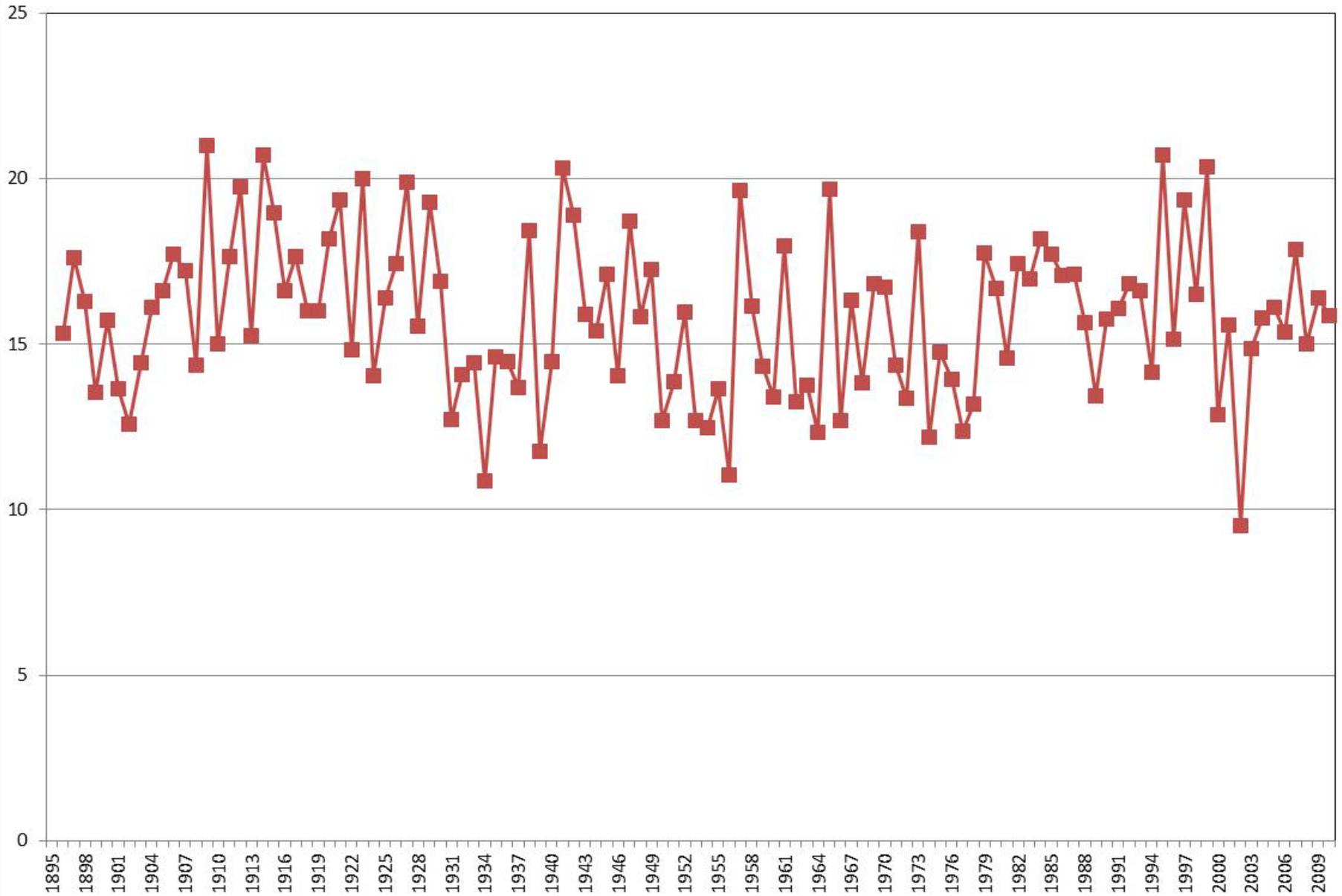
Fort Collins Precipitation

Fort Collins Water Year Precipitation (in) 1890-2010



Colorado Statewide Water Year Precipitation

Colorado Statewide Water Year Precipitation (in) 1896-2010



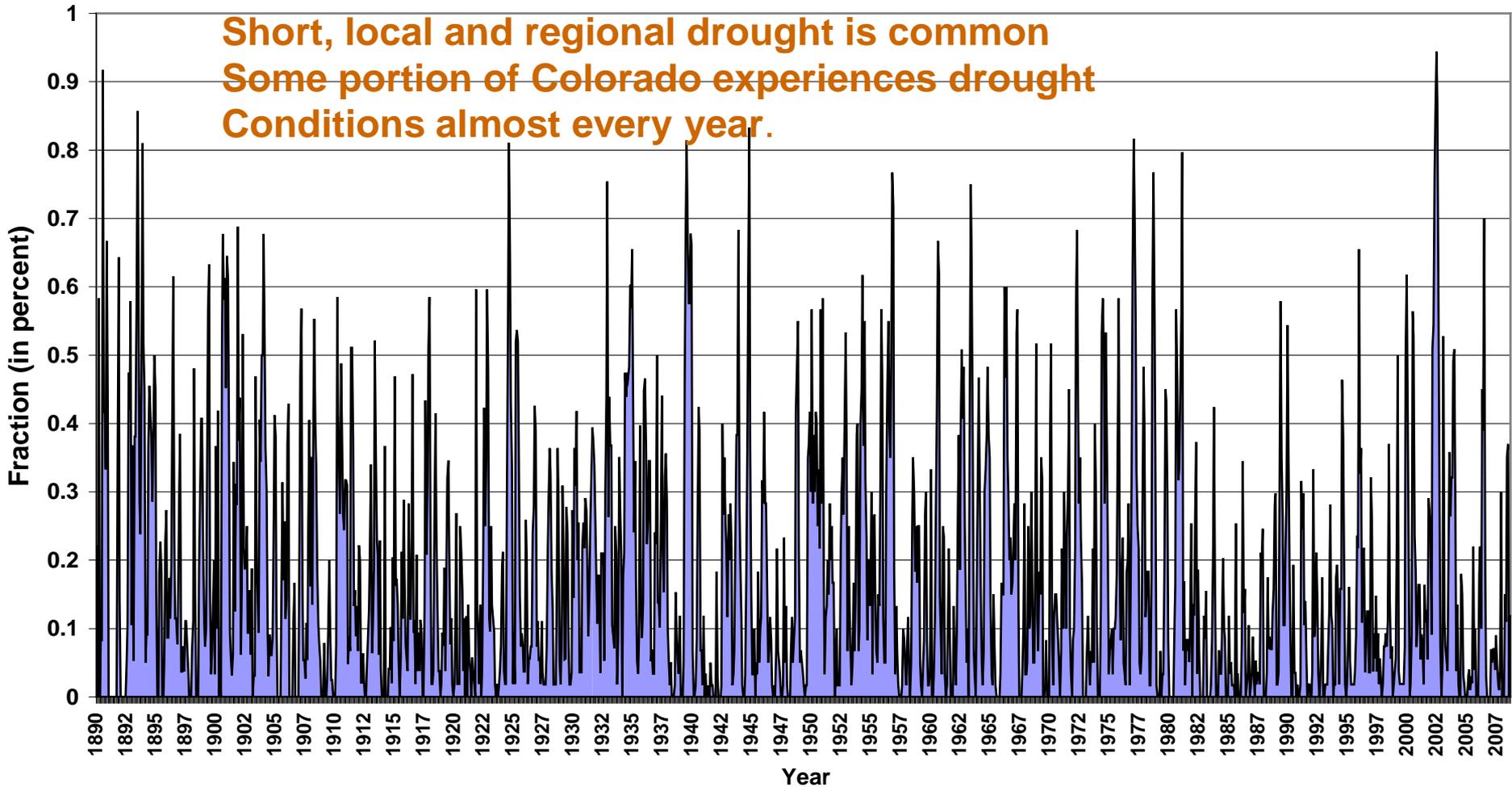
Drought Visits Our Area Regularly



Photo by NRCS

Fraction of Colorado in Drought Based on 3 month SPI (1890 - July 2009)

Short, local and regional drought is common
Some portion of Colorado experiences drought
Conditions almost every year.

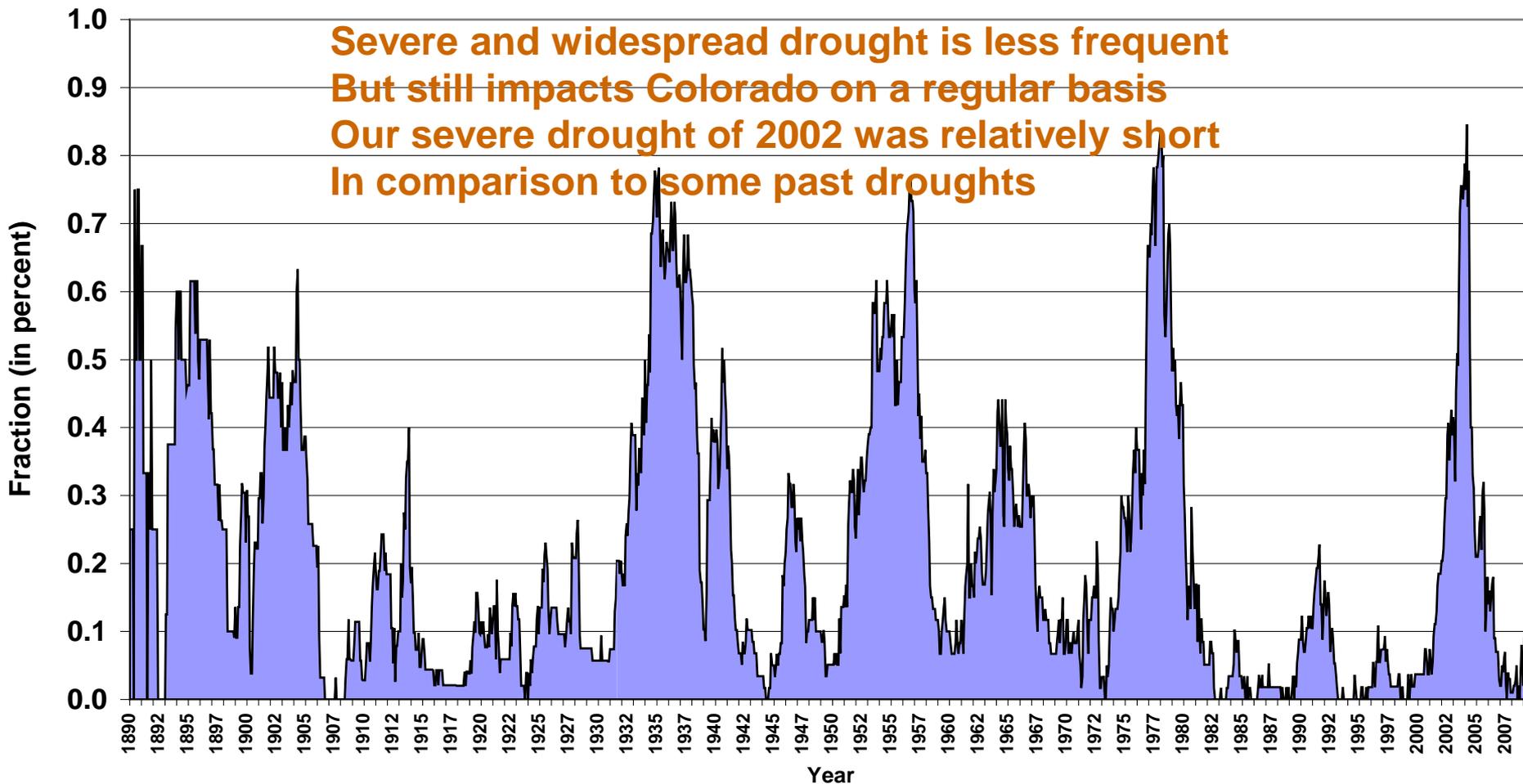


Fraction of Colorado in Drought

Based on 48 month SPI

(1890 - July 2009)

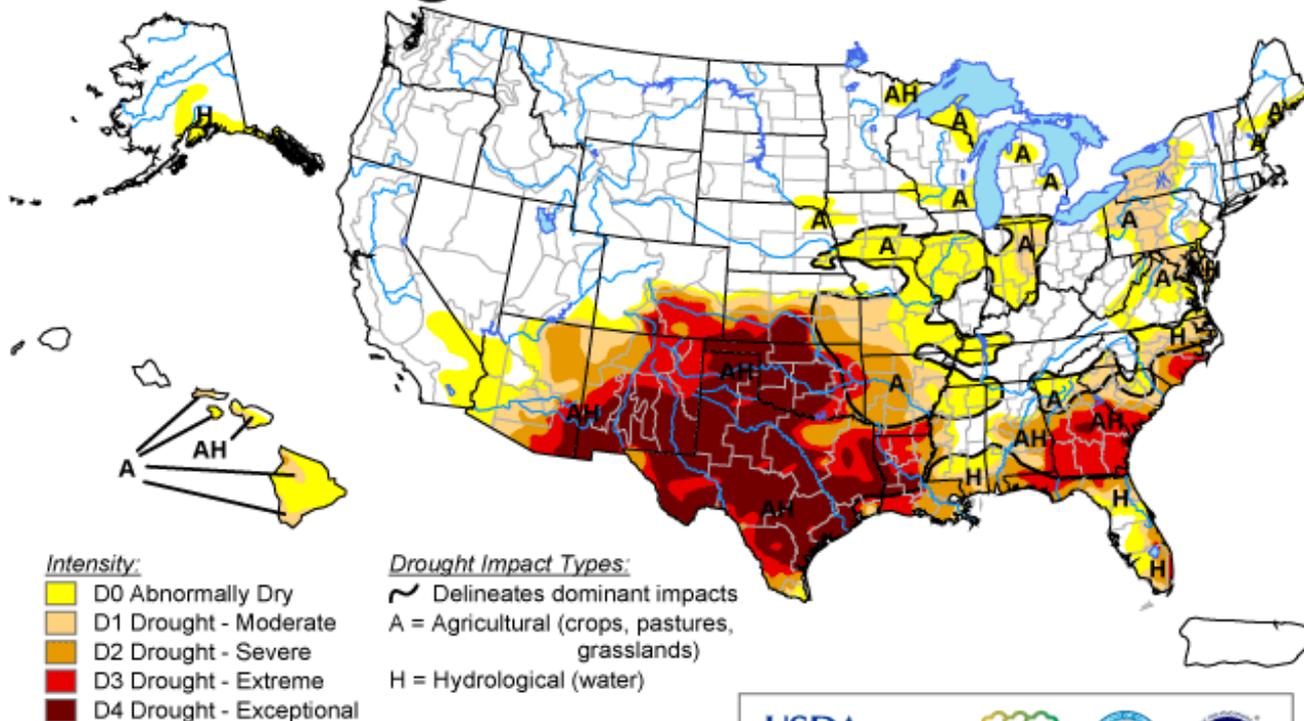
Severe and widespread drought is less frequent
But still impacts Colorado on a regular basis
Our severe drought of 2002 was relatively short
In comparison to some past droughts



Colorado has been impacted by the recent and ongoing southern drought, but conditions are improving here

U.S. Drought Monitor

August 2, 2011
Valid 8 a.m. EDT



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://drought.unl.edu/dm>



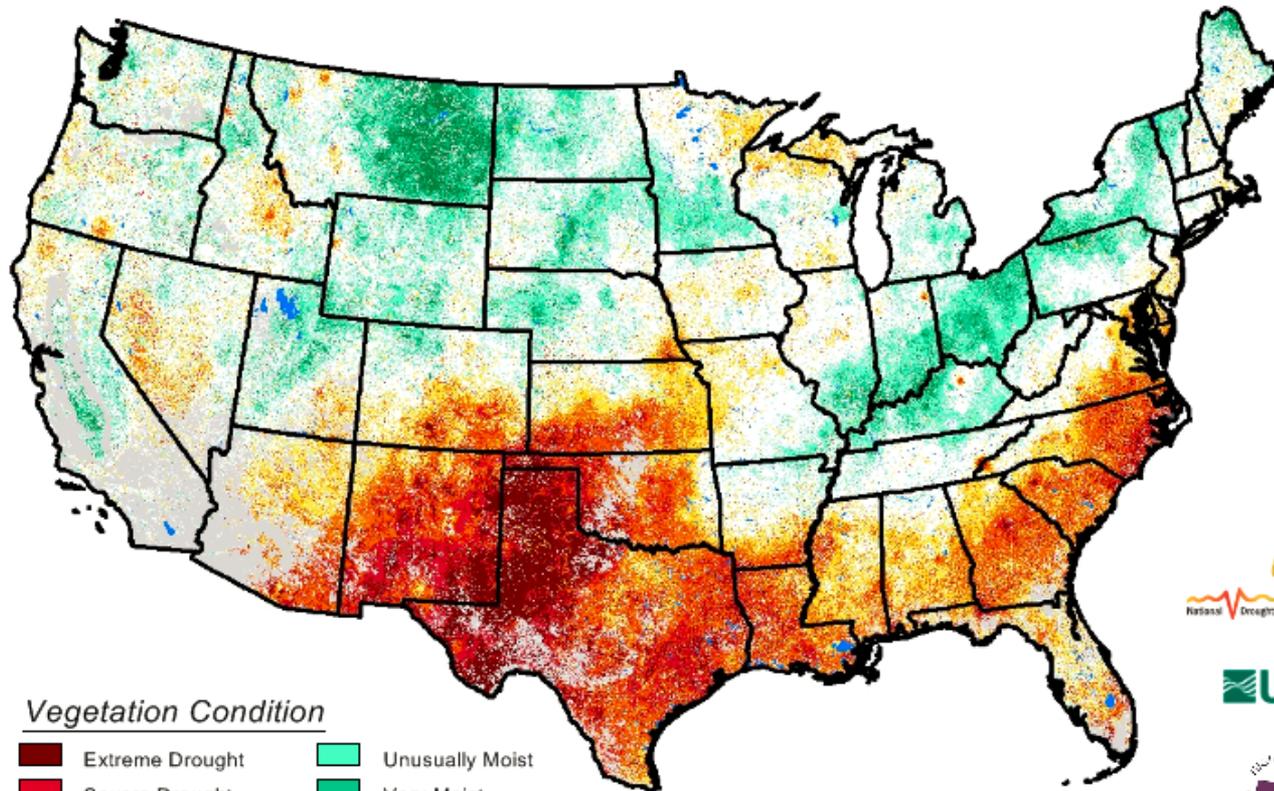
Released Thursday, August 4, 2011

Author: Brad Rippey, U.S. Department of Agriculture

Drought conditions can sometimes be detected from space

Vegetation Drought Response Index Complete

July 25, 2011



Vegetation Condition

 Extreme Drought	 Unusually Moist
 Severe Drought	 Very Moist
 Moderate Drought	 Extremely Moist
 Pre-Drought	 Out of Season
 Near Normal	 Water



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

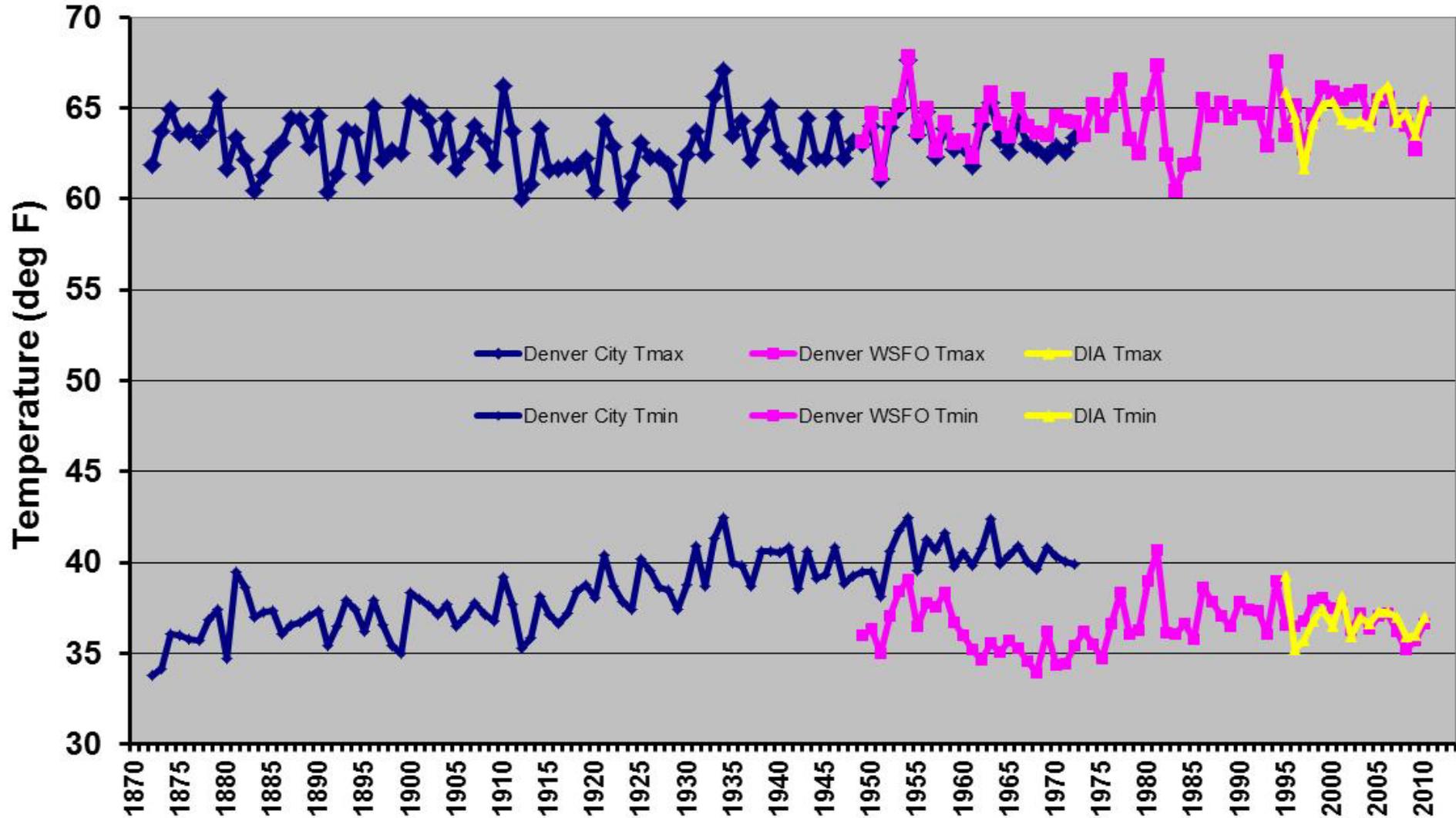


We can find many frustrating limitations to our climate records:

- Changing instrumentation
 - Changing environments around our weather stations
 - Changing weather station locations and observation times
 - Automation, etc.
- 

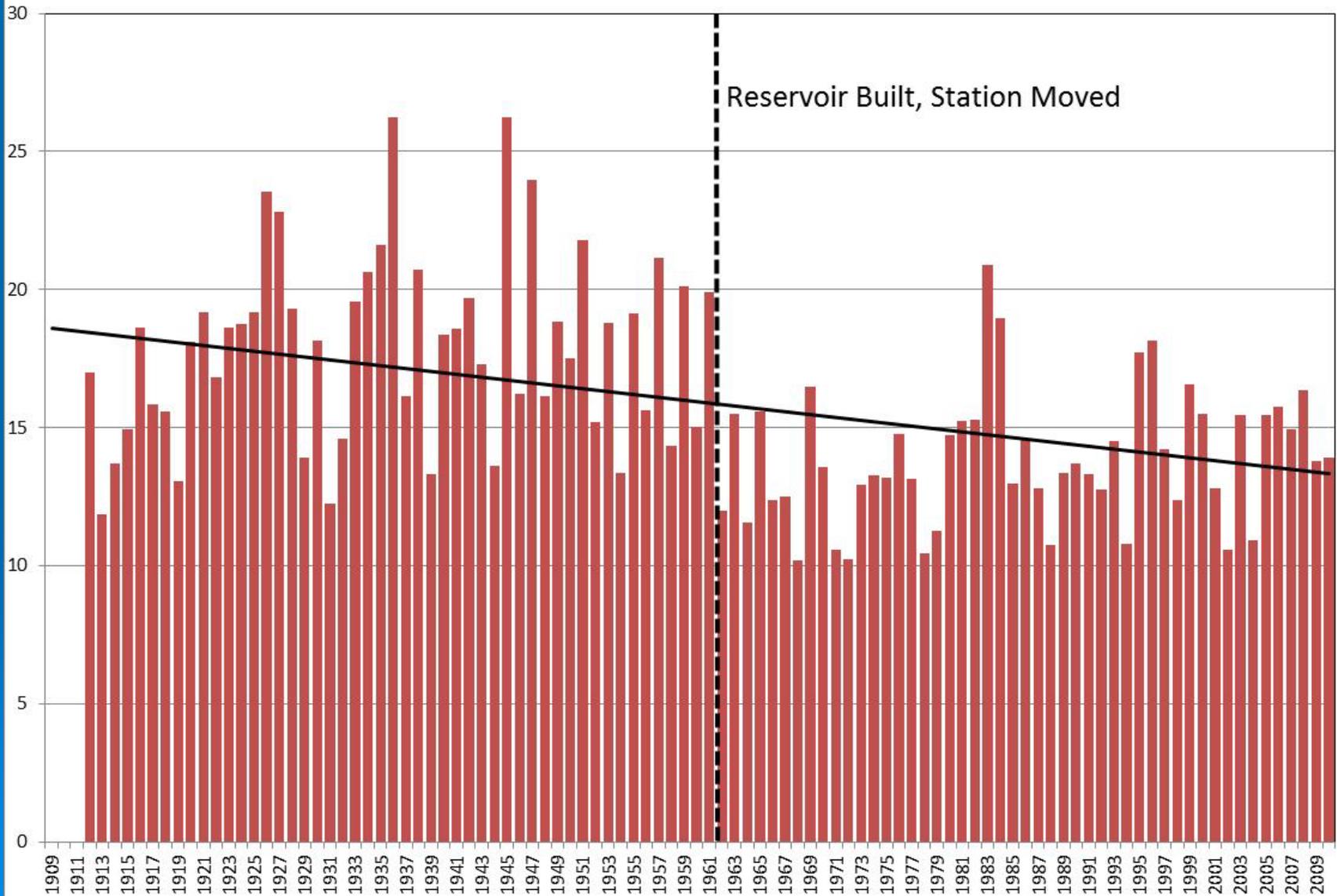
Denver – Station Keeps Changing

Denver (all 3 stations) 1897 - 2010
Annual Average Maximum and Minimum Temperatures



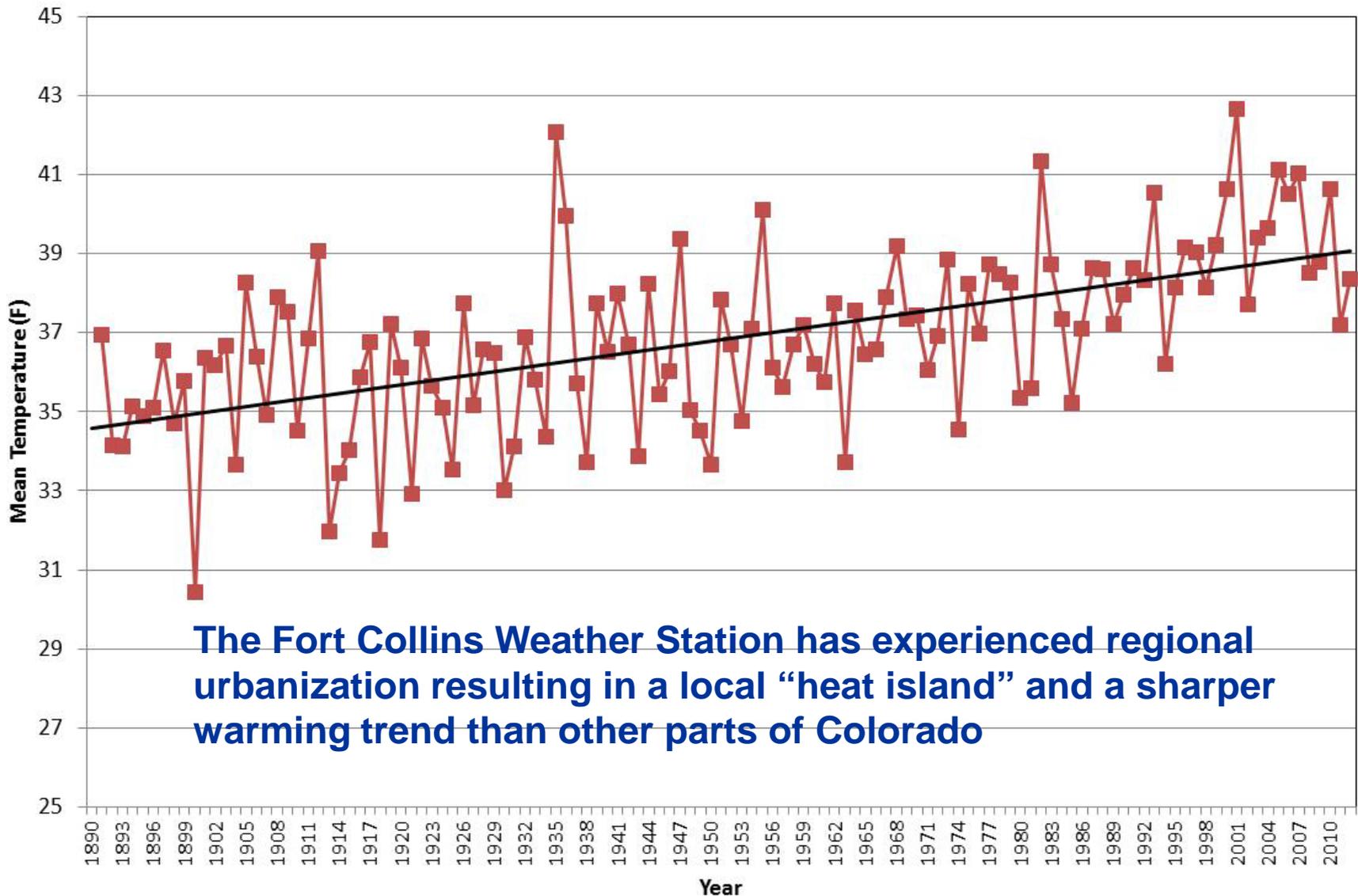
Dillon Annual Precipitation

Dillon Annual Precipitation (in) 1912 - 2010



Fort Collins Winter Temperatures

Fort Collins Average Winter (Oct - Apr) Temperature



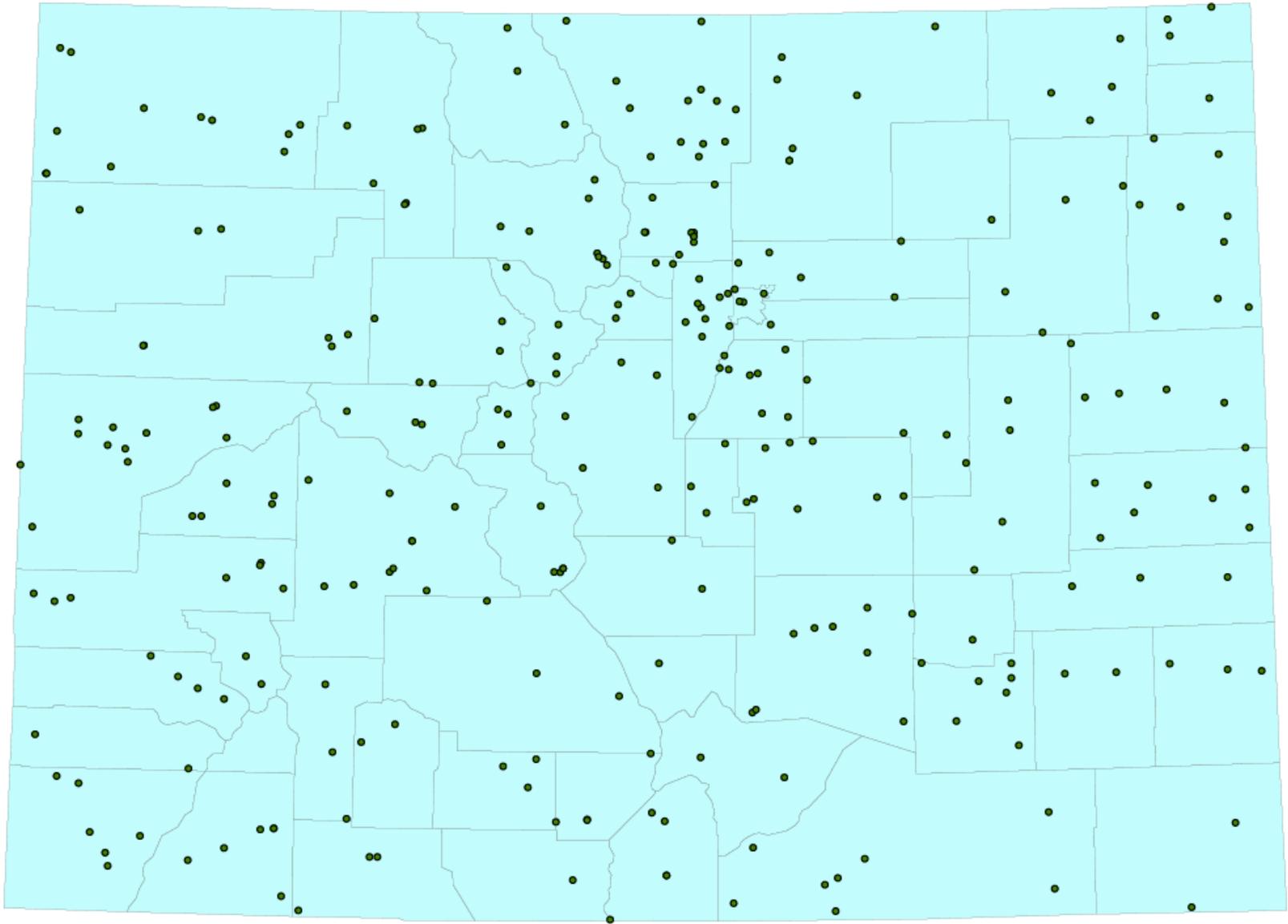
The Fort Collins Weather Station has experienced regional urbanization resulting in a local “heat island” and a sharper warming trend than other parts of Colorado

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).



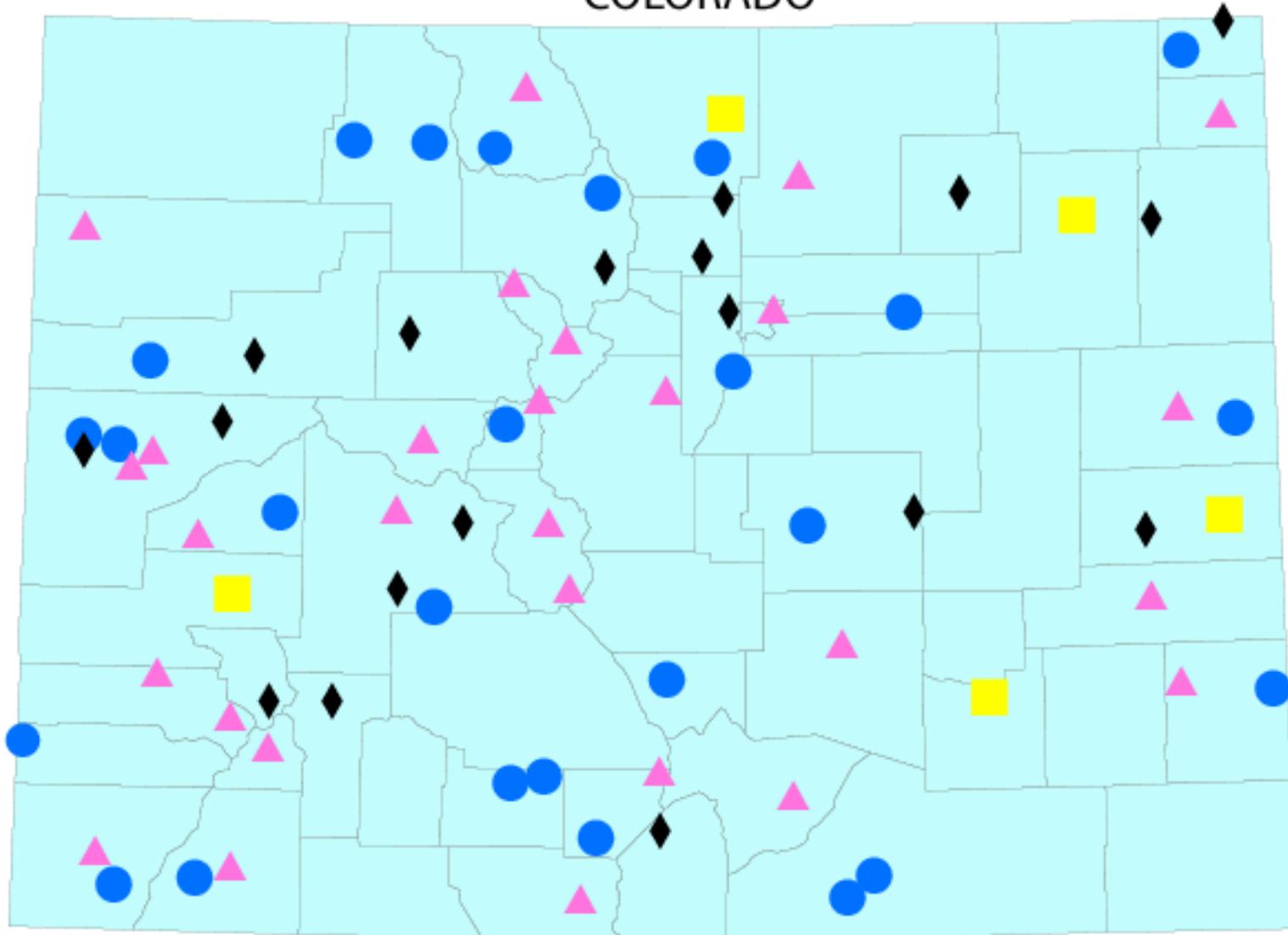
Colorado Cooperative Stations

COLORADO



Long-Term Analysis Stations

COLORADO



Legend

- ▲ Good
- ◆ Useful
- Better
- Best

NEW! Colorado Climate Trends Website

Colorado State University

Colorado Climate Trends

[Climate Trends Home](#) | [Colorado Climate Center](#) | [CIRA](#) | [Atmospheric Science](#)

[Colorado Climate Center](#) » [Climate Trends](#) » [Home](#)

Search by Google

Welcome to the Colorado Climate Trends Website

[Climate Trends](#) | [Station Map](#) | [Station Info](#) | [Data Access](#) | [Links + Resources](#) | [About](#)

Climate Trends of Colorado



Welcome! The climate of Colorado is a valued natural resource affecting our lives and livelihoods. By nature, climate is variable. No two years are ever exactly alike. Instrumental observations of our climate dating back to the late 1800s give a sense of our average climate, typical variations, extremes and long-term trends. (For a description of historic weather observations in Colorado, click here). Tracking temperatures and precipitation through history reveal seasonal patterns, cold and warm periods, and episodes of drought and abundant water.

Today there is great interest in climate change. If our state is warming, these data will show it. This Website lets you view, graph and download historic temperature and precipitation data for selected weather stations in Colorado having the longest and most consistent historical data. Historic consistency is critical for accurately assessing climate trends. There have been hundreds of weather stations operated in Colorado since the 1890s, but very few have data that are complete and consistent. Even the best stations selected for this site are imperfect.

For each station shown here, a description of the history of the station is provided so that data users will know what factors may have affected the long-term time series. To learn more

National Weather Service Co-op Program

Weather observations in Colorado using thermometers and rain gauges date back to the late 1800s. Some of the earliest weather stations were established in the largest cities during the 1870s by the U.S. Signal Service. In the 1880s Colorado formed a "State Weather Service" and began setting up more basic weather stations in smaller towns and rural areas. By 1890, the first nationwide civilian weather service was formed within the U.S. Department of Agriculture. State networks, such as Colorado's were combined to form a single nationwide volunteer weather observing network. This same network continues today managed by the National Weather Service. What began as a few dozen stations in the 1880s grew to over 200 in the 1940s and 50s and continues today.



<http://climatetrends.colostate.edu>

This website is a resource that anyone can use to keep tabs on Colorado's observed climate – its variations and trends.

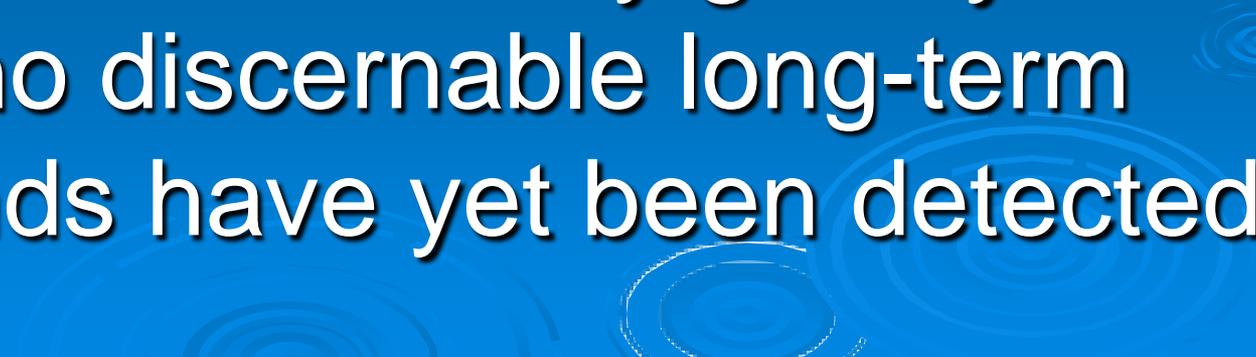
<http://climatetrends.colostate.edu>

The background of the slide features several concentric, light blue circular ripples that resemble water droplets hitting a surface, scattered across the lower half of the image.



For much of Colorado, upward trends in seasonal temperatures are being observed and analyzed.

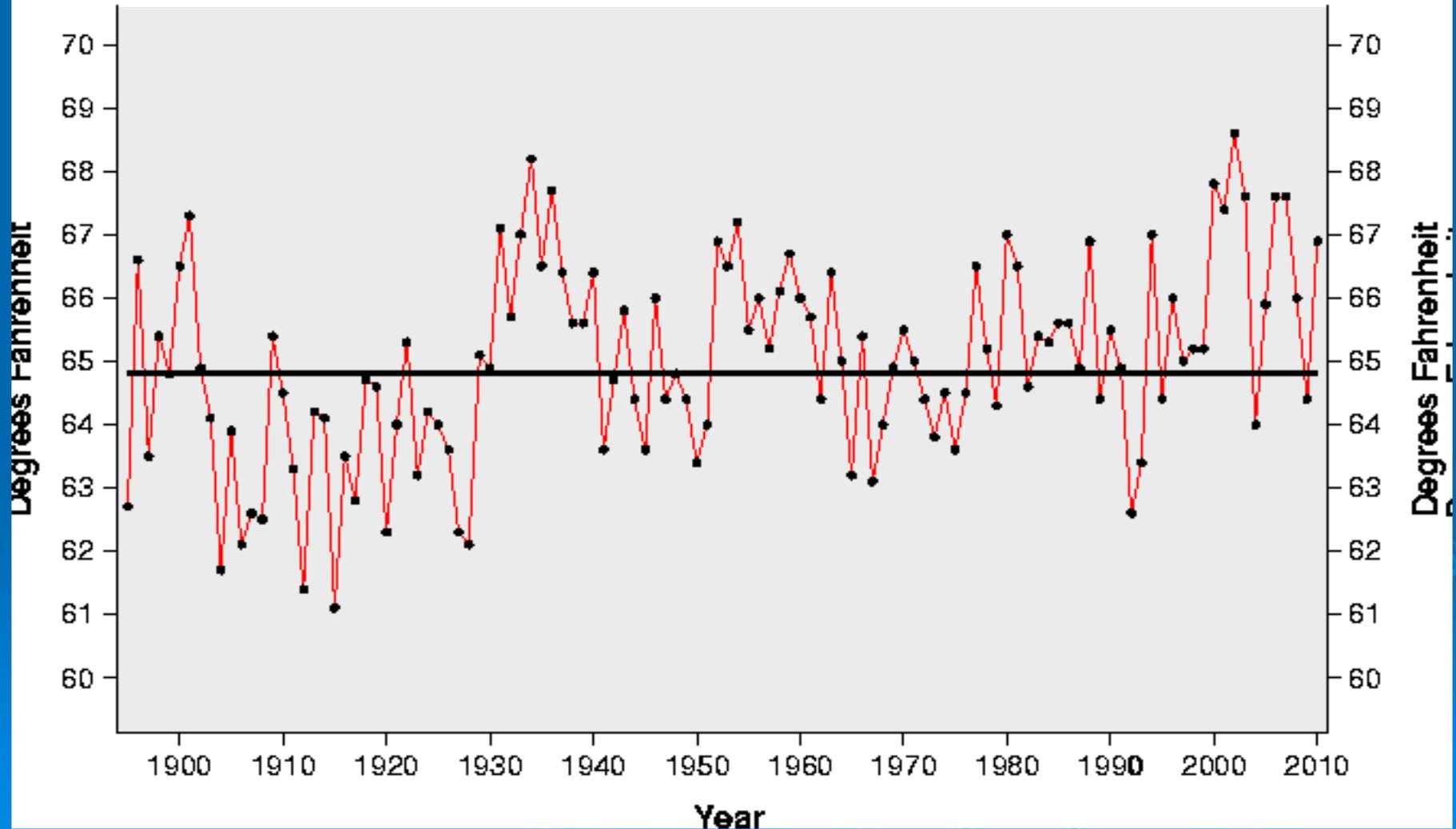
However, precipitation continues to vary greatly and no discernable long-term trends have yet been detected



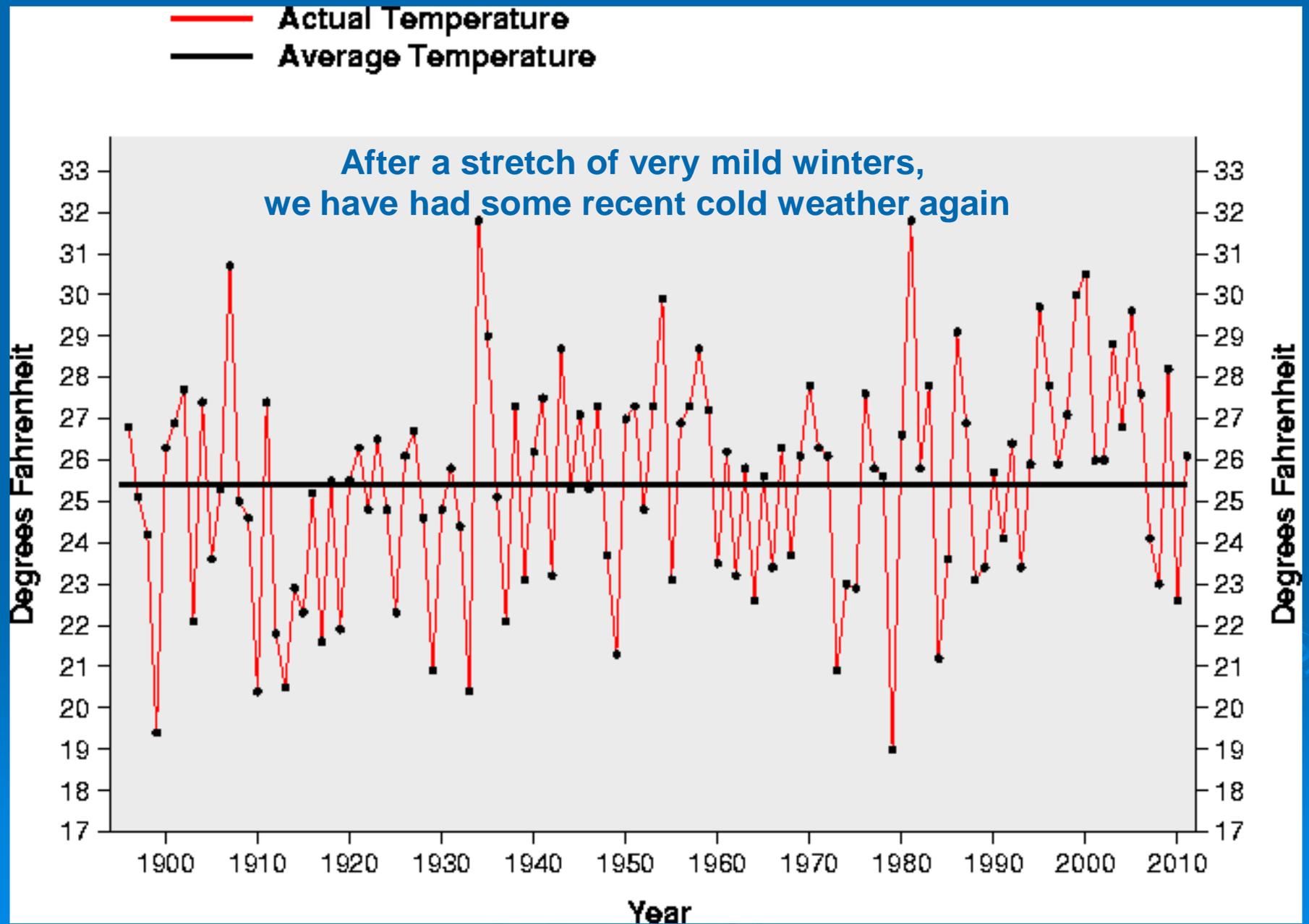
Colorado Statewide Summer Temperatures (JJA) Averages 1895-2010

— Actual Temperature
— Average Temperature

2010 was another hot one

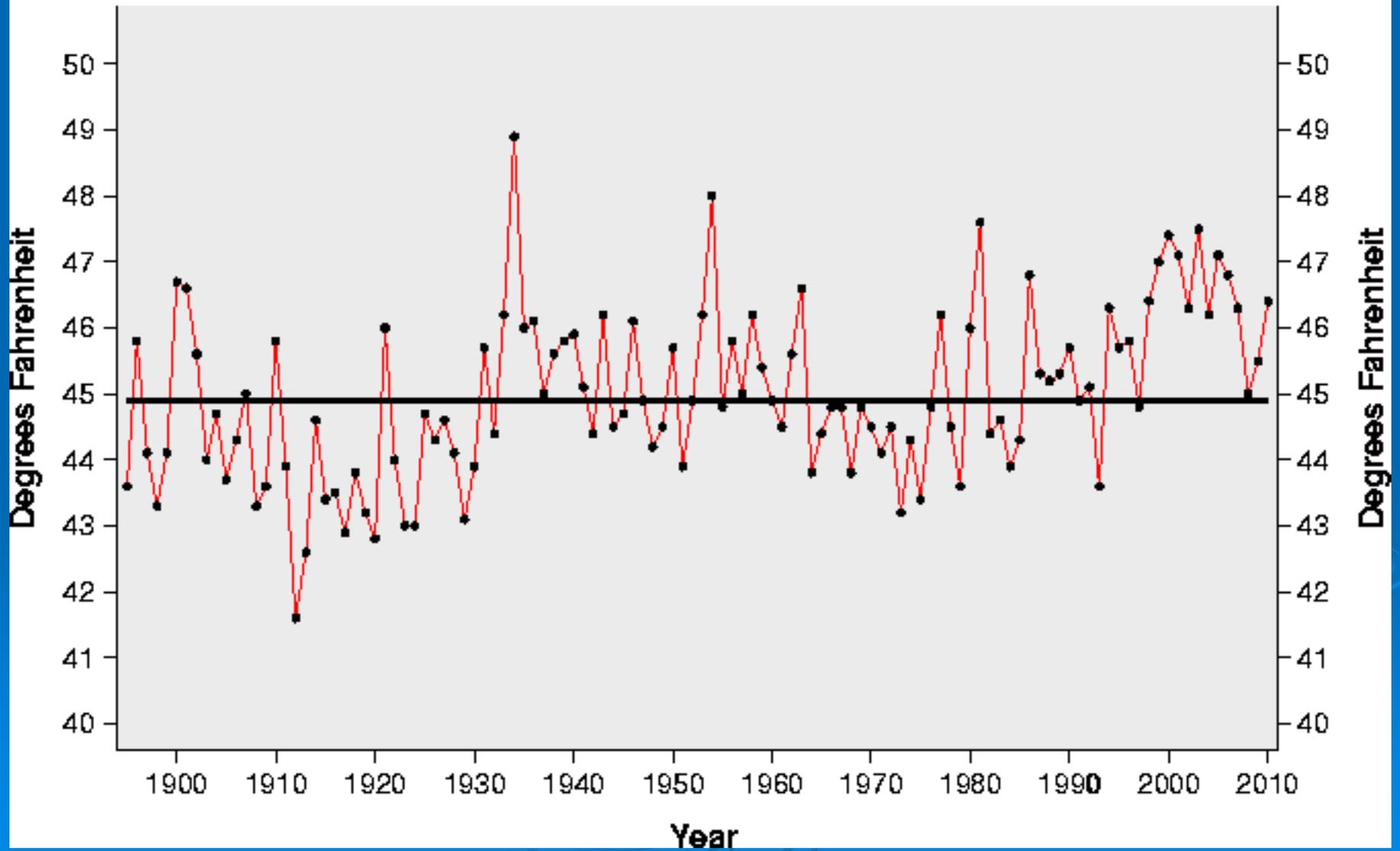


Colorado Average Winter (DJF) Temperatures 1895-2011

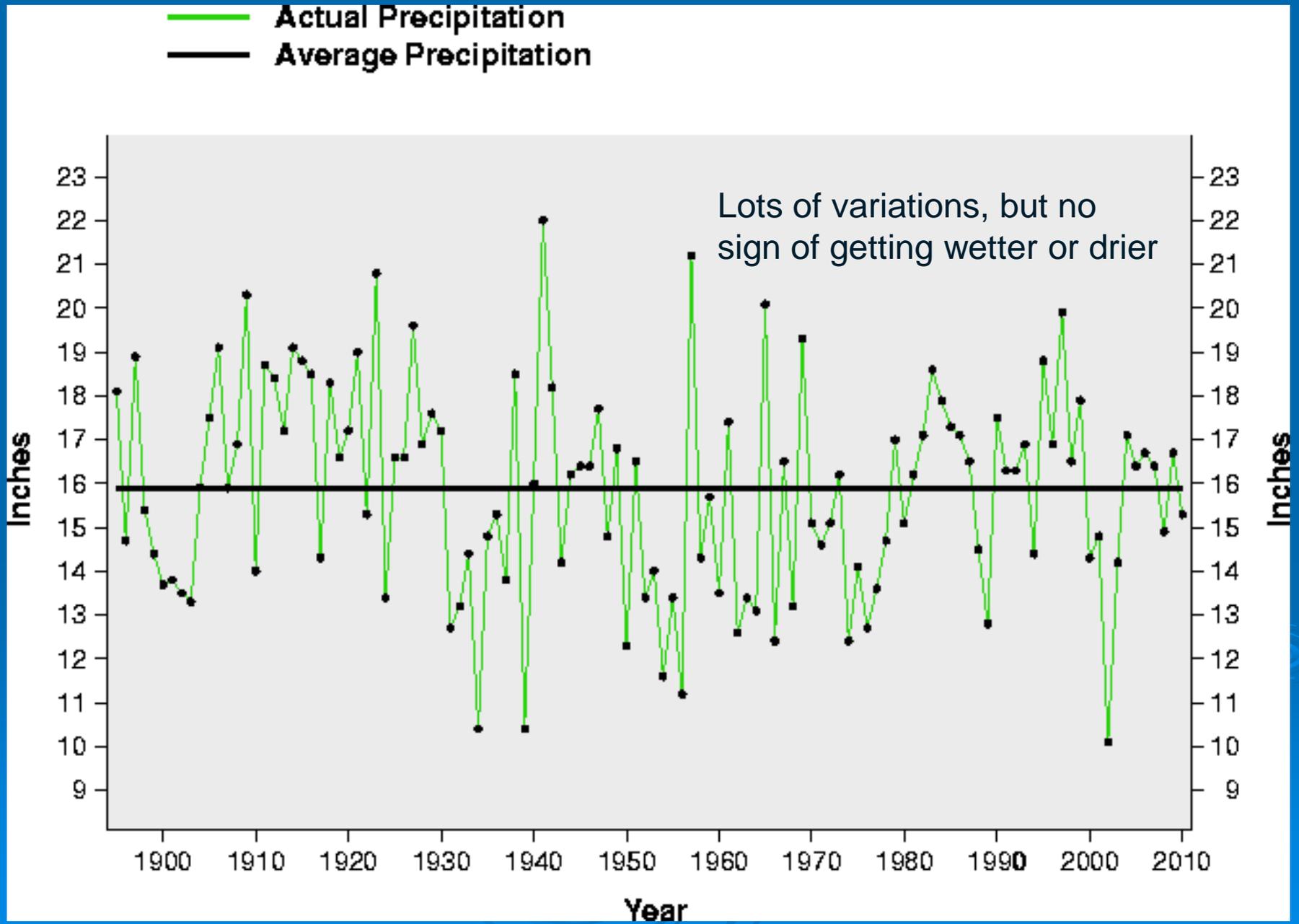


Statewide Mean Annual Temperature 1895 - 2010

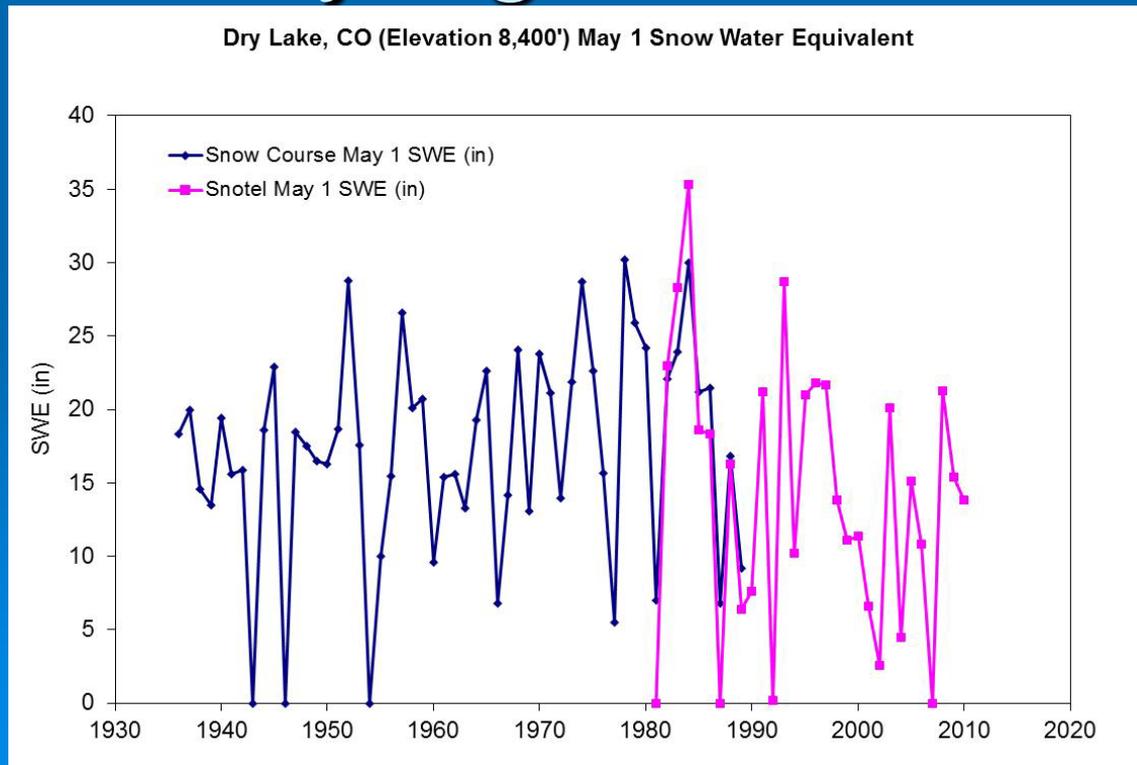
— Actual Temperature
— Average Temperature



Colorado statewide annual precipitation 1895- 2010



There has been evidence of earlier snowmelt in Colorado, but it is less evident here than in other Western States, probably because of our very high elevation



So Do we need to be concerned about climate change when we have so many other challenges to deal with?

- Any recent (past 120 years) climate trends are still rather subtle - - - but that may not always be the case

Has our Climate Always Been the Same

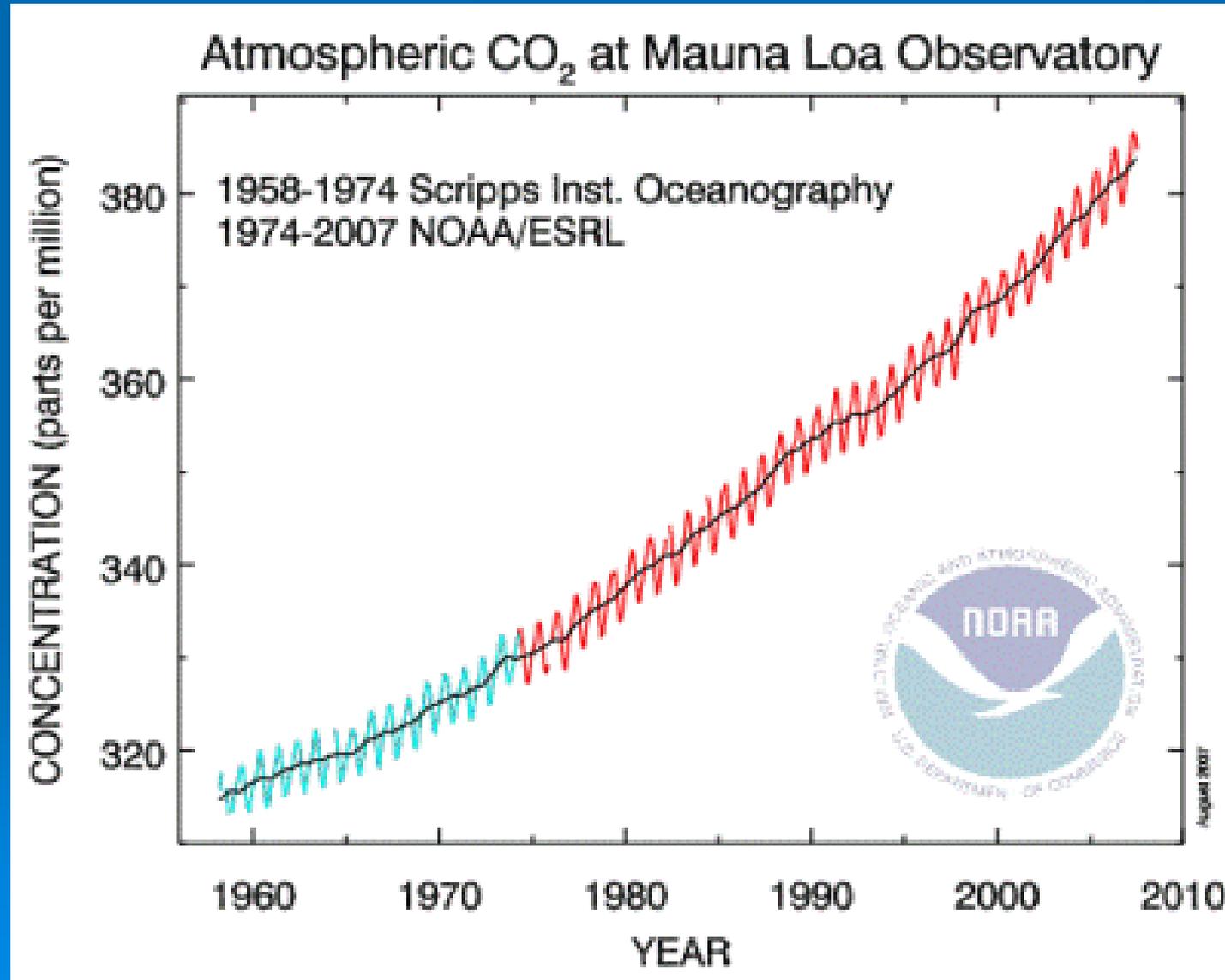
- No, climate is always a changing, dynamic equilibrium



But it looks like we're headed
somewhere we've never been
before – or at least not for a long,
long time



Increases in greenhouse gases are real, large and continuing



The Greenhouse Effect

Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and lower atmosphere.

Solar radiation powers the climate system.



Some solar radiation is reflected by the Earth and the atmosphere.



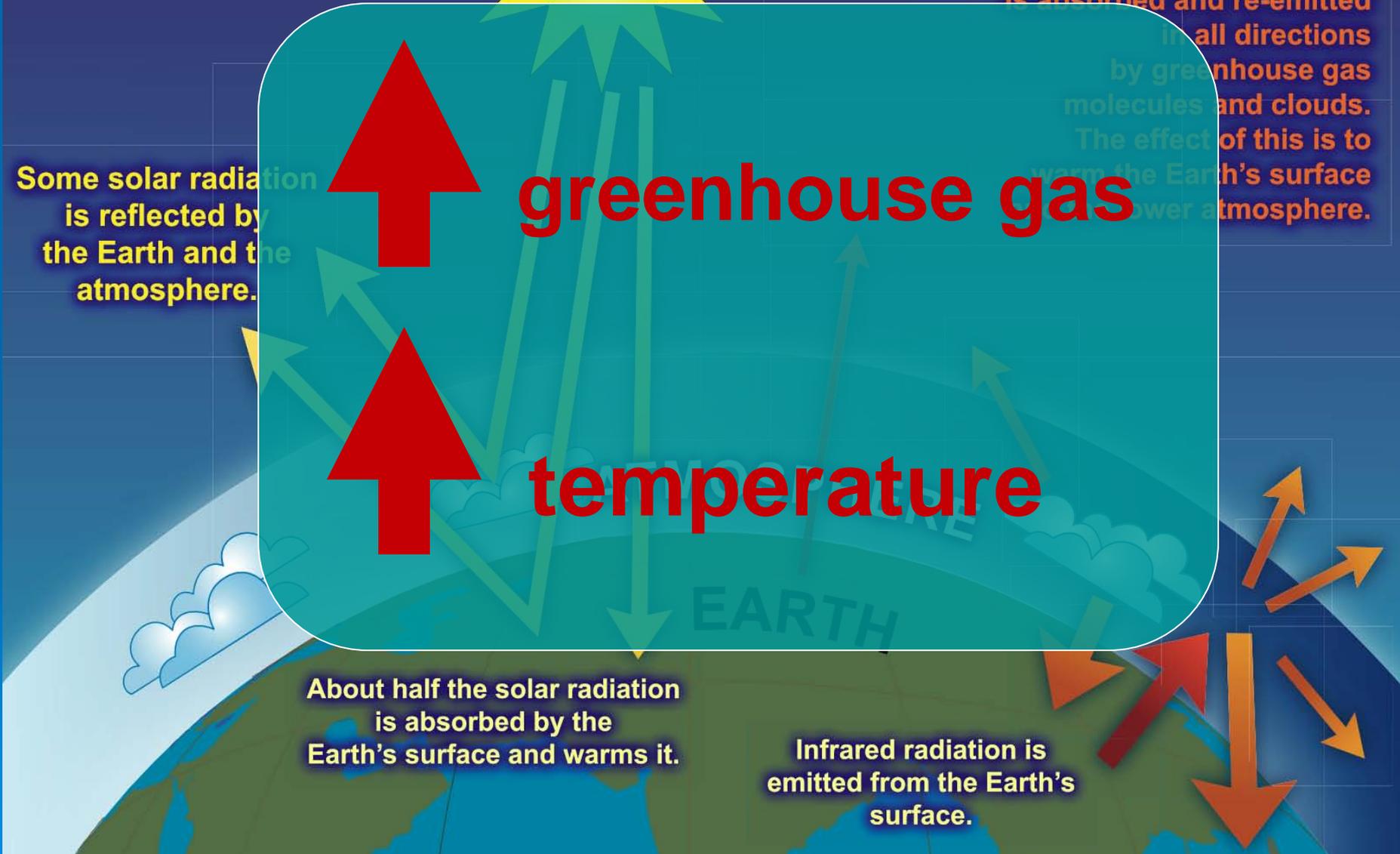
greenhouse gas



temperature

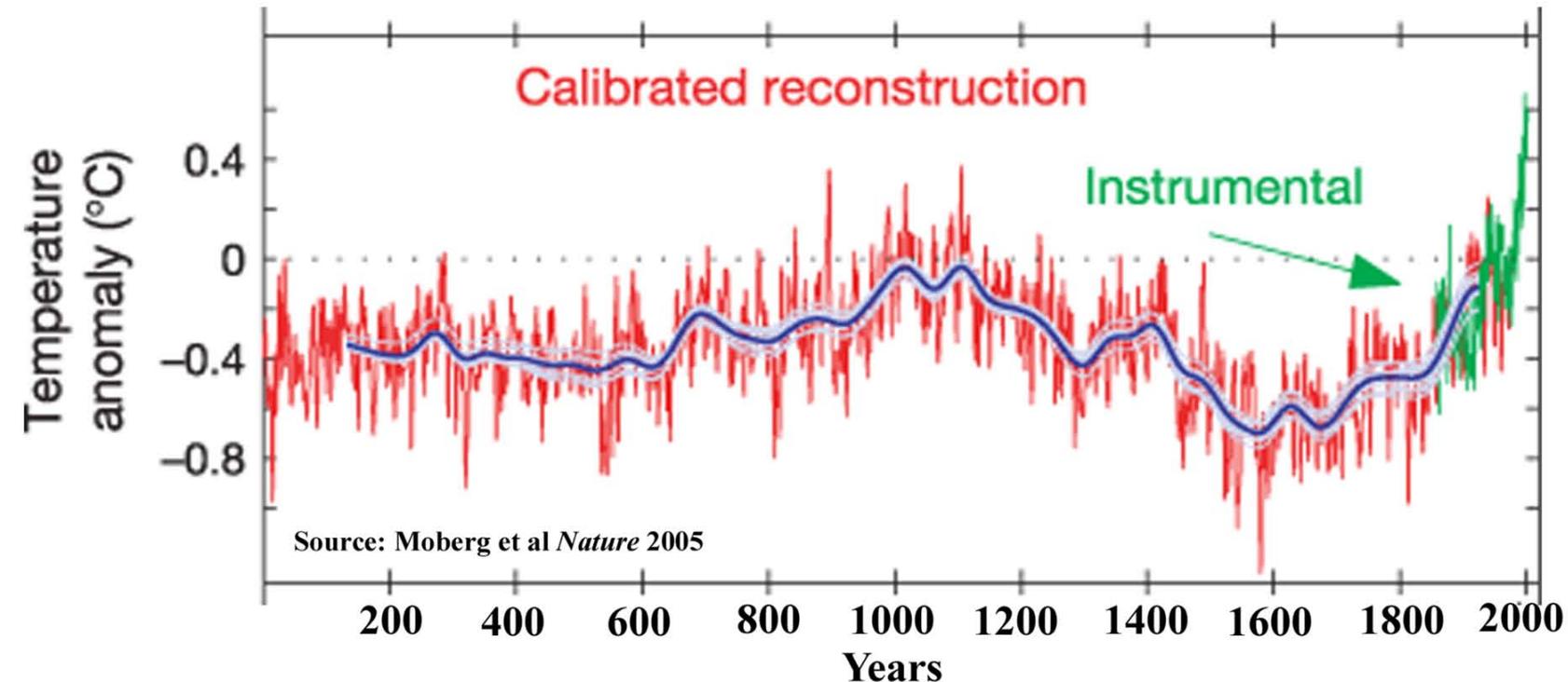
About half the solar radiation is absorbed by the Earth's surface and warms it.

Infrared radiation is emitted from the Earth's surface.

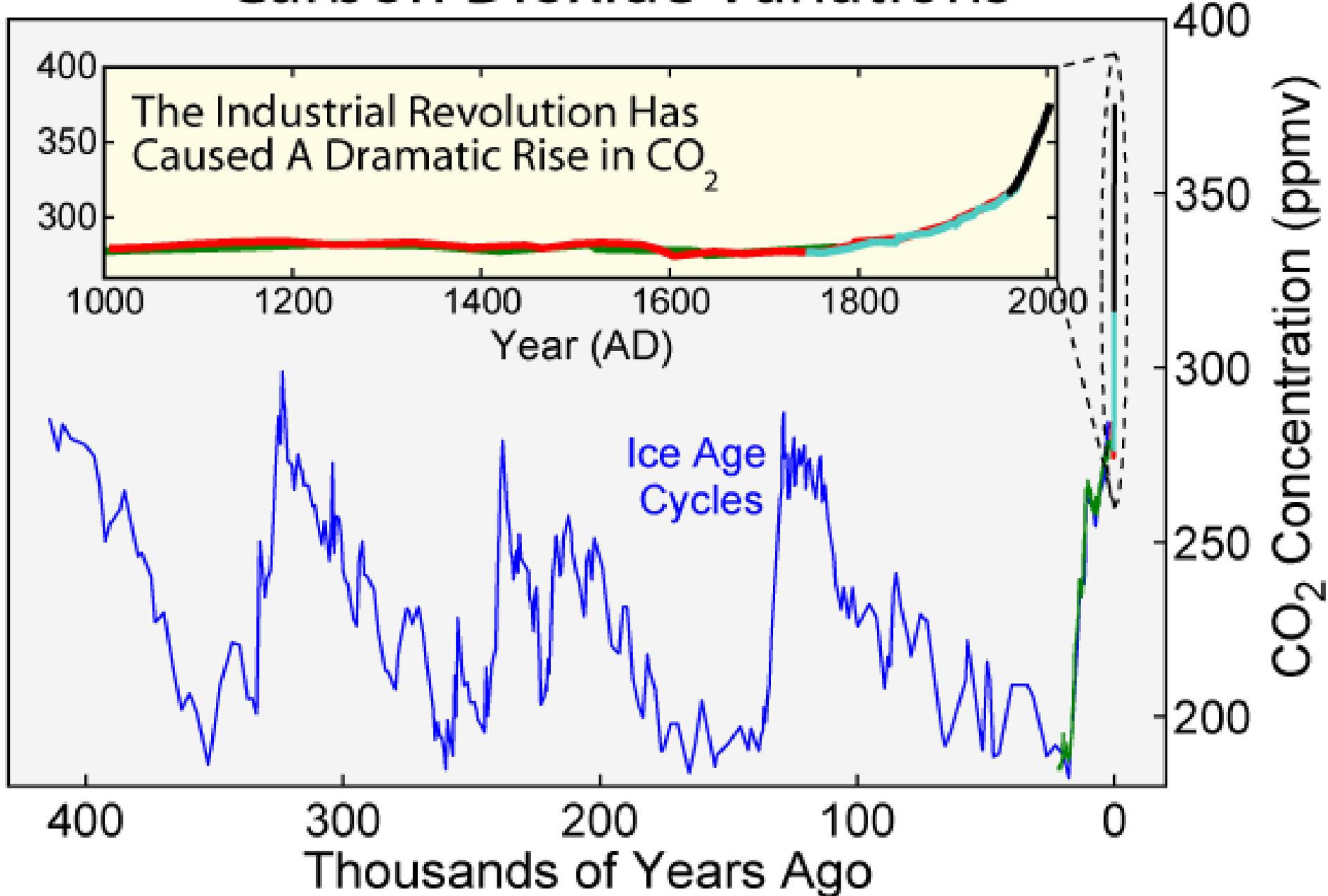


The recent warming is unusual...

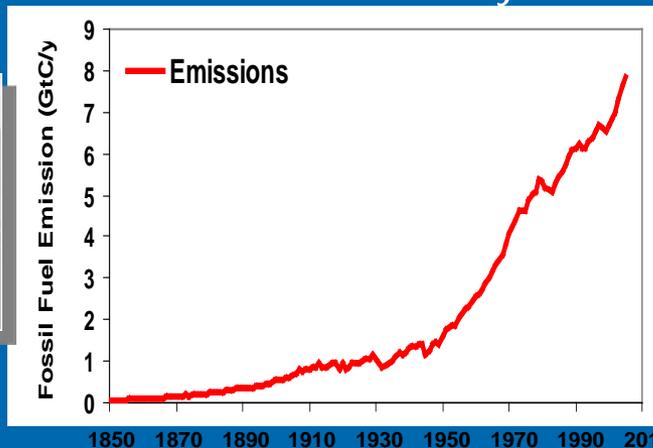
2000 Year Northern Hemisphere Reconstruction of Surface Air Temperatures



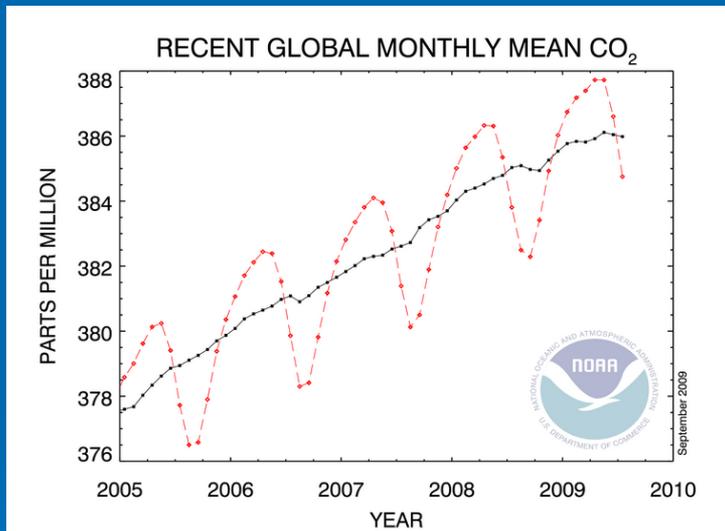
Carbon Dioxide Variations



Climate Change: Emissions



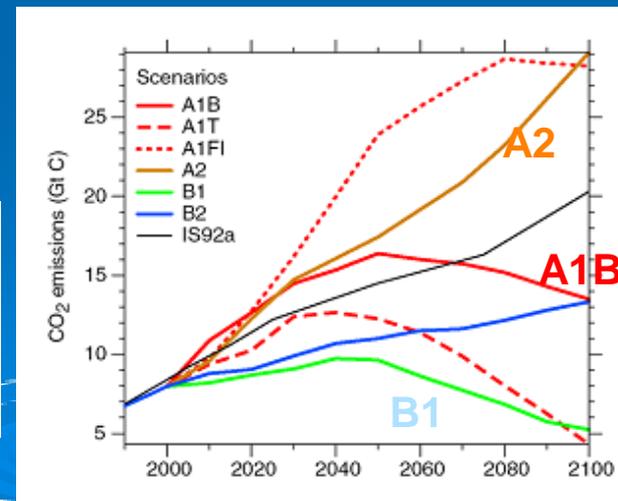
2009: projected
2-3% drop from
2008 (recession)



Pre-Industrial: 270 ppm

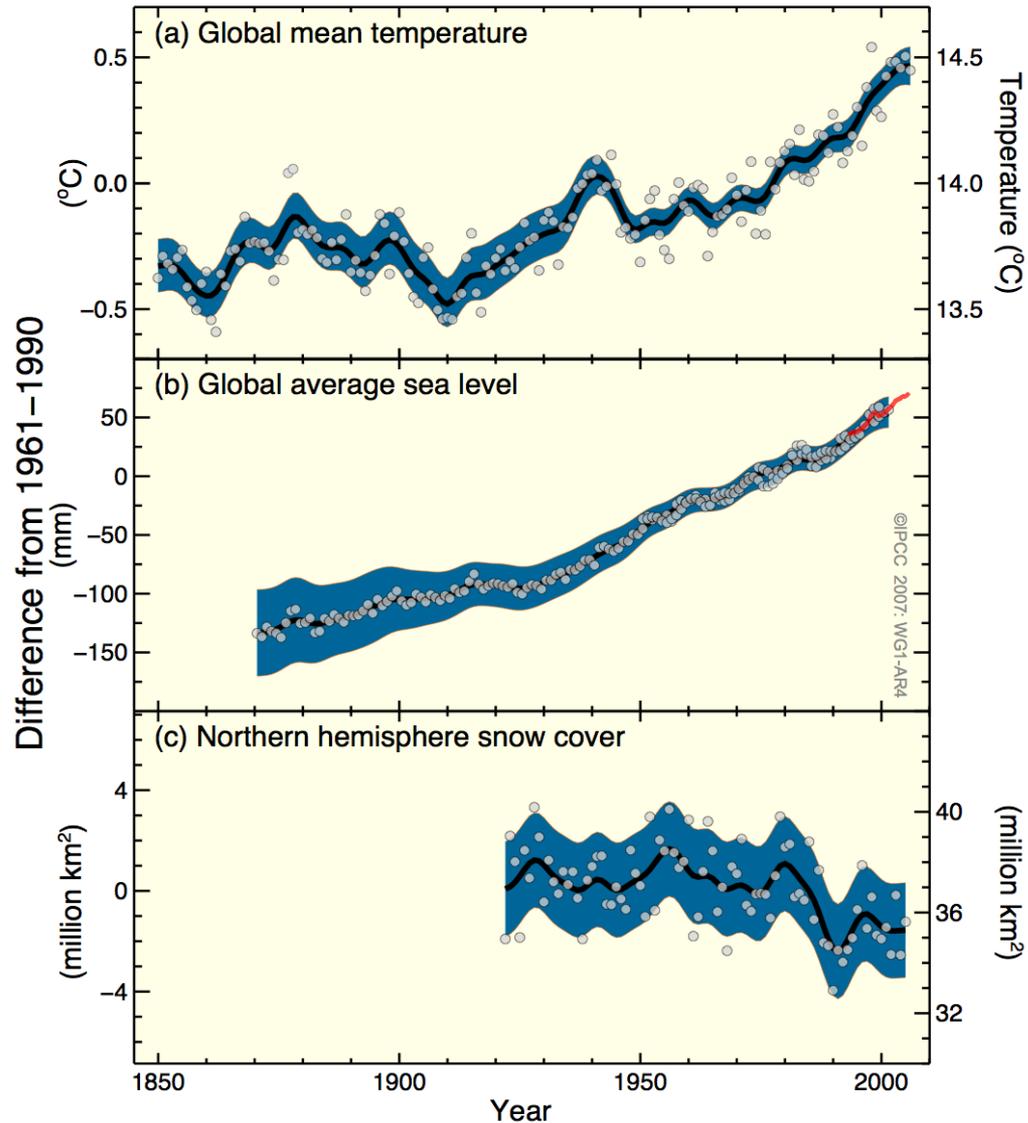
2009: 386 ppm

Future Emissions Scenarios: B1 (low);
A1B (mid) ; A2(high); A1FI (higher)



Global Indicators of Warming

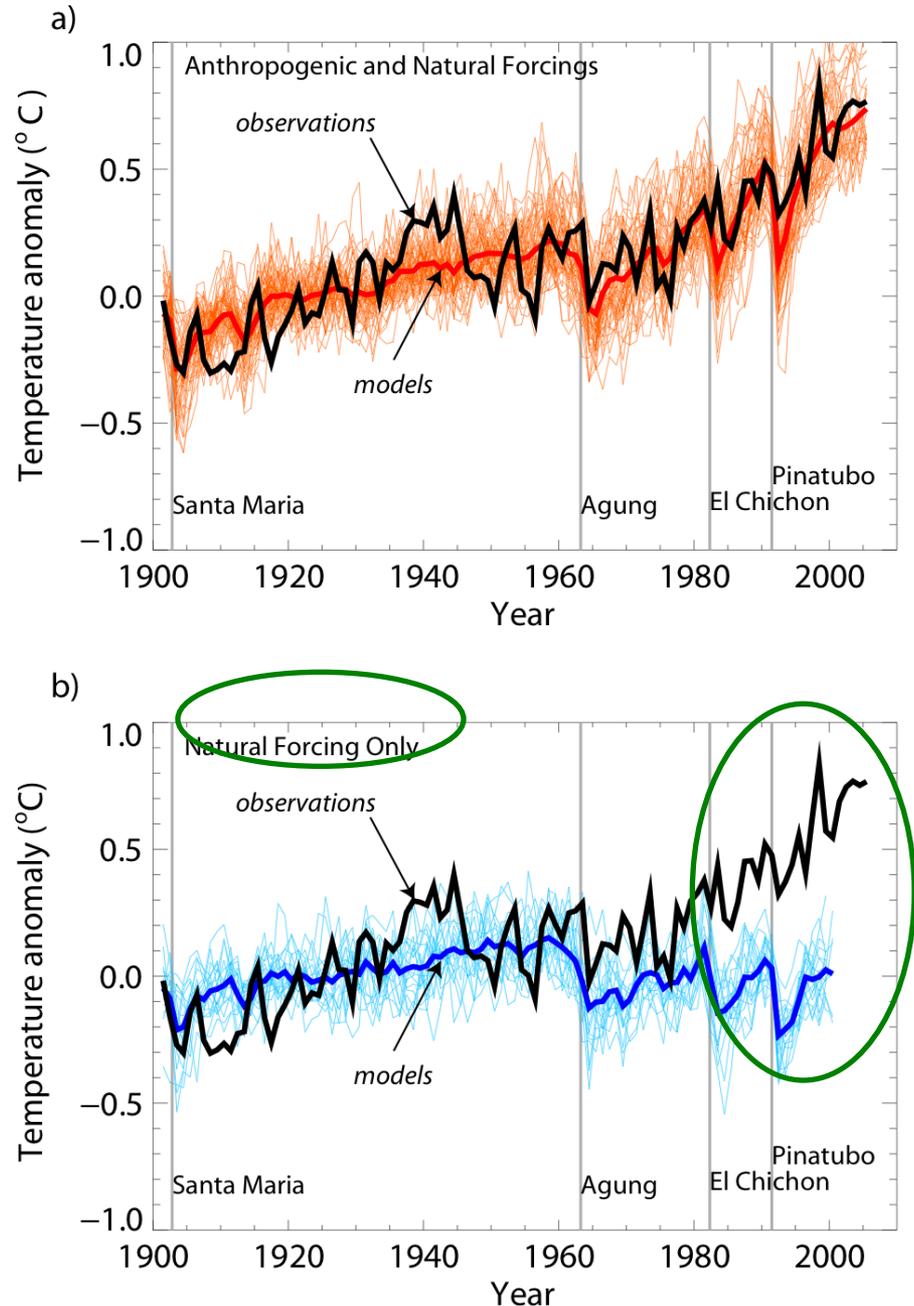
Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover



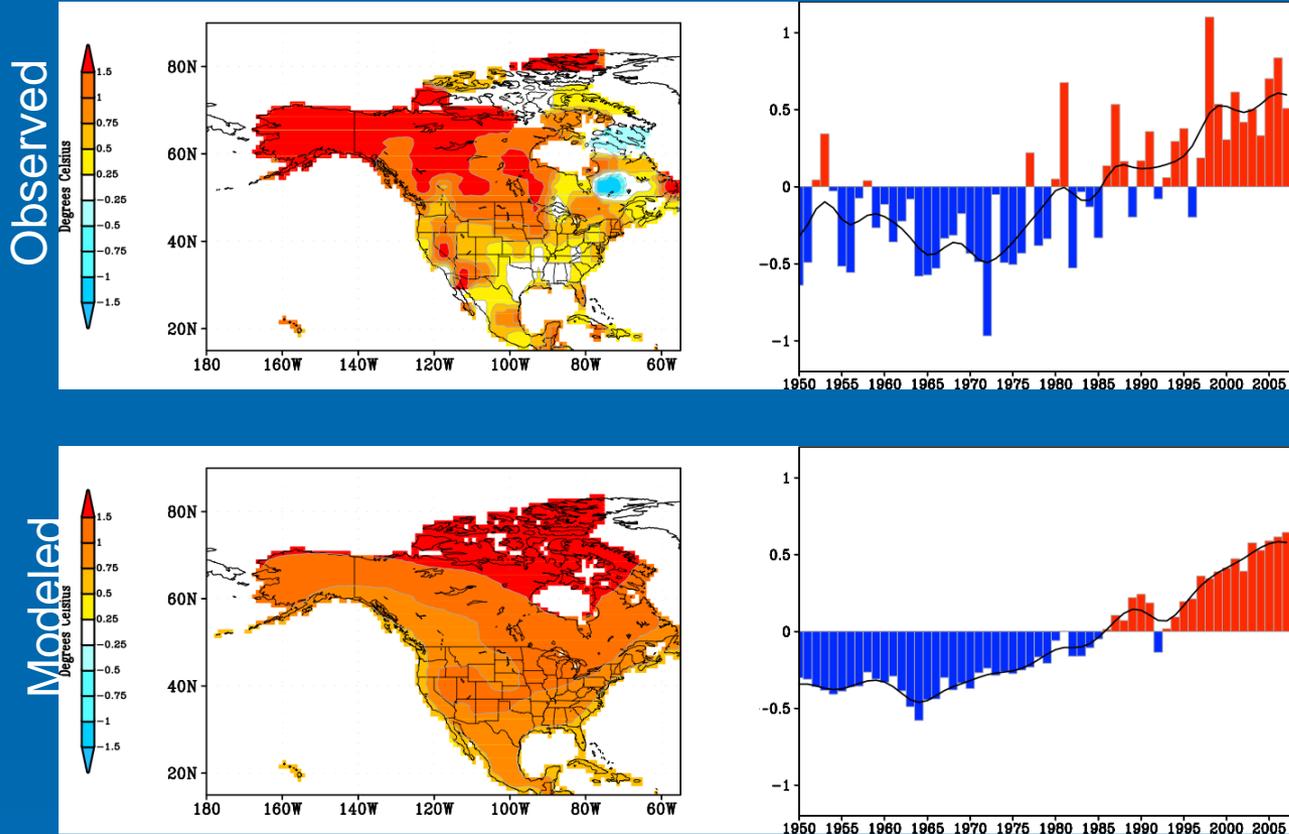
Attribution

- Observed changes are **consistent** with expected responses to forcings as well as **inconsistent** with alternative explanations
- **Most of the observed increase in globally averaged temperatures since the 1970s is very likely (>90%) due to the observed increase in anthropogenic greenhouse gas concentrations**

Global Mean Surface Temperature Anomalies



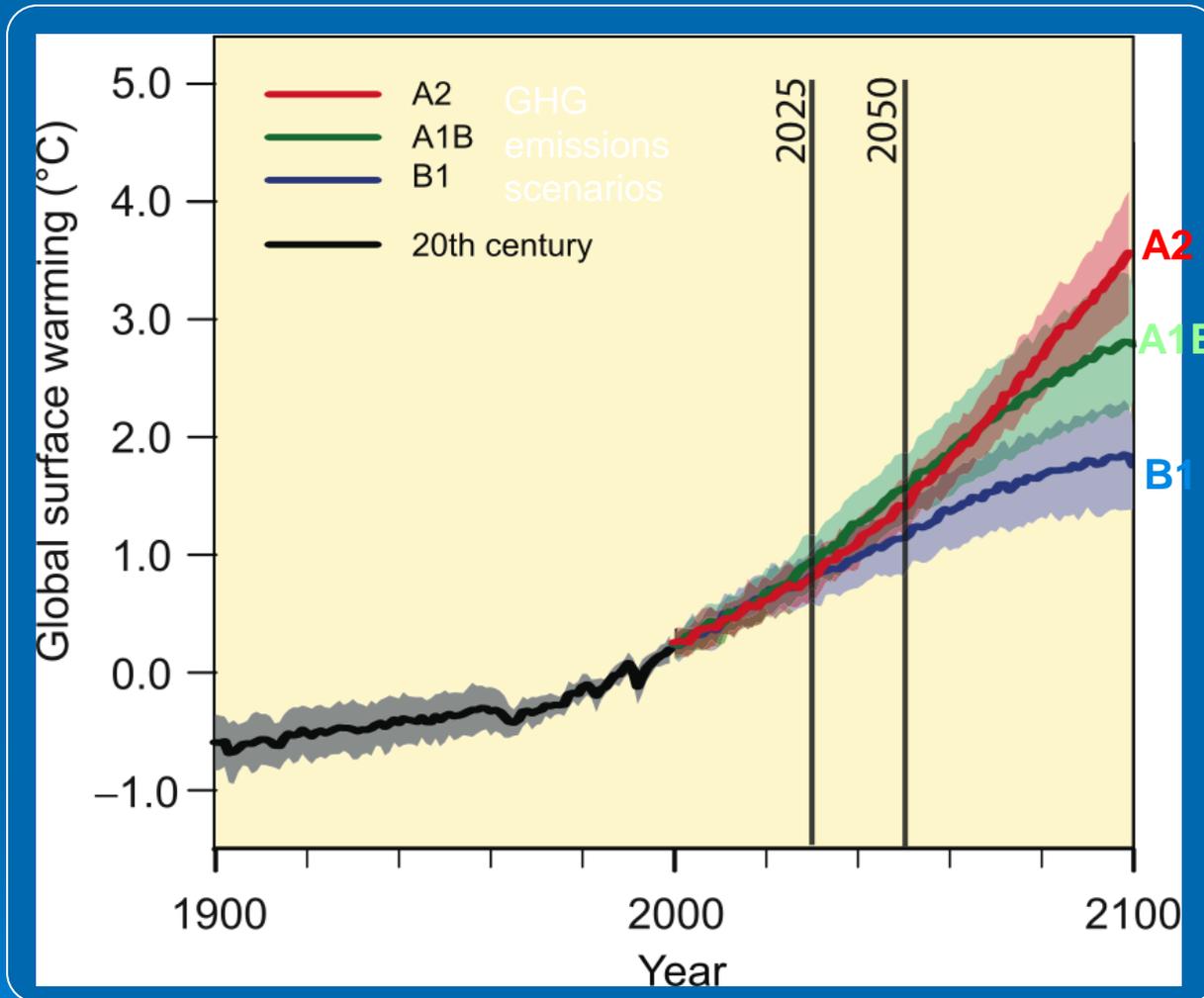
Attribution: Observed v. Modeled Temperature (1950–2007)



Attribution of observed temperature changes to greenhouse gas emissions is more difficult at smaller spatial scales because climate variability is larger at these scales.

- The accumulation of greenhouse gases in the atmosphere is *very likely* the cause of most of the increase in global average temperature (IPCC).
- In North America, “human-induced warming has *likely* caused much of the average temperature increase over the past 50 years” (CCSP 3.3).
- Climate models show a 1F warming in the West in the last 30 years in response to greenhouse gas emissions.

Global Temperature Projections

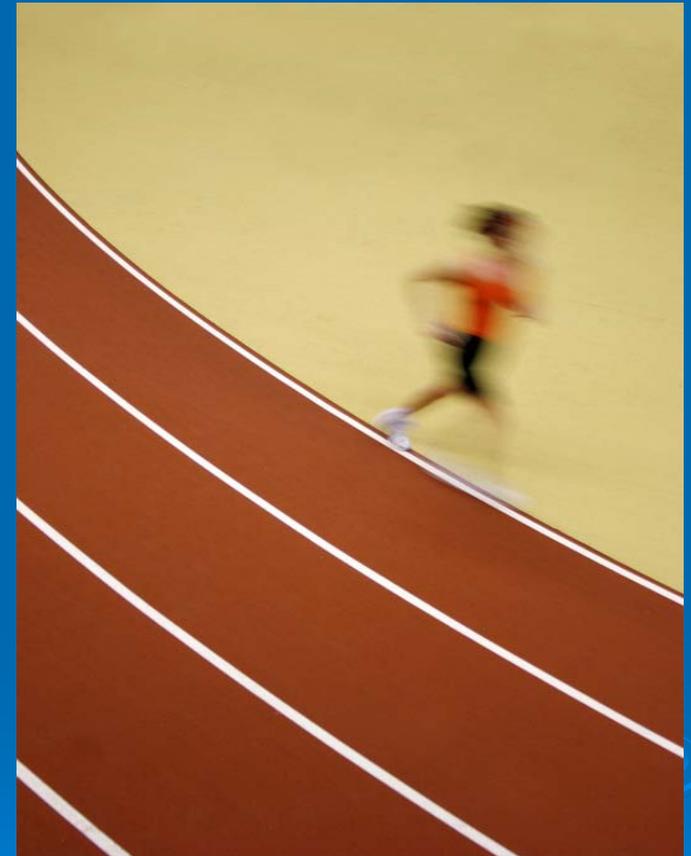
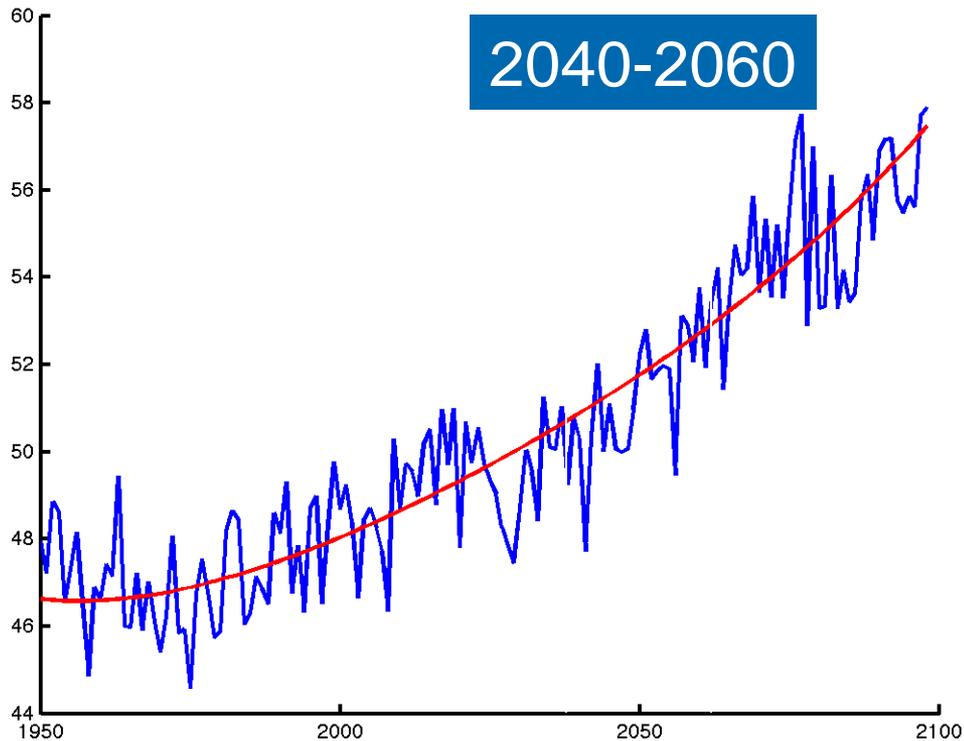


Source: IPCC AR4 WGI, 2007

Regardless of GHG emissions, temperature increases by 2025 and 2050 will be about the same

Projections: Time-evolving vs. "snapshots"

Annual average temperature



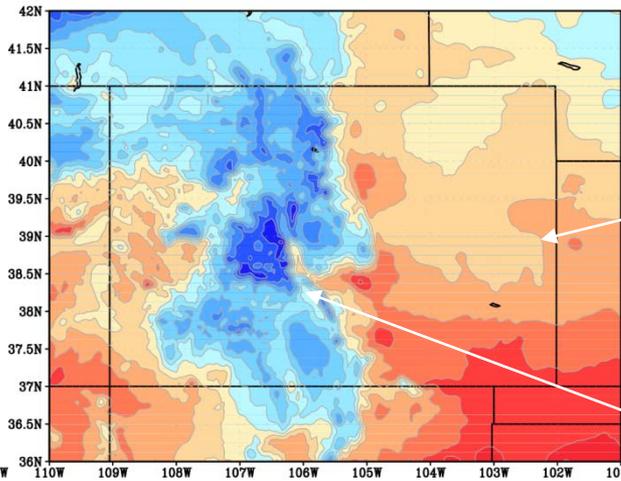
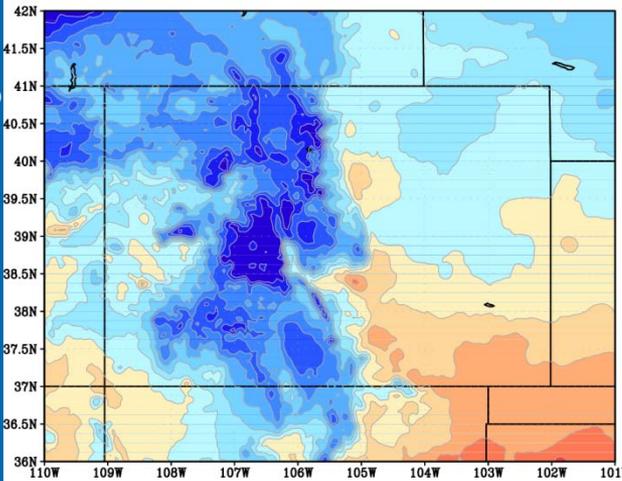
A climatological average in the future will be like taking a snapshot of moving object...

Projections: Temperature

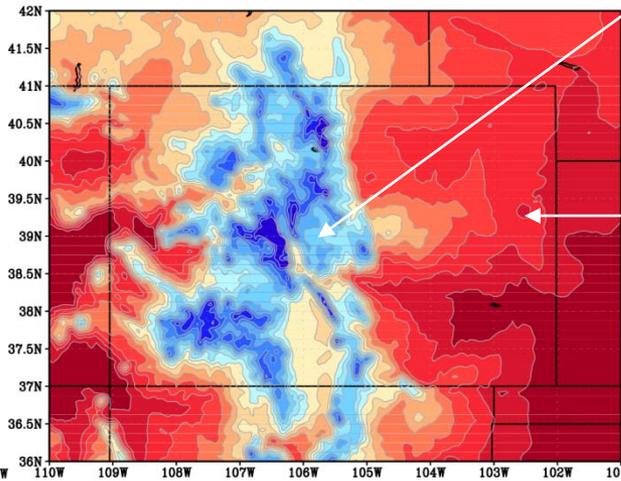
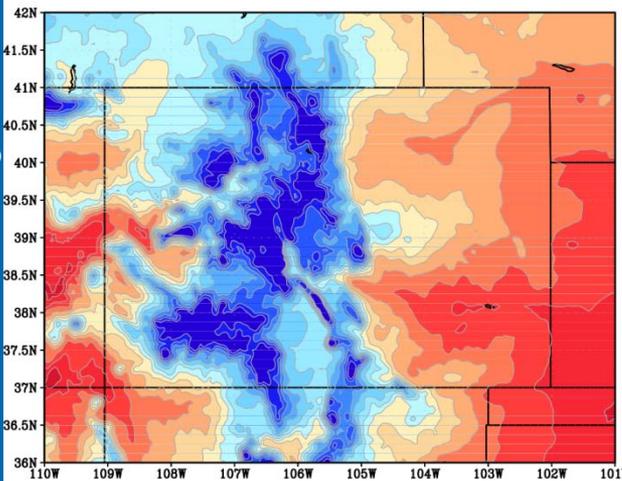
Temperatures
(1950–1999)

Temperatures
(Projected 2050)

January



July

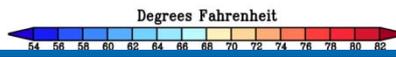
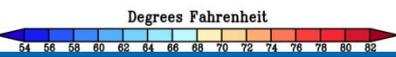


What would the projected changes mean for Colorado's varied climate?

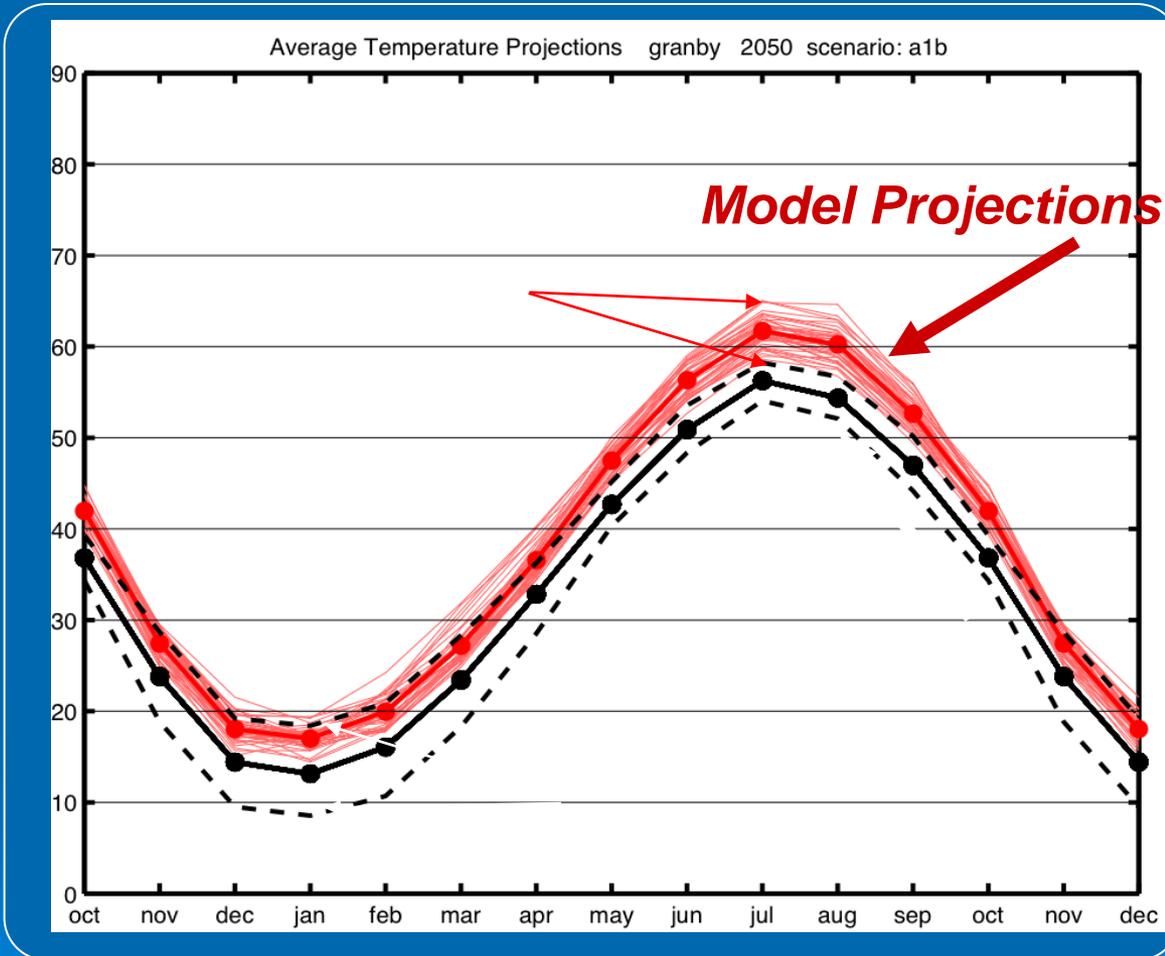
Winter temperatures shift northward on the plains

Temperatures creep upwards in the mountains in all seasons

Summer temperatures shift westward on the plains bringing the temperatures of the Kansas border to the Front Range.



Projections: Temperature



Summers warm
more than winters

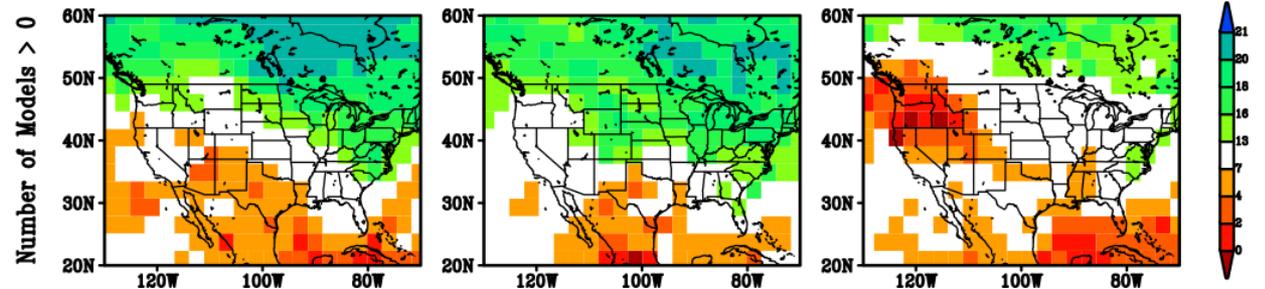
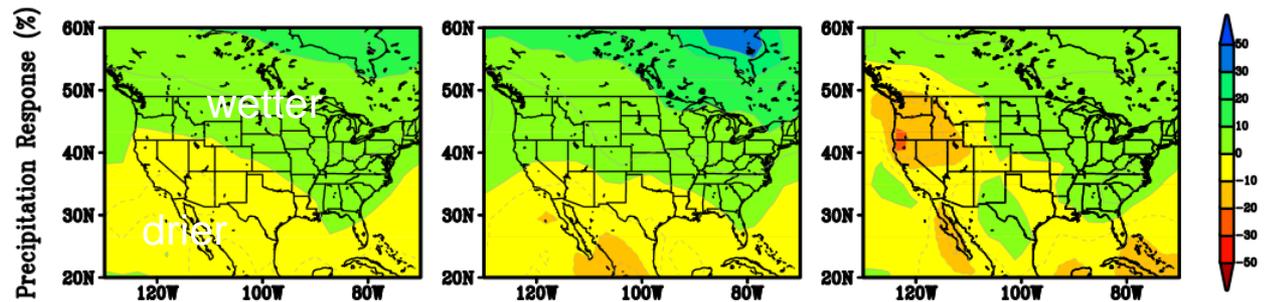
Average summer
temps similar to
hottest days in the
past few years

Earlier spring

Projections: Precipitation

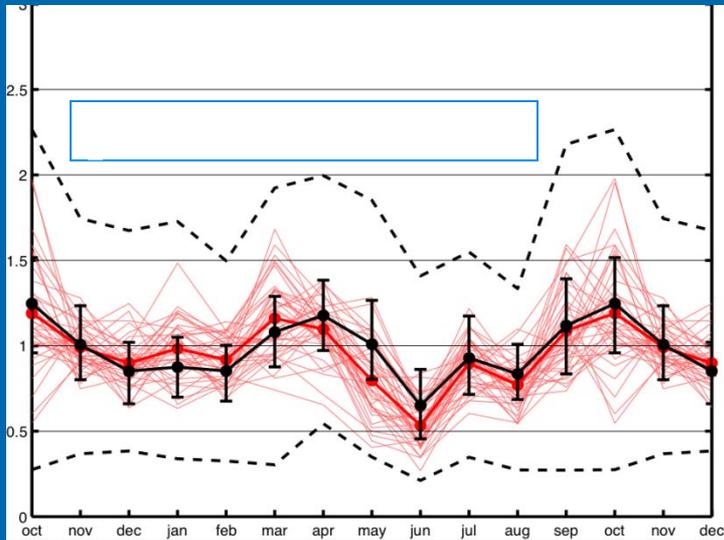
Source: CO Climate Report, 2008

Climate model projections do not agree whether annual mean precipitation will increase or decrease in Colorado by 2050. The multi-model average projection shows little change in annual mean precipitation...



Projections: Precipitation

Grand Junction

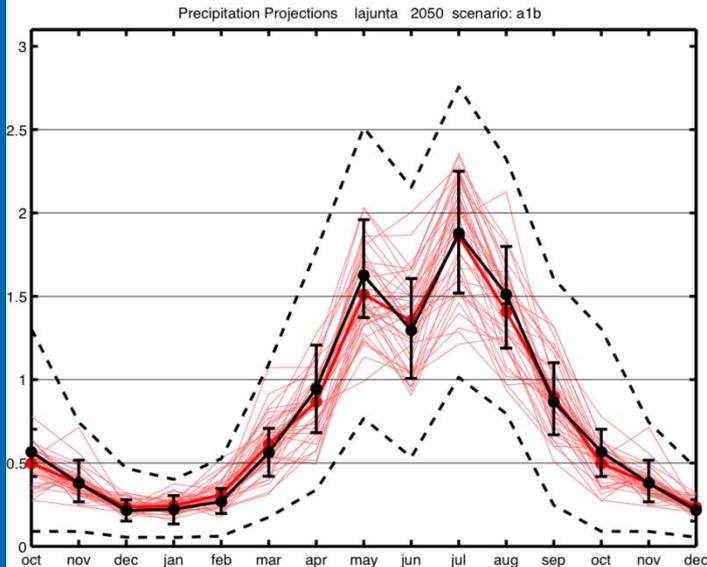


Precipitation will continue to be variable

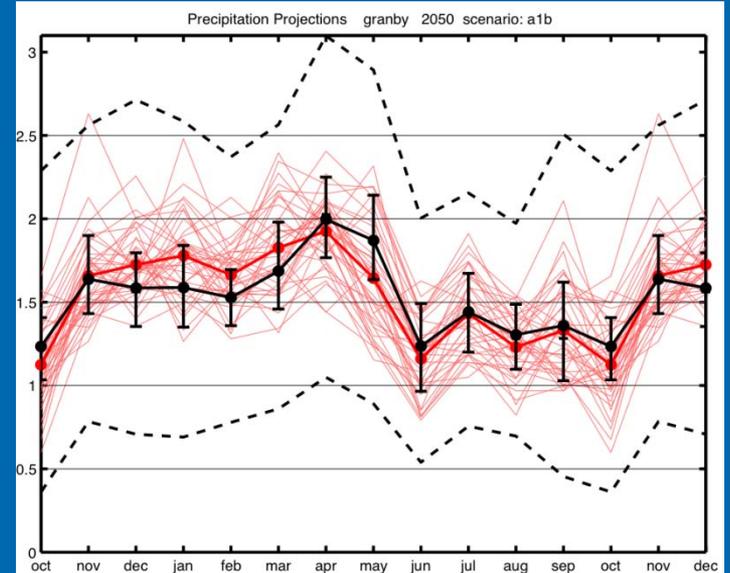
More mid-winter precipitation and less in late spring and summer

Extremes?? Worse floods and drought seems likely

La Junta



Granby



Recap

- Temperature projections (relative to 1950-1999)
 - + 2.5 °F by 2025
 - + 4 °F by 2050
- Precipitation projections
 - Annual precipitation trends uncertain
 - Some agreement on more mid-winter precipitation and less in late spring and summer
- Both temperature and precipitation trends have implications for the hydrologic cycle.



What shall we do?

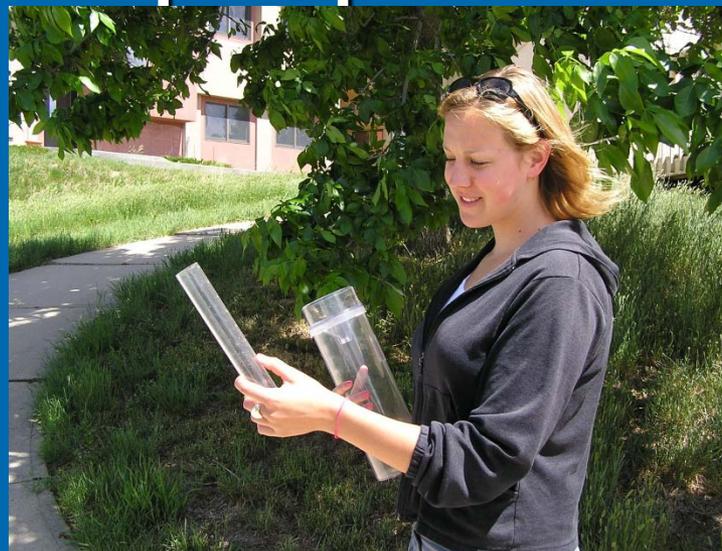
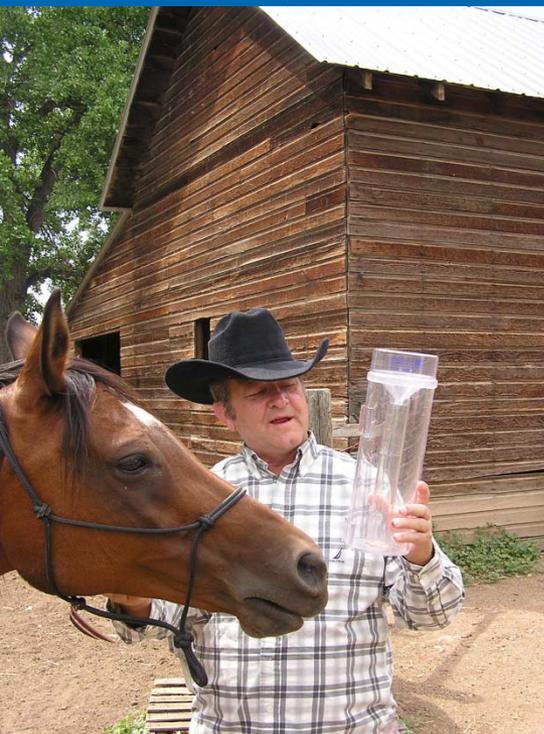
- Changes observed so far have not been dramatic and are similar to other observed climate changes in recent centuries,
 - However, we may not be able to stop the momentum from already rapidly increasing greenhouse gases
 - Hang on == because we're all a part of a crazy global climate experiment
- 

-- - and in the meantime –

We could use your help



We are encouraging citizens across the State and Nation to help us measure local precipitation



Photos by H. Reges

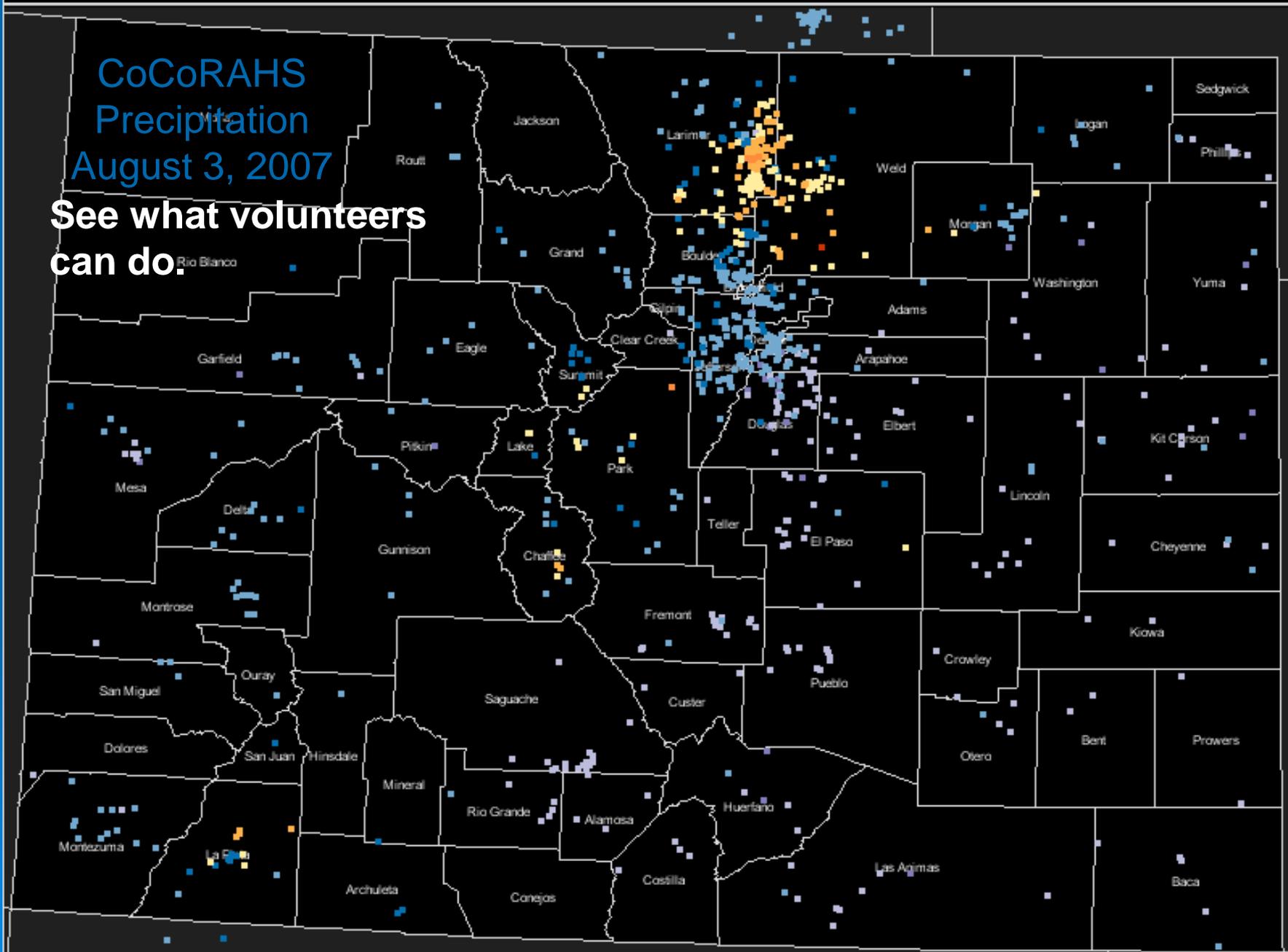
Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am

Colorado 8/3/2007



CoCoRAHS
Precipitation
August 3, 2007

See what volunteers
can do.

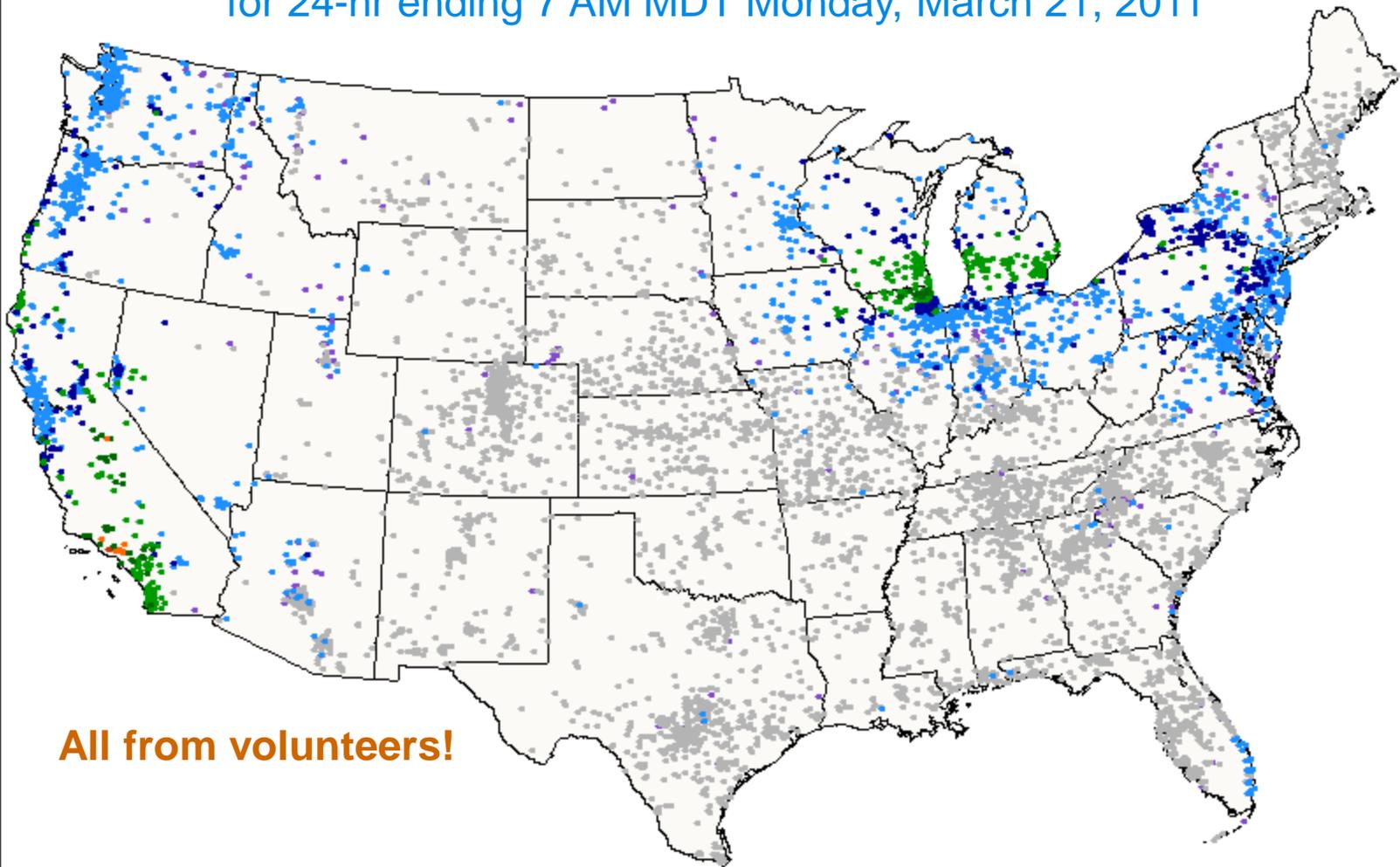


Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am

USA 3/21/2011

0.0 Trace 0.01-0.32 0.33-0.64 0.65-1.62 1.63-3.90 3.91-5.85 5.86-6.50

CoCoRaHS Daily Precipitation for 24-hr ending 7 AM MDT Monday, March 21, 2011



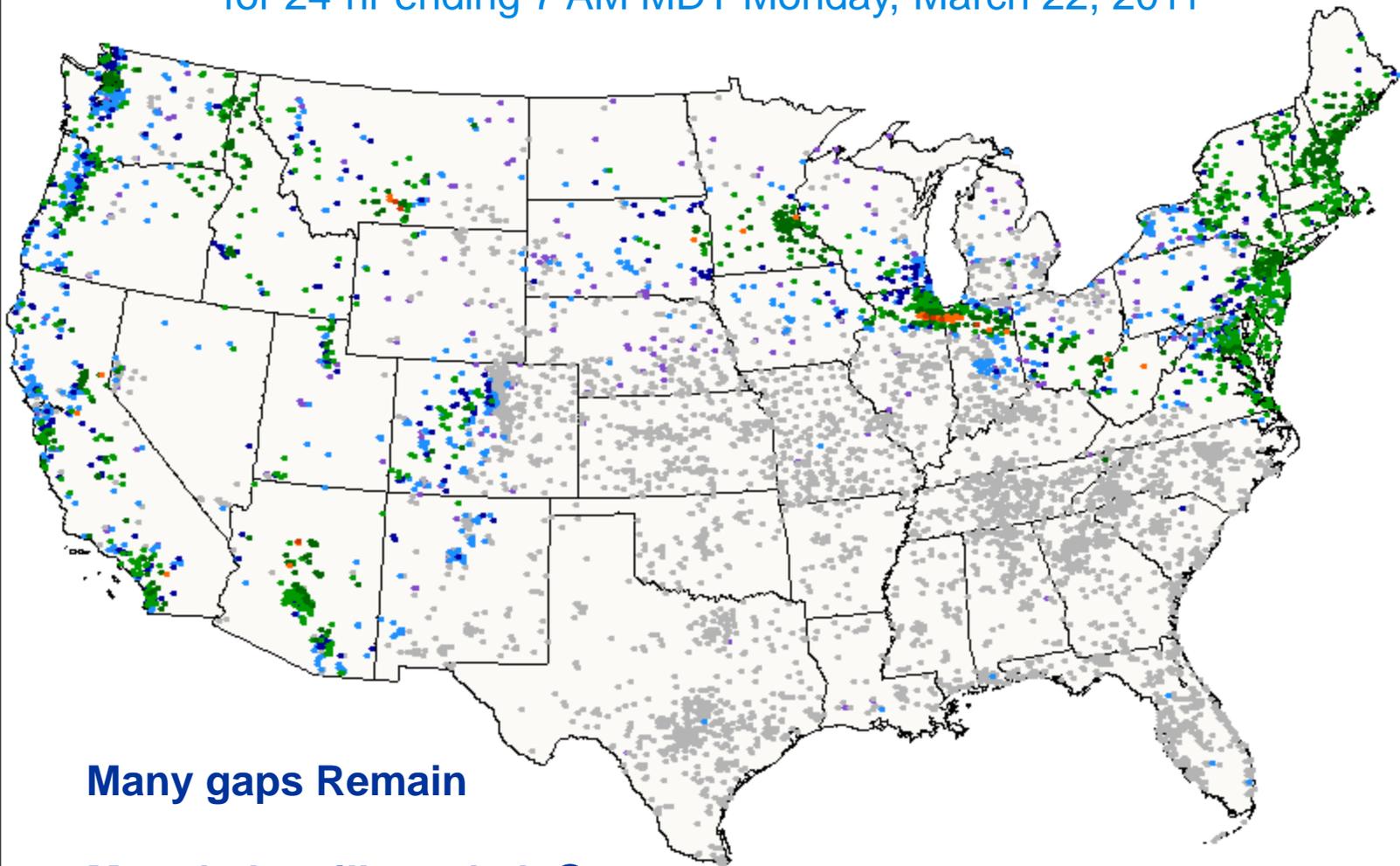
All from volunteers!

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

USA 3/22/2011



CoCoRaHS Daily Precipitation for 24-hr ending 7 AM MDT Monday, March 22, 2011



Many gaps Remain

More help still needed ☺

For information and to volunteer, 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.

2012 Water Celebration

- Colorado will be celebrating water in 2012
- As a part of this statewide “2012 -- Year of Water” celebration, we are encouraging every school in Colorado to help us measure and track precipitation. Because “the weather is our source of water”



We are already finding sponsors
for Colorado's ~1800 Schools

Now we need teachers or
volunteer leaders to serve as
contacts for each participating
school

Colorado Climate Center

Data and Power Point Presentations available for downloading

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

Nolan.Doesken@Colostate.edu

Colorado
State
University
Knowledge to Go Places



**Colorado: It's a great place
but we have to be ready**



Photo by Lynn Kral, Loveland, January 2006