

Climate and Colorado's Water Future

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Colorado State University



Colorado
State
University

2017 Sustainovate Conf.
UCCS

8 March 2017

Colorado Springs, CO

Graphics by Zach Schwalbe



COLORADO
CLIMATE
CENTER



First – Some History of the Colorado Climate Center

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



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 expertise, education and outreach)

Topics for today

- Where our data come from
- Colorado Climate Basics
- Observed trends
 - temperatures
 - growing season length
 - precipitation
 - drought
 - snowpack

Summary

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.

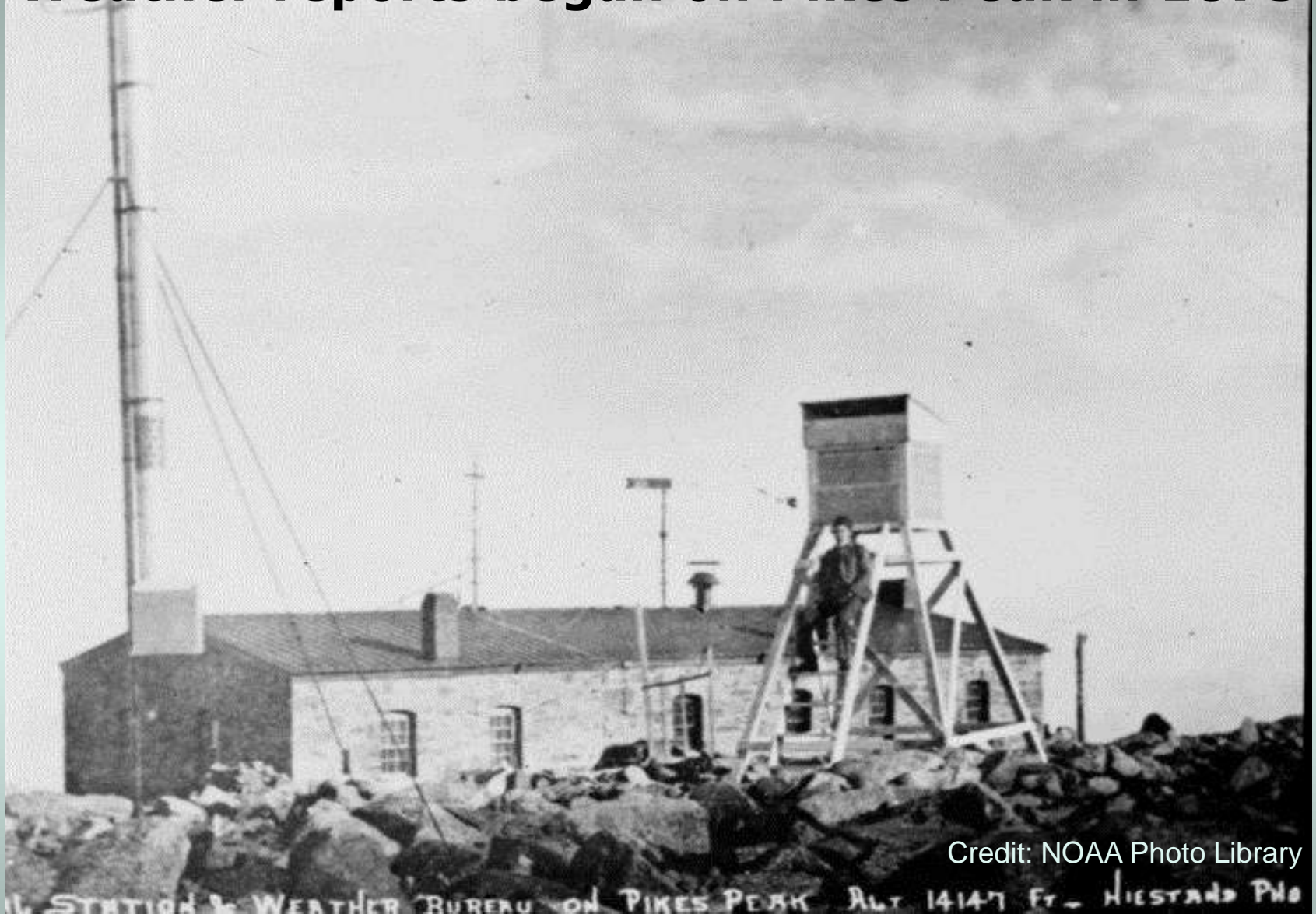
METEOROLOGICAL RECORD for the *Month* ending *Nov. 25th 1871* at *Denver, Col. Ter.*

Date of Observation.	Time of Observation.	Height of Barometer.	Height of attached Thermometers.	Reduced Barometer.	THERMOMETER.		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 come.	Rain (or snow) measured. (Time.)	Rain (or snow) ended. (Time.)	Amount of rain or melted snow.	Remarks.	
					Day.	Night.										
<i>1871</i>																
<i>Sunday Nov 19</i>	<i>5:43 a.m.</i>	<i>25.00</i>	<i>51 50</i>	<i>51.07</i>	<i>22</i>	<i>21</i>	<i>S</i>	<i>0</i>	<i>0</i>	<i>4/4</i>					<i>Light snow</i>	
	<i>2:43 p.m.</i>	<i>25.09</i>	<i>63 50</i>	<i>63.17</i>	<i>30</i>	<i>35</i>	<i>S</i>	<i>2</i>	<i>.02</i>	<i>0</i>					<i>Clear</i>	
	<i>4:43 p.m.</i>	<i>25.13</i>	<i>50 74</i>	<i>50.26</i>	<i>14</i>	<i>15</i>	<i>S</i>	<i>11</i>	<i>.00</i>	<i>0</i>					<i>Clear</i>	
	<i>5:43 a.m.</i>	<i>25.00</i>	<i>57 82</i>	<i>57.07</i>	<i>22</i>	<i>21</i>	<i>S.W.</i>	<i>0</i>	<i>0</i>	<i>4/4</i>					<i>Light snow</i>	
	<i>2:43 p.m.</i>	<i>25.09</i>	<i>63 30</i>	<i>63.17</i>	<i>34</i>	<i>30</i>	<i>S</i>	<i>2</i>	<i>.03</i>	<i>0</i>	<i>12</i>				<i>Clear</i>	
<i>Monday Nov 20</i>	<i>4:43 p.m.</i>	<i>25.18</i>	<i>50 74</i>	<i>50.26</i>	<i>14</i>	<i>15</i>	<i>S</i>	<i>11</i>	<i>.00</i>	<i>0</i>					<i>Clear</i>	
	<i>5:43 a.m.</i>	<i>24.99</i>	<i>50 31</i>	<i>50.06</i>	<i>31</i>	<i>19</i>	<i>S</i>	<i>13</i>	<i>.04</i>	<i>4/4</i>	<i>24</i>				<i>Stratus</i>	
	<i>2:43 p.m.</i>	<i>24.67</i>	<i>50 43</i>	<i>49.67</i>	<i>43</i>	<i>34</i>	<i>N.W.</i>	<i>10</i>	<i>1.62</i>	<i>4/4</i>	<i>103</i>				<i>Stratus</i>	
<i>Tuesday Nov 21</i>	<i>4:43 p.m.</i>	<i>24.80</i>	<i>50 39</i>	<i>49.70</i>	<i>39</i>	<i>34</i>	<i>N.W.</i>	<i>5</i>	<i>.02</i>	<i>4/4</i>	<i>943</i>				<i>Stratus</i>	
	<i>5:43 a.m.</i>	<i>24.70</i>	<i>55 31</i>	<i>54.59</i>	<i>34</i>	<i>29</i>	<i>S.W.</i>	<i>4</i>	<i>.00</i>	<i>4/4</i>	<i>97</i>				<i>Stratus</i>	
	<i>2:43 p.m.</i>	<i>24.37</i>	<i>62 33</i>	<i>62.50</i>	<i>35</i>	<i>32</i>	<i>W</i>	<i>2</i>	<i>.02</i>	<i>4/4</i>	<i>97</i>				<i>"</i>	
<i>Wednesday Nov 22</i>	<i>4:43 p.m.</i>	<i>24.71</i>	<i>61 31</i>	<i>61.59</i>	<i>31</i>	<i>30</i>	<i>S</i>	<i>10</i>	<i>.00</i>	<i>4/4</i>	<i>32.3</i>	<i>8 a.m.</i>		<i>24</i>	<i>Light snow</i>	
	<i>5:43 a.m.</i>	<i>24.54</i>	<i>55 35</i>	<i>54.67</i>	<i>35</i>	<i>31</i>	<i>S</i>	<i>6</i>	<i>.08</i>	<i>4/4</i>	<i>90</i>	<i>10:30 a.m.</i>			<i>Stratus</i>	
	<i>2:43 p.m.</i>	<i>24.31</i>	<i>63 34</i>	<i>63.06</i>	<i>34</i>	<i>35</i>	<i>N.W.</i>	<i>5</i>	<i>.13</i>	<i>4/4</i>	<i>30</i>				<i>Clear</i>	
<i>Thursday Nov 23</i>	<i>4:43 p.m.</i>	<i>24.20</i>	<i>60 31</i>	<i>60.97</i>	<i>31</i>	<i>30</i>	<i>S</i>	<i>7</i>	<i>.40</i>	<i>3/4</i>	<i>25</i>				<i>"</i>	
	<i>5:43 a.m.</i>	<i>24.36</i>	<i>56 32</i>	<i>56.17</i>	<i>32</i>	<i>32</i>	<i>S.W.</i>	<i>4</i>	<i>.08</i>	<i>4/4</i>	<i>101</i>		<i>8 a.m.</i>	<i>31</i>	<i>Cloudy</i>	
	<i>2:43 p.m.</i>	<i>24.37</i>	<i>70 42</i>	<i>70.04</i>	<i>42</i>	<i>37</i>	<i>S</i>	<i>2</i>	<i>.02</i>	<i>4/4</i>	<i>33.7</i>				<i>Light snow</i>	
<i>Friday Nov 24</i>	<i>4:43 p.m.</i>	<i>24.38</i>	<i>65 27</i>	<i>65.23</i>	<i>27</i>	<i>27</i>	<i>N.W.</i>	<i>2</i>	<i>.02</i>	<i>4/4</i>					<i>Light snow</i>	
	<i>5:43 a.m.</i>	<i>24.37</i>	<i>58 32</i>	<i>57.17</i>	<i>32</i>	<i>28</i>	<i>S.W.</i>	<i>7</i>	<i>.24</i>	<i>4/4</i>	<i>98</i>				<i>Stratus</i>	
	<i>2:43 p.m.</i>	<i>24.42</i>	<i>70 49</i>	<i>70.00</i>	<i>49</i>	<i>39</i>	<i>S.E.</i>	<i>2</i>	<i>.02</i>	<i>4/4</i>	<i>32.7</i>				<i>Light snow</i>	
<i>Saturday Nov 25</i>	<i>4:43 p.m.</i>	<i>24.60</i>	<i>68 17</i>	<i>68.40</i>	<i>17</i>	<i>15</i>	<i>N.E.</i>	<i>18</i>	<i>1.62</i>	<i>3/4</i>					<i>Light snow</i>	

1871

Denver November 19-25, 1871 *Wm. Taylor, Observer*

Weather reports began on Pikes Peak in 1873



Credit: NOAA Photo Library

Reports were sent by telegraph every few hours

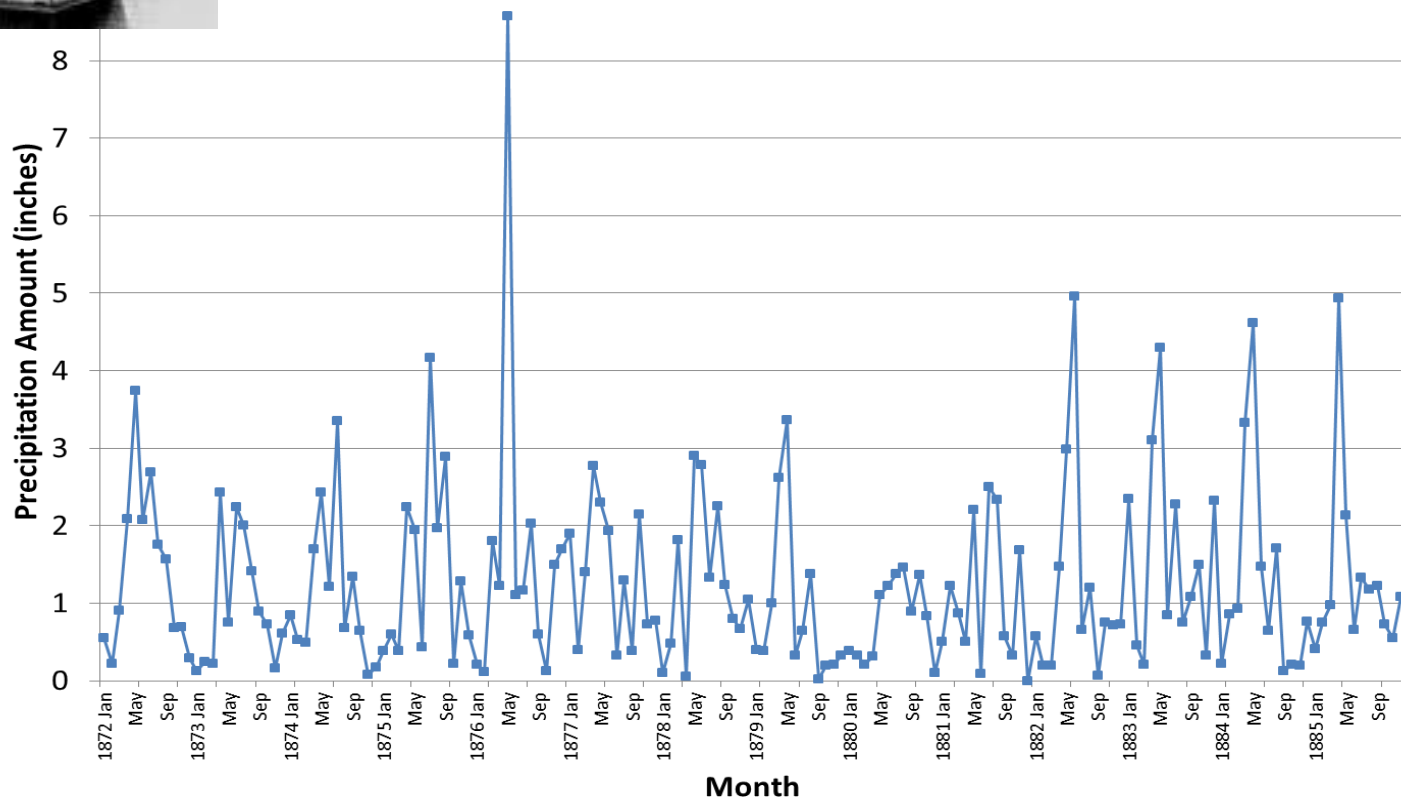
Stories abounded in the national media of the rigors of Colorado Climate


By 1885 initial "climatology" of Colorado was taking shape

The semiarid and highly variable nature of Colorado was identified quickly -- in many ways similar to today..



Denver Monthly Precipitation (1872 - 1885)

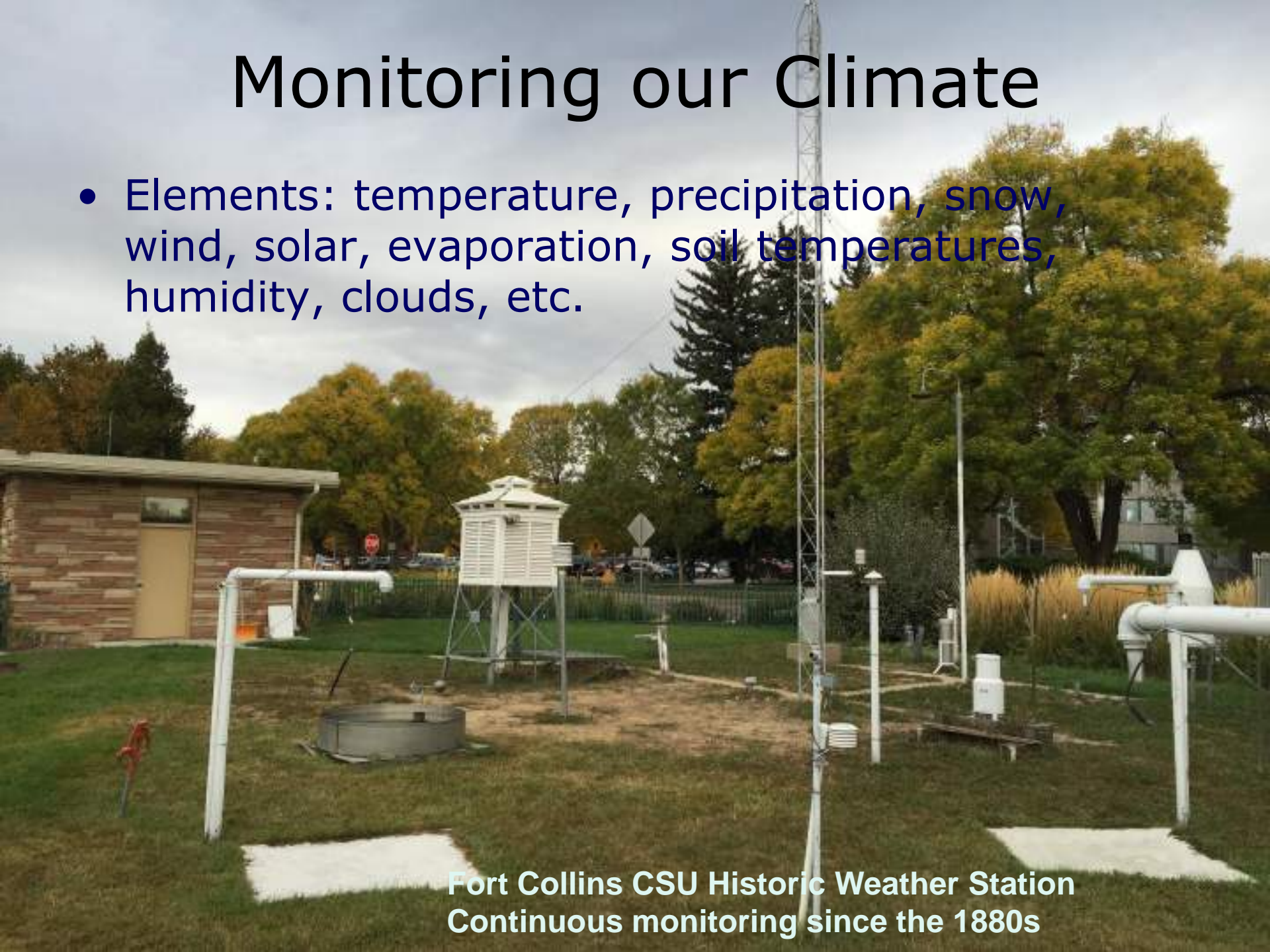




Thanks to the National Weather Service for
faithfully maintaining the Cooperative
Observer Network since 1890
Our historic baseline for temperature and
precipitation

Monitoring our Climate

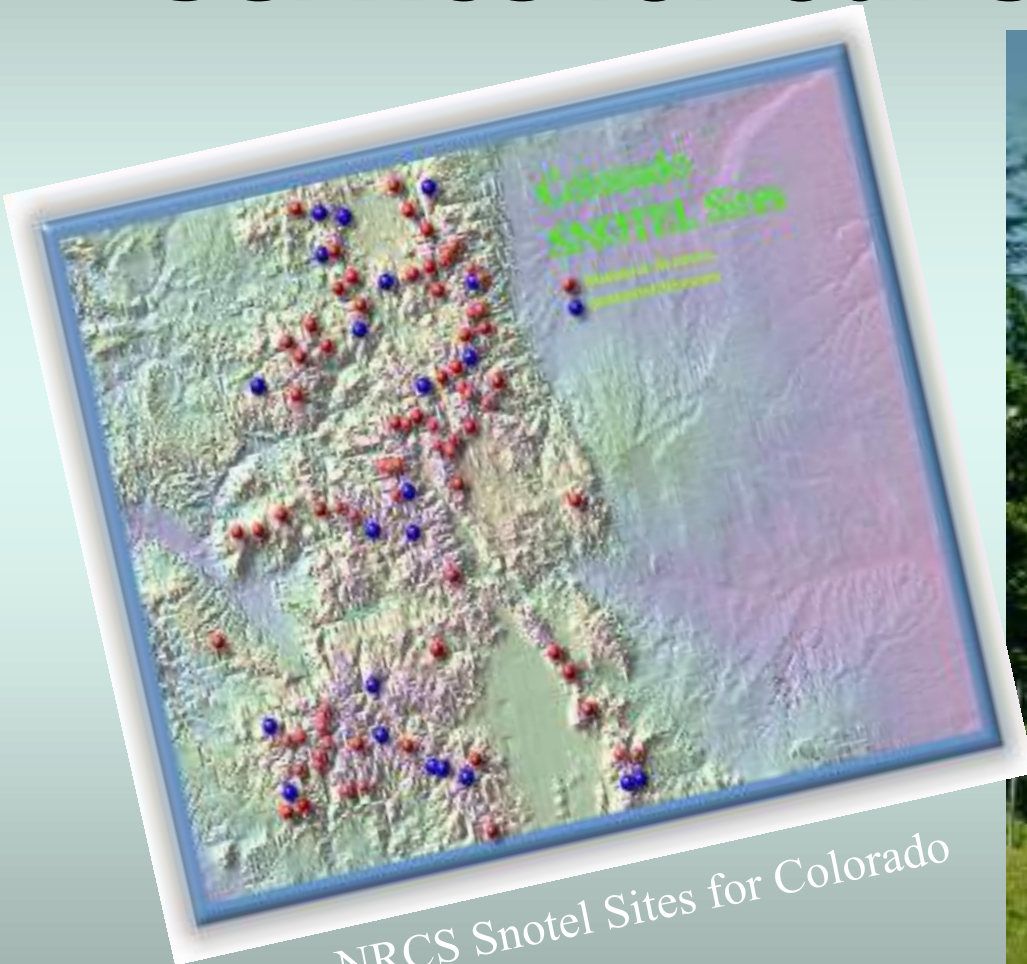
- Elements: temperature, precipitation, snow, wind, solar, evaporation, soil temperatures, humidity, clouds, etc.



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

The map displays the contiguous United States and four insets. The main map is color-coded by region: West (pink), North Central (purple), South Central (yellow), and East (brown). Red squares indicate sampling locations. The insets show Alaska (green), Puerto Rico (brown), Pacific Islands (blue), and Hawaii (green).

Thanks to the USDA Natural Resources Conservation Service for our snow data



NRCS Snotel Sites for Colorado



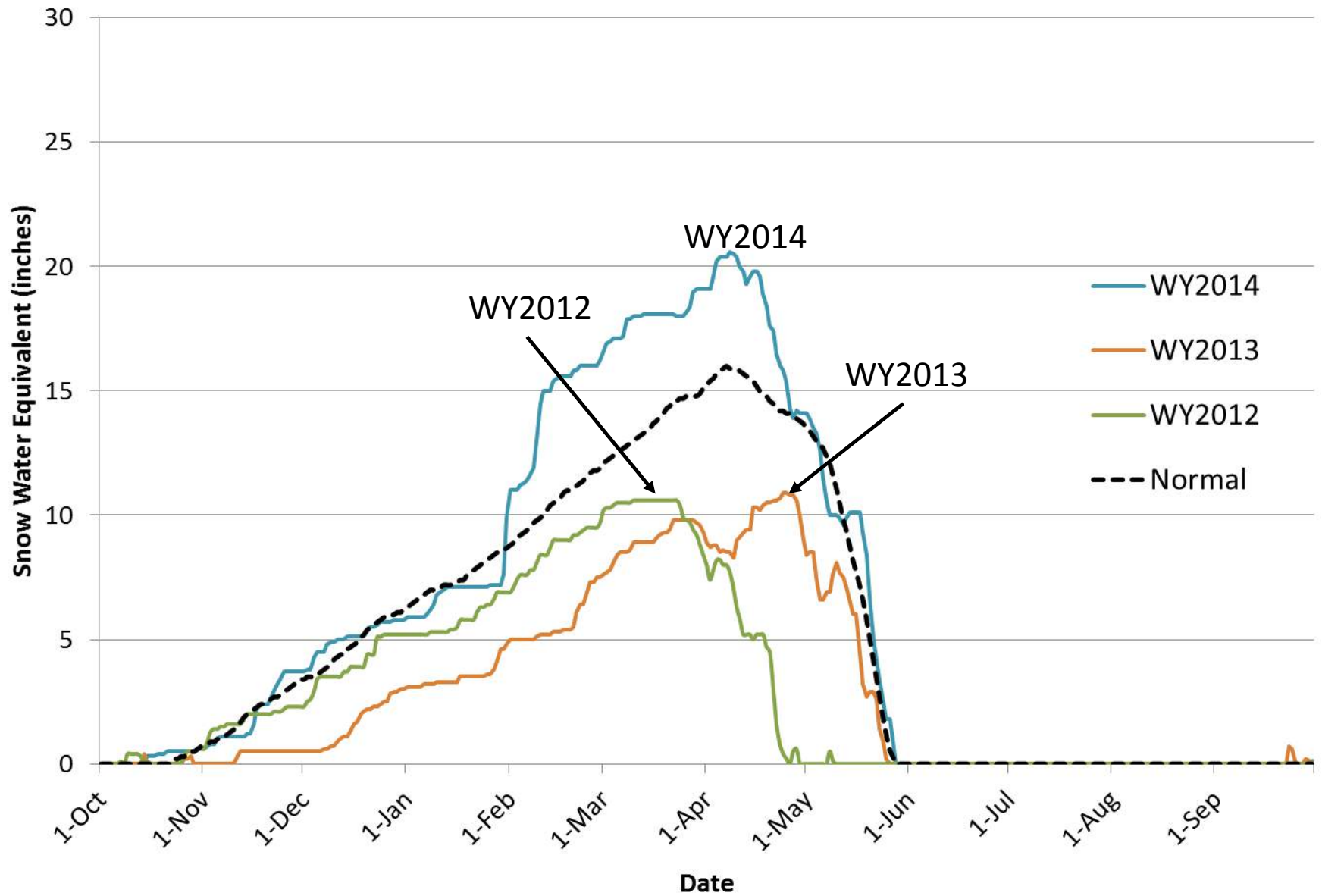
Typical NRCS Snotel Site

Snow surveys began in the 1930s to help predict seasonal streamflow

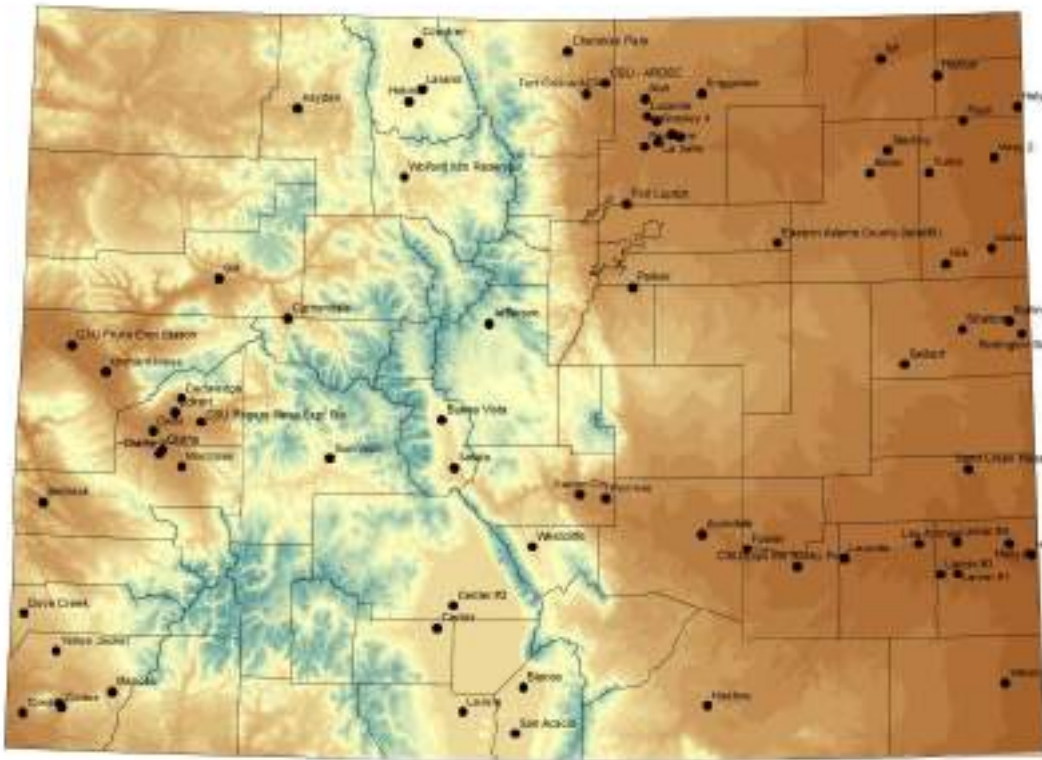


Credit: NOAA Photo Library

Porpyry Creek Snotel Daily Snow Water Equivalent

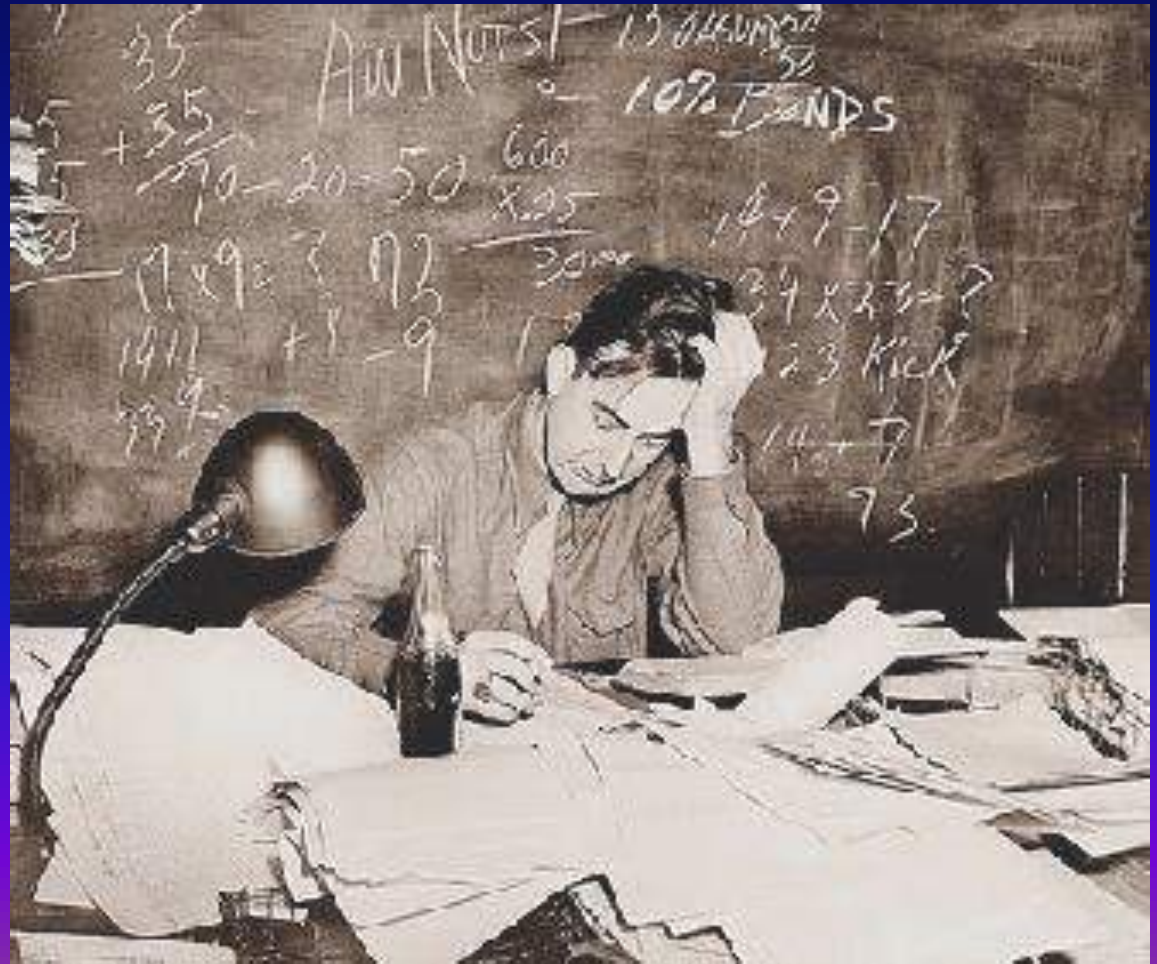


CSU's Colorado Agricultural Meteorological Network "CoAgMet"



**THANKS!! to those of
You who help support
CoAgMet**

The DATA help tell the STORY
of what we think our climate is



So let's step back



Where we are on the planet controls much about our climate



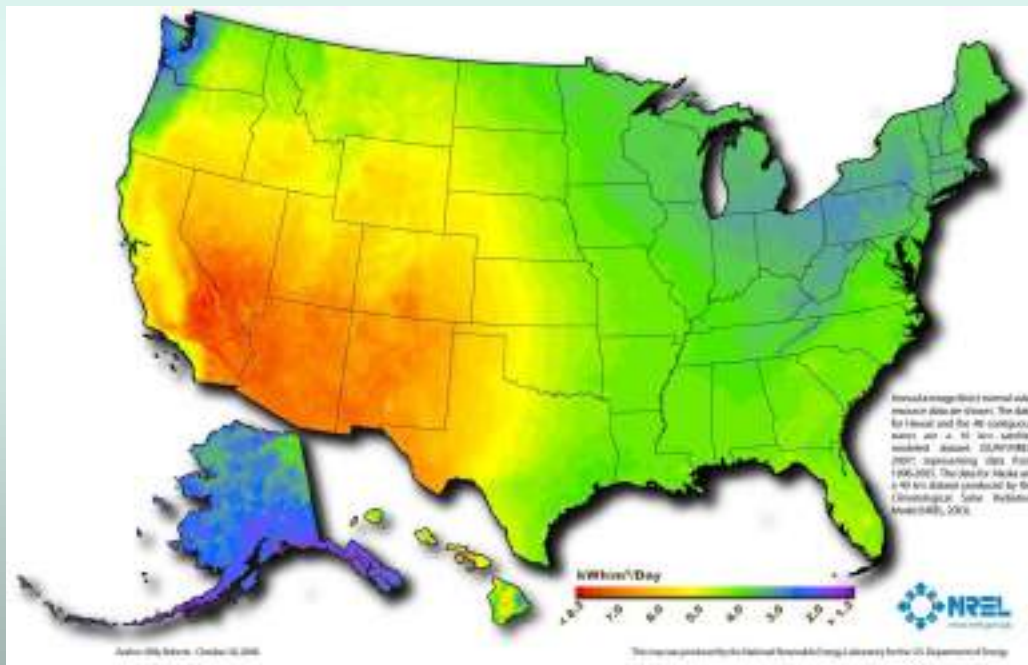
What Makes Our Colorado Climate

- High elevation (highest state by far)
- Mid-Latitude location (lively seasonal changes)
- Interior Continental Location far from moisture sources
- Complex Mountain topography
- Solar energy and seasonal cycles drive our climate

**What have we
learned from 125
years of continuous
climate monitoring?**

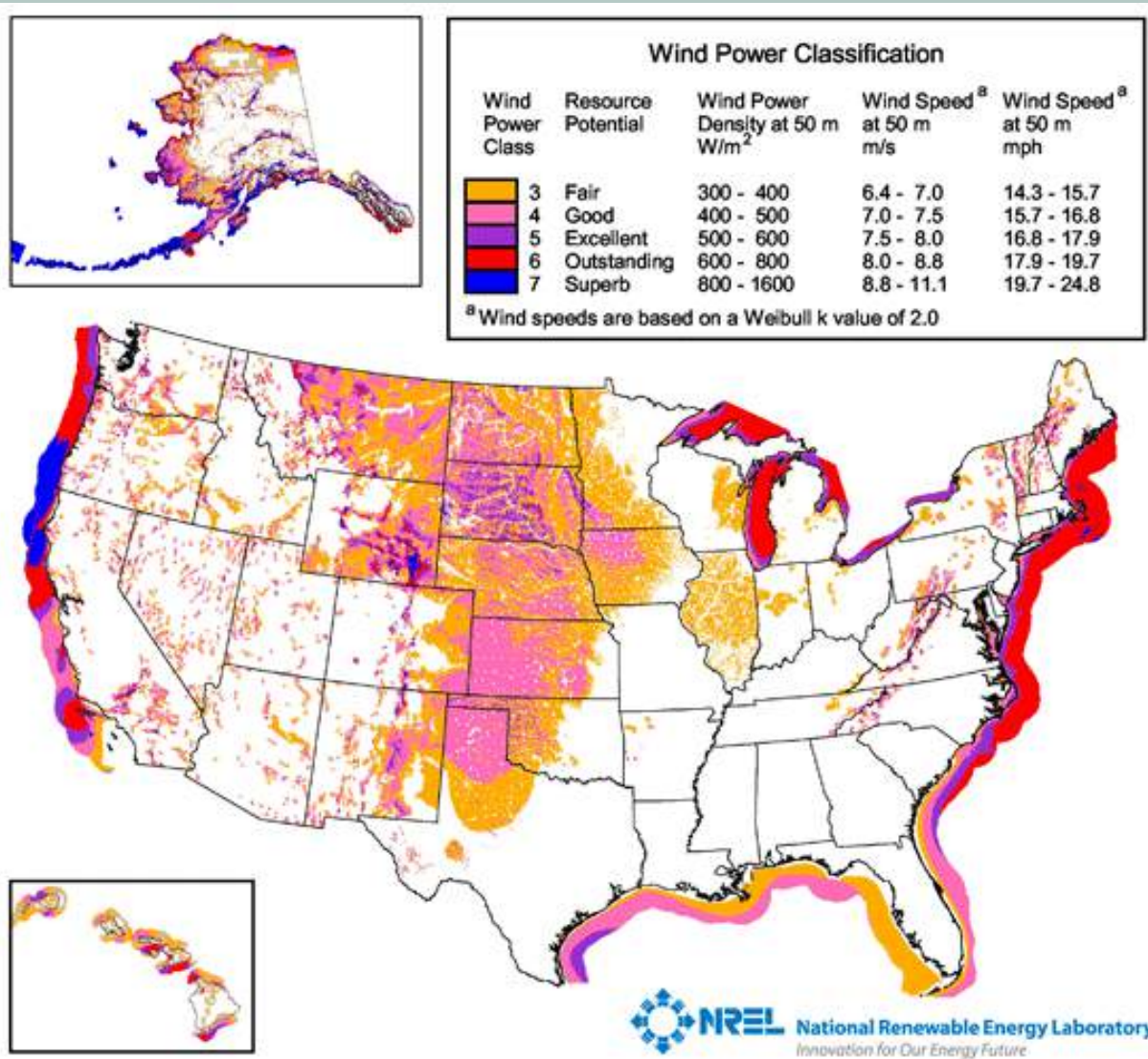


**Colorado is a sunny place.
People like sunshine!
So does vegetation – to a point.**



National Renewable Energy Laboratory: www.nrel.gov

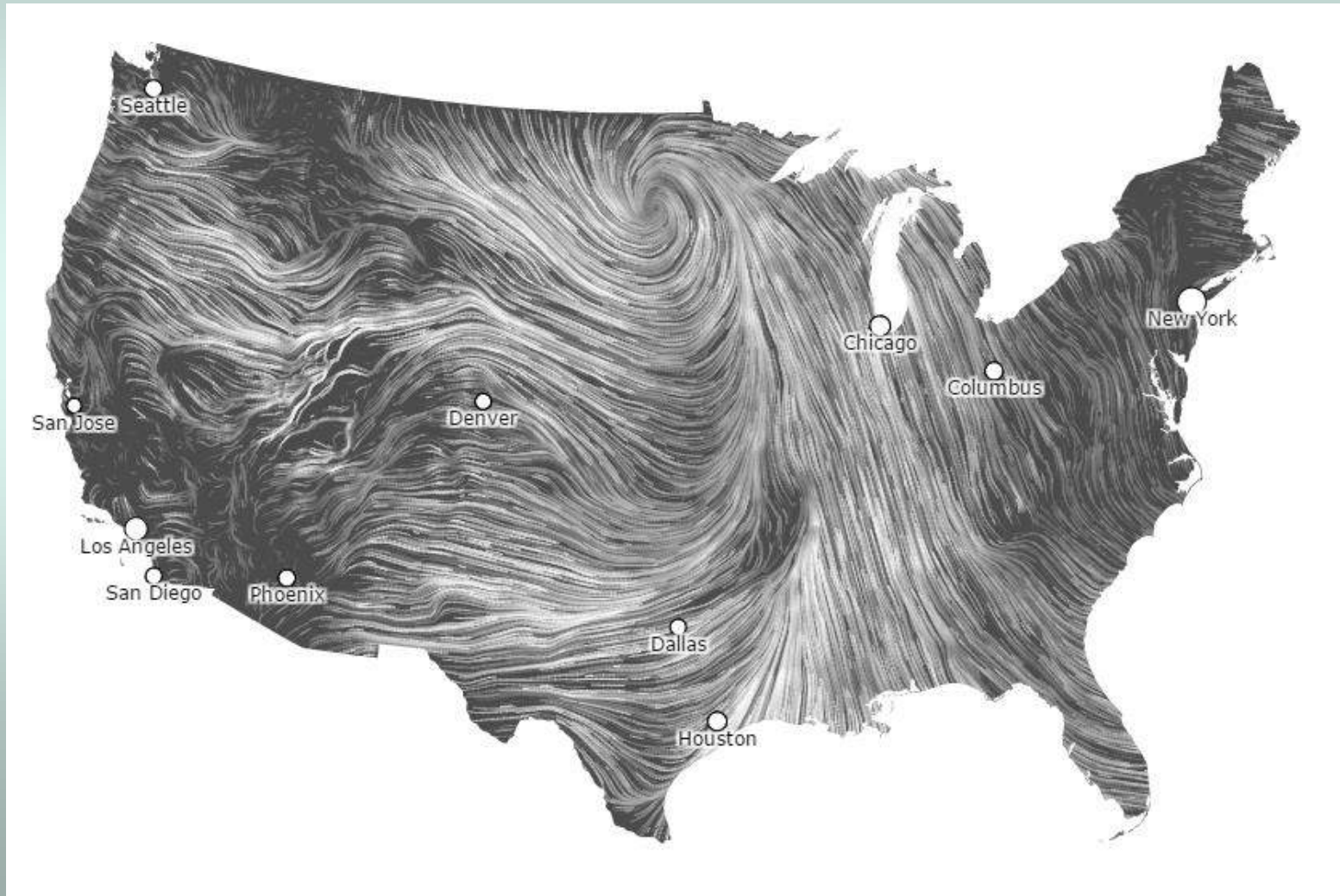
The winds blow, but not as much as some places



Nov. 28, 2016 winds

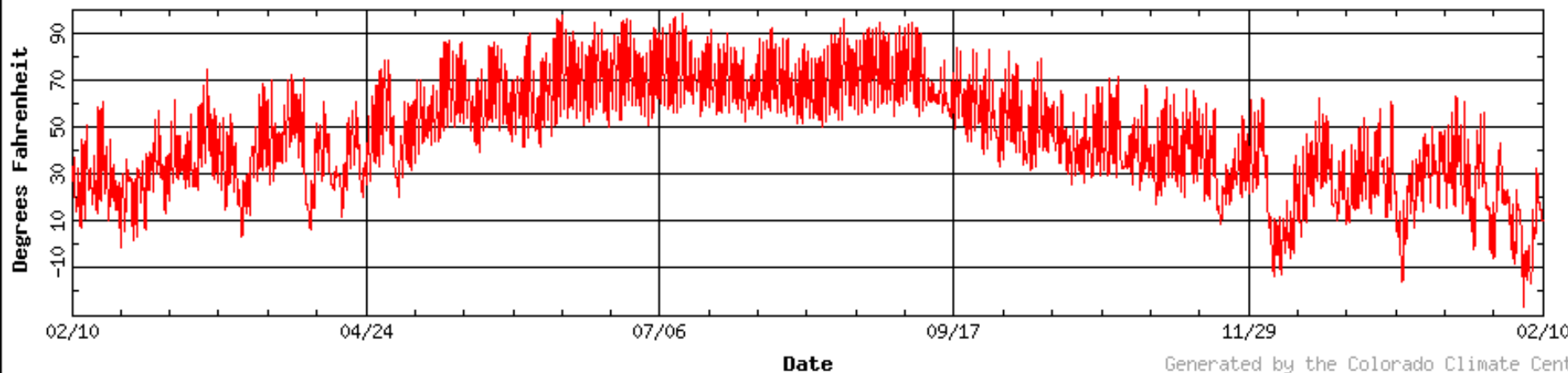
For meteorological entertainment

<http://hint.fm/wind/index.html>



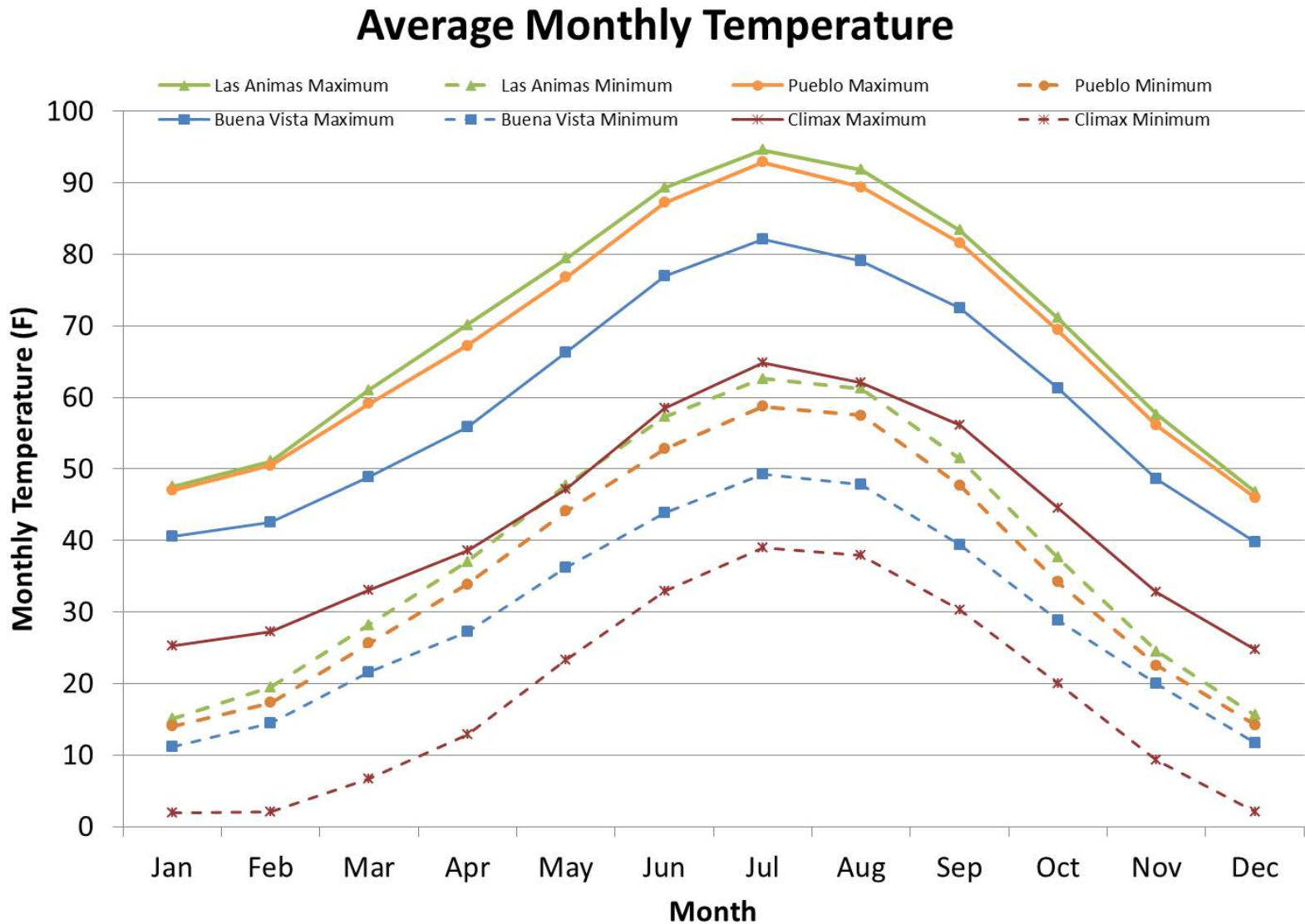


Temperature for GLY84 (02-10-2013 - 02-10-2014)

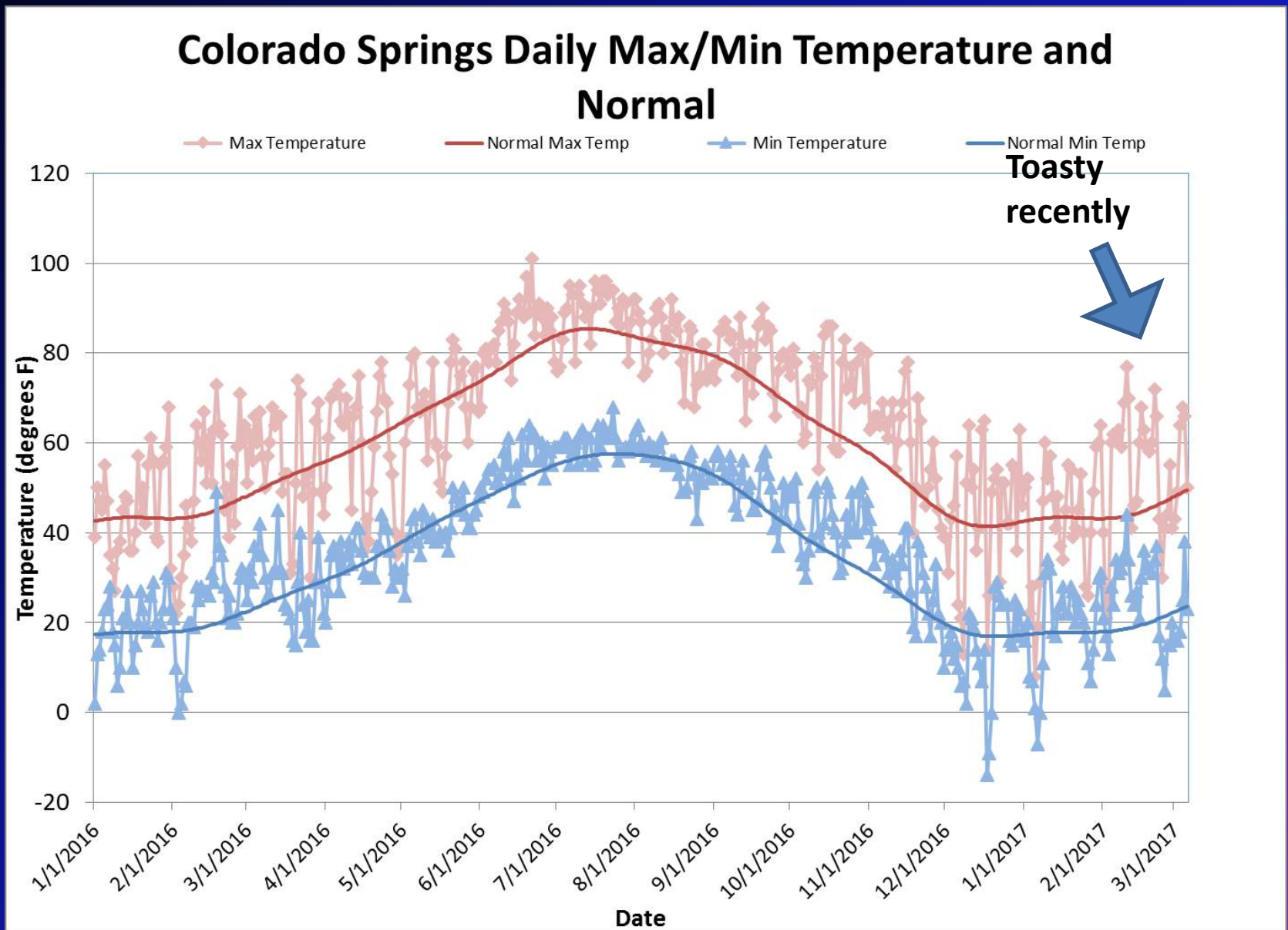


**We always experience large
seasonal and diurnal
temperature variations**

The annual cycle of Colorado Temperatures

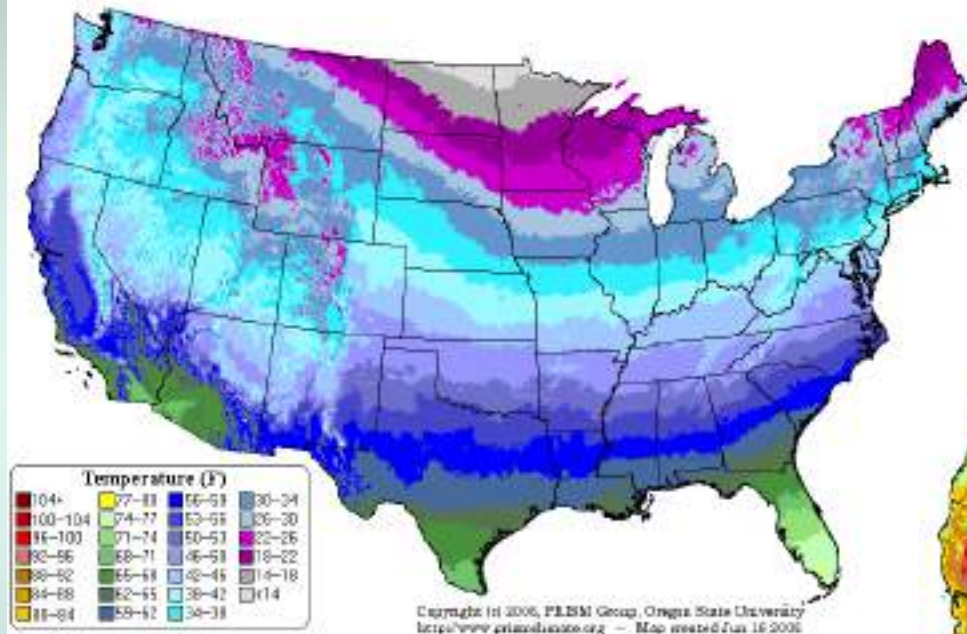


But this is how daily weather, over time, defines our climate

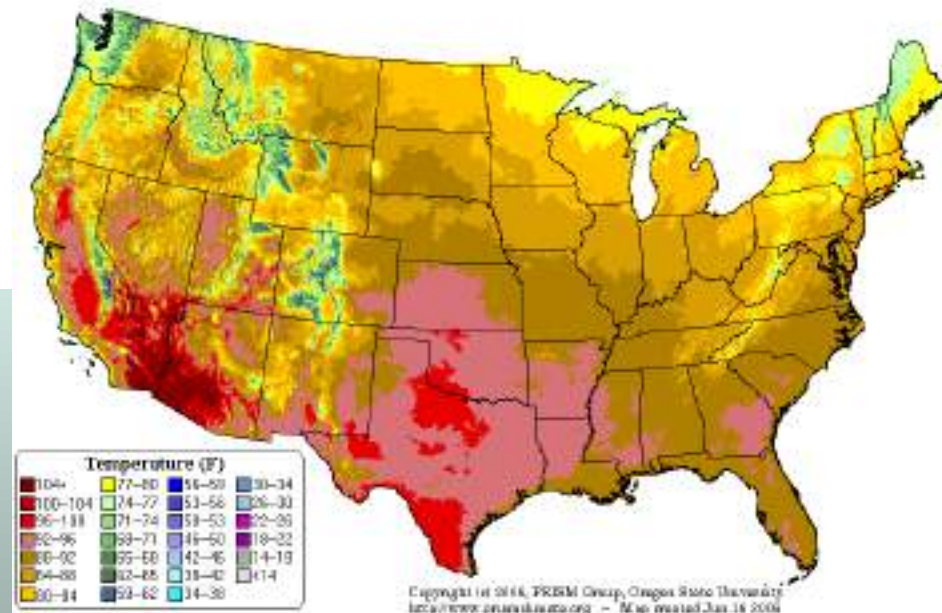


Complex temperature variations due to elevation and topography

Maximum Temperatures January Climatology (1971–2000)



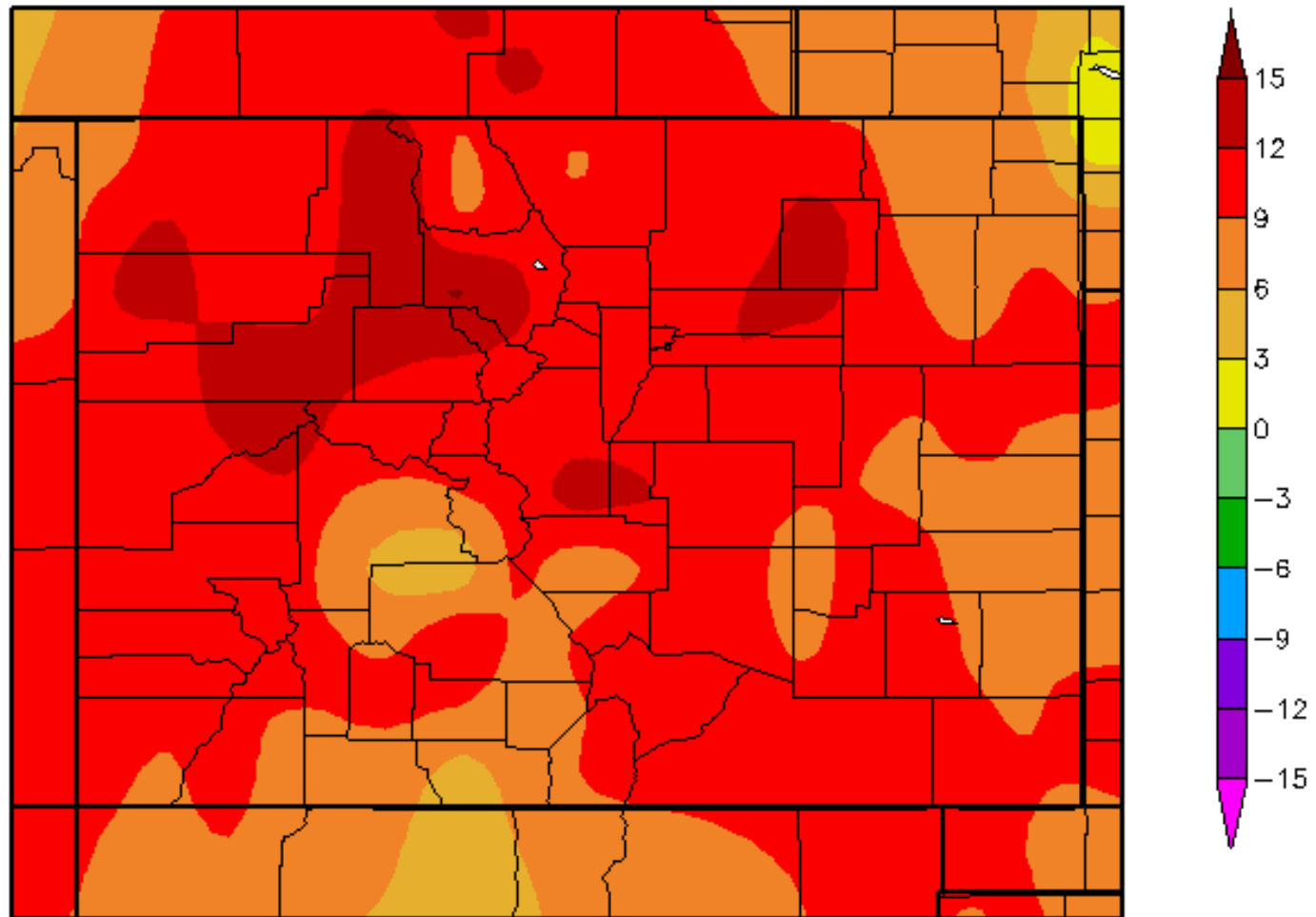
Maximum Temperature: July Climatology (1971–2000)



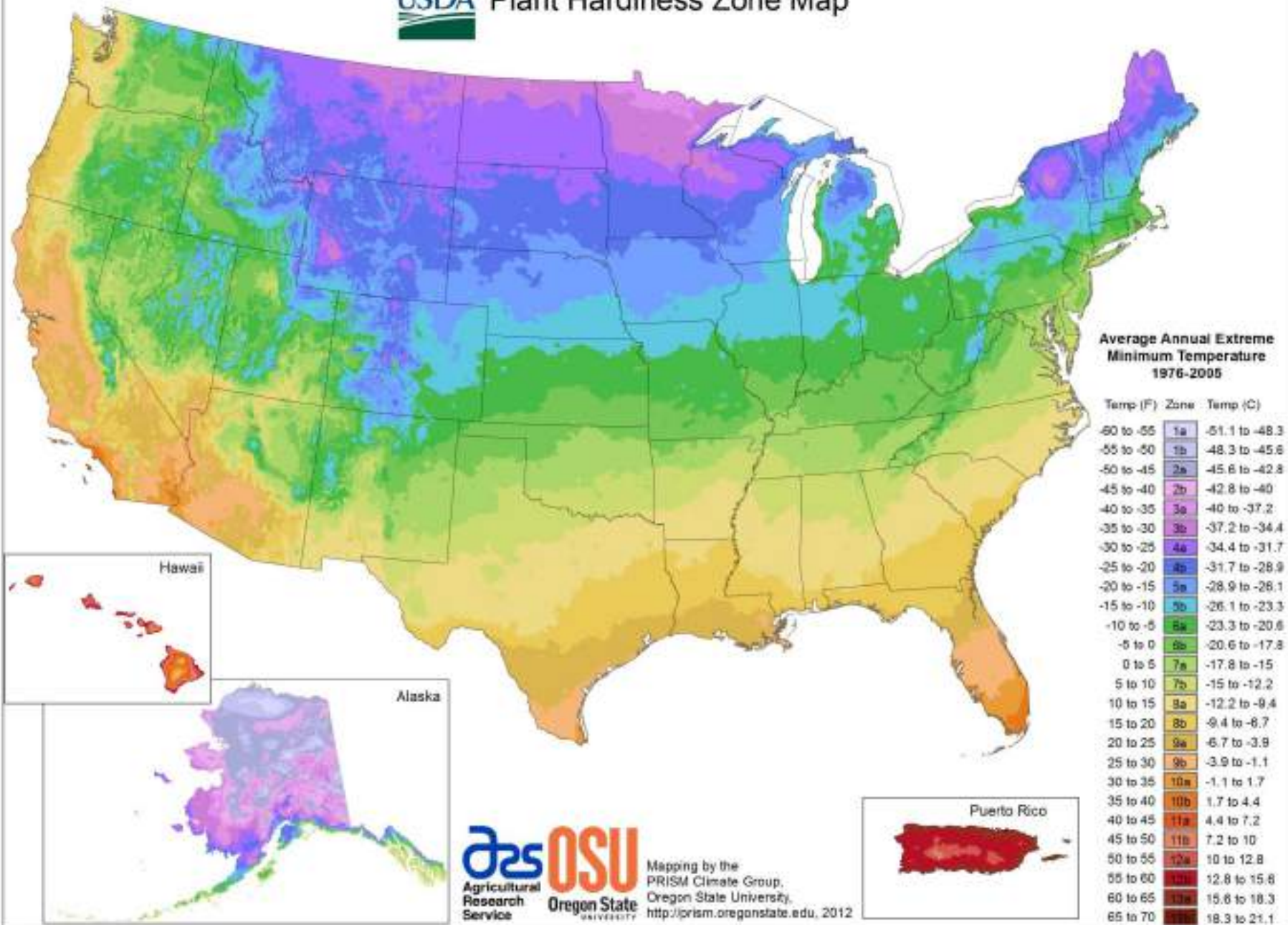
Usually colder in the mountains!

With some nice anomalies from time to time

Departure from Normal Temperature (F)
2/1/2017 – 2/19/2017



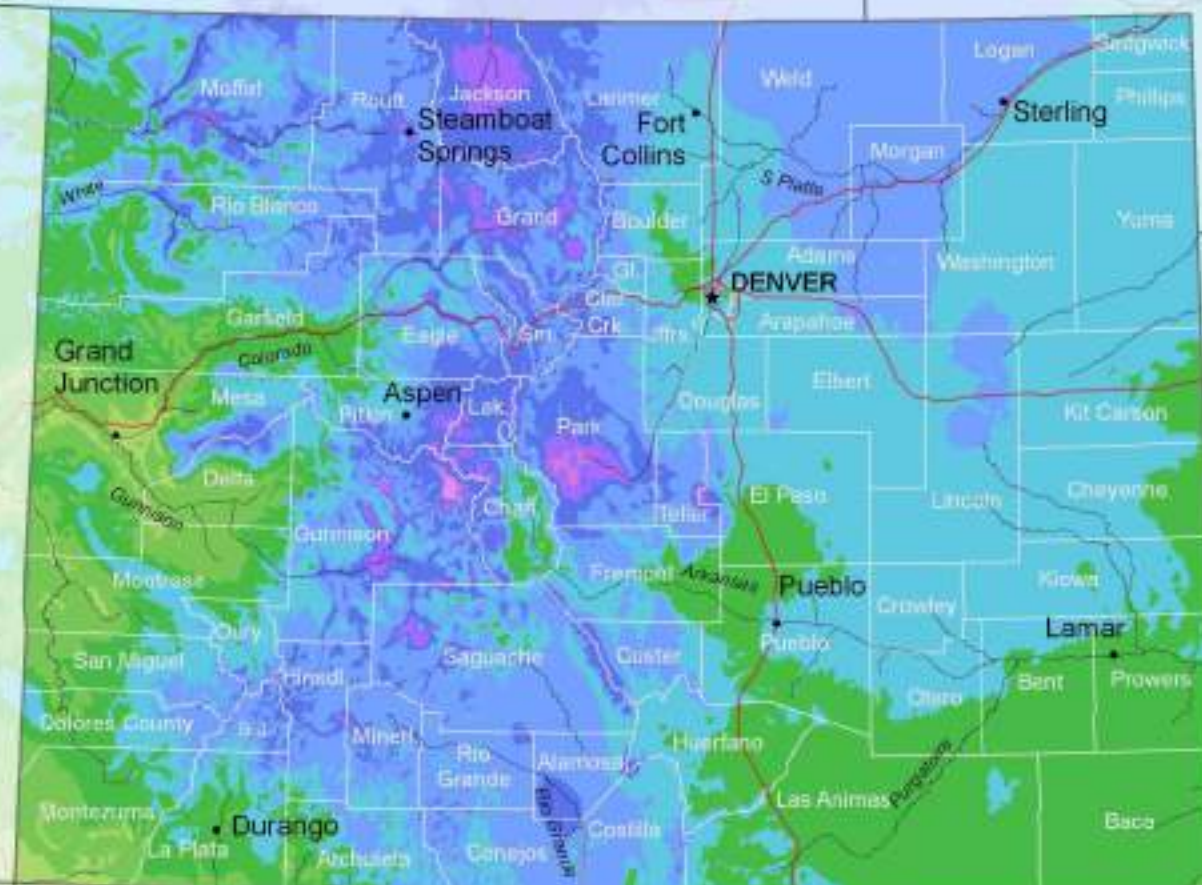
USDA Plant Hardiness Zone Map



USDA Plant Hardiness Zone Map
Colorado

Average Annual Extreme
Minimum Temperature
1976-2005

Temp (F)	Zone	Temp (C)
-40 to -35	3a	-40 to -37.2
-35 to -30	3b	-37.2 to -34.4
-30 to -25	4a	-34.4 to -31.7
-25 to -20	4b	-31.7 to -28.9
-20 to -15	5a	-28.9 to -26.1
-15 to -10	5b	-26.1 to -23.3
-10 to -5	6a	-23.3 to -20.6
-5 to 0	6b	-20.6 to -17.8
0 to 5	7a	-17.8 to -15



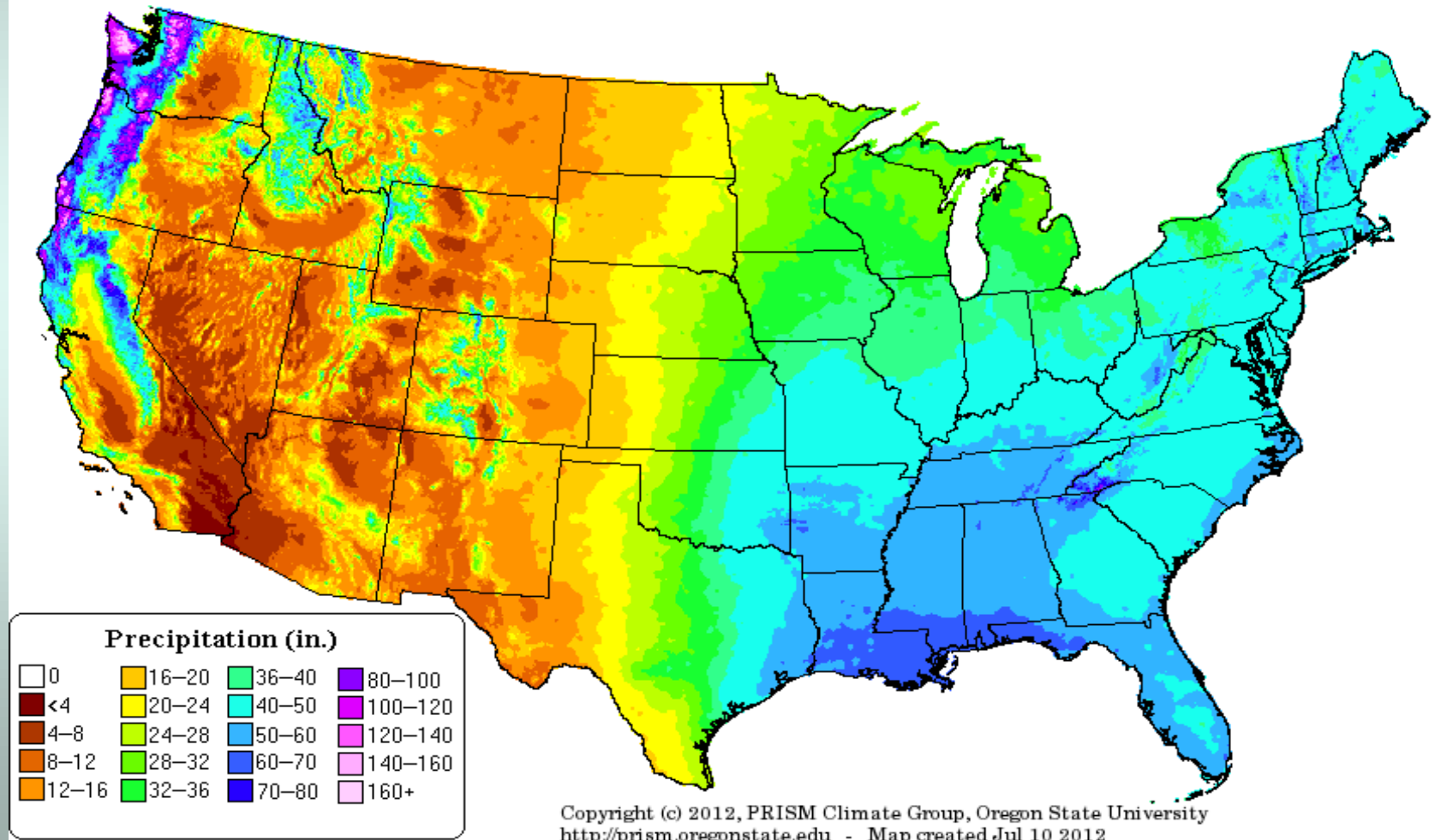
0 15 30 60 Miles
0 25 50 100 Kilometers

OSU
Oregon State University
Agricultural Research Service

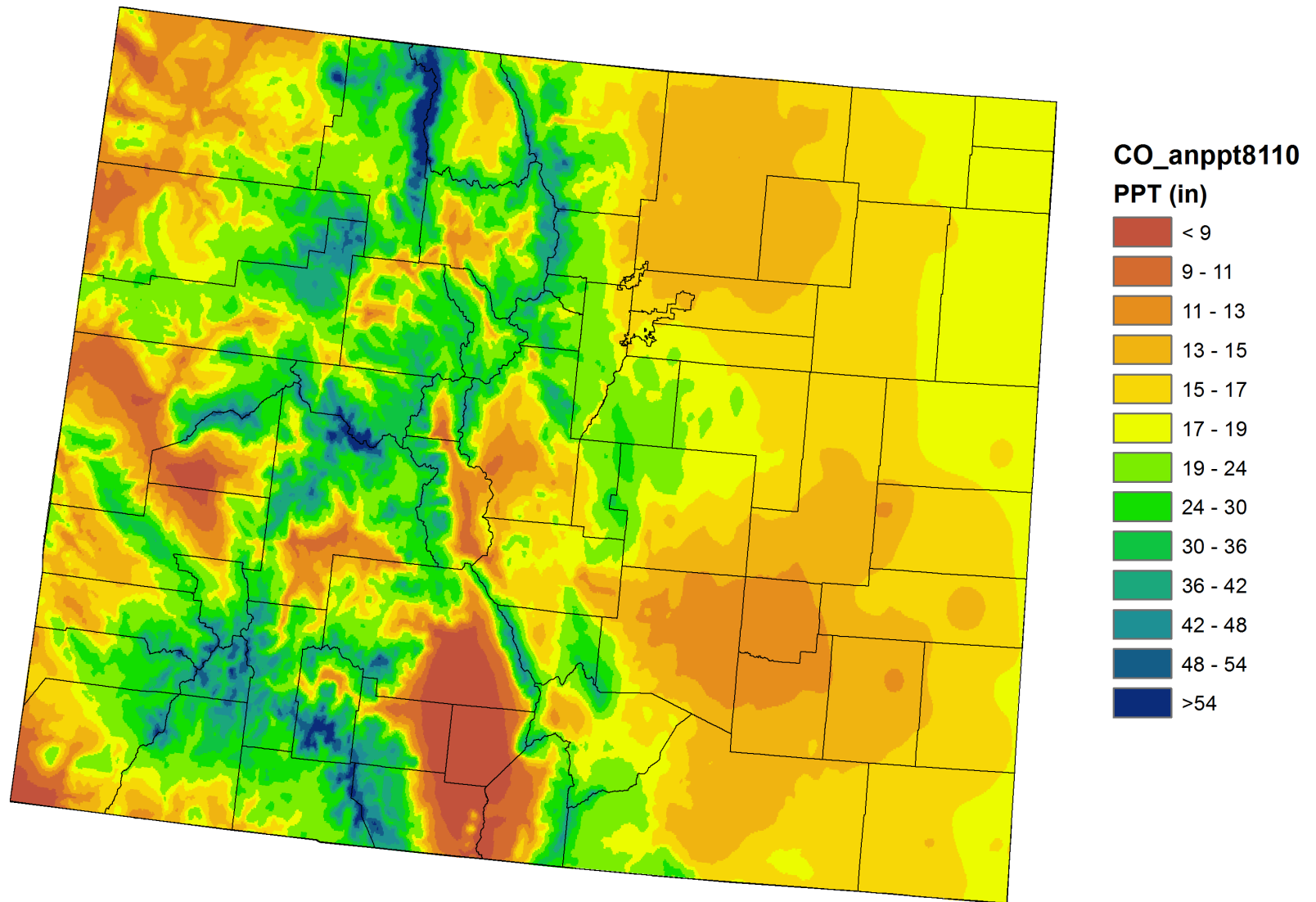
Mapping by the
PRISM Climate Group
Oregon State University

We get rain and snow – but often not enough

Precipitation: Annual Climatology (1981-2010)

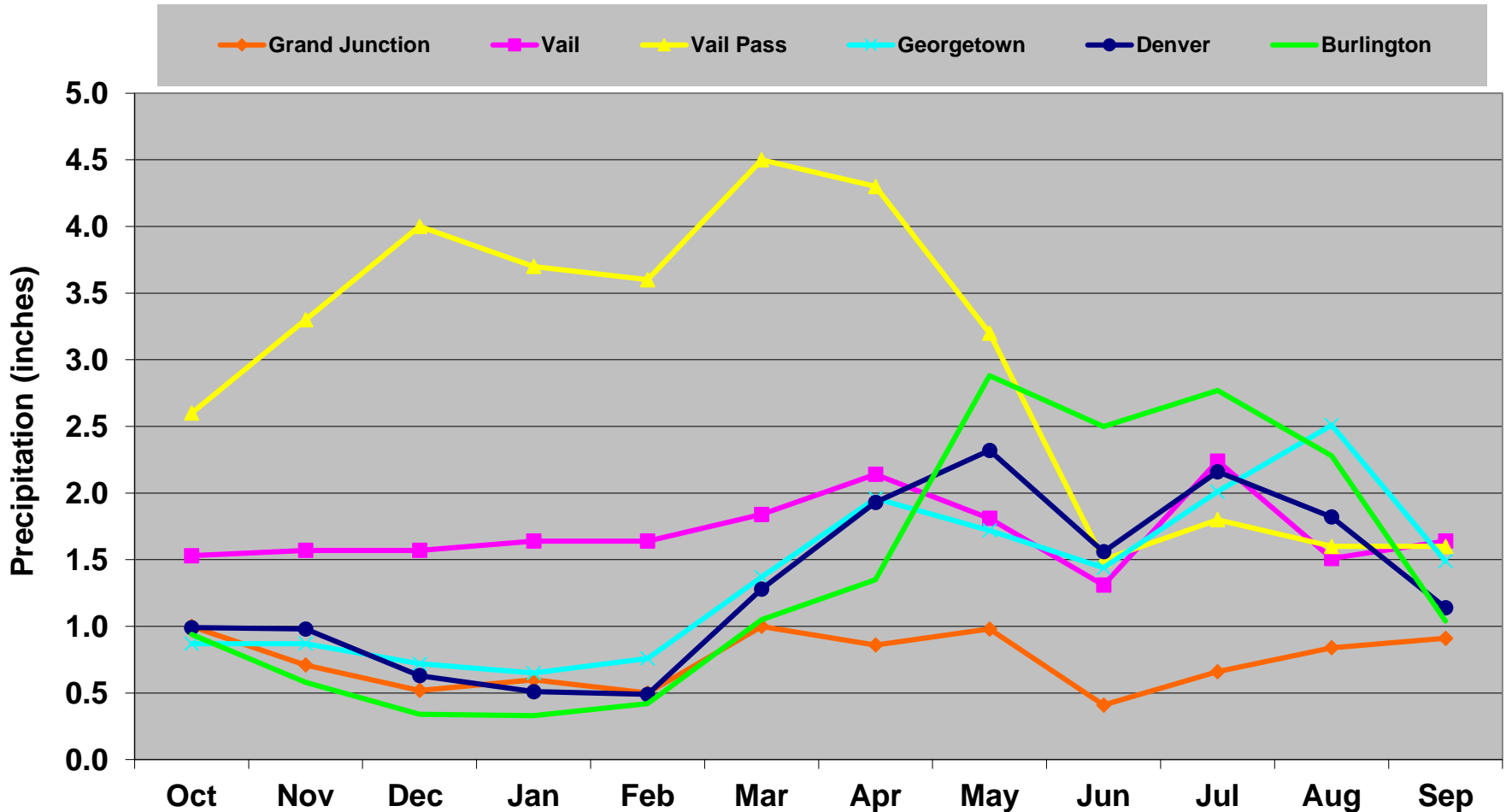


Colorado Annual Average Precipitation (in) 1981-2010



Seasonal Precipitation in Colorado varies greatly from place to place

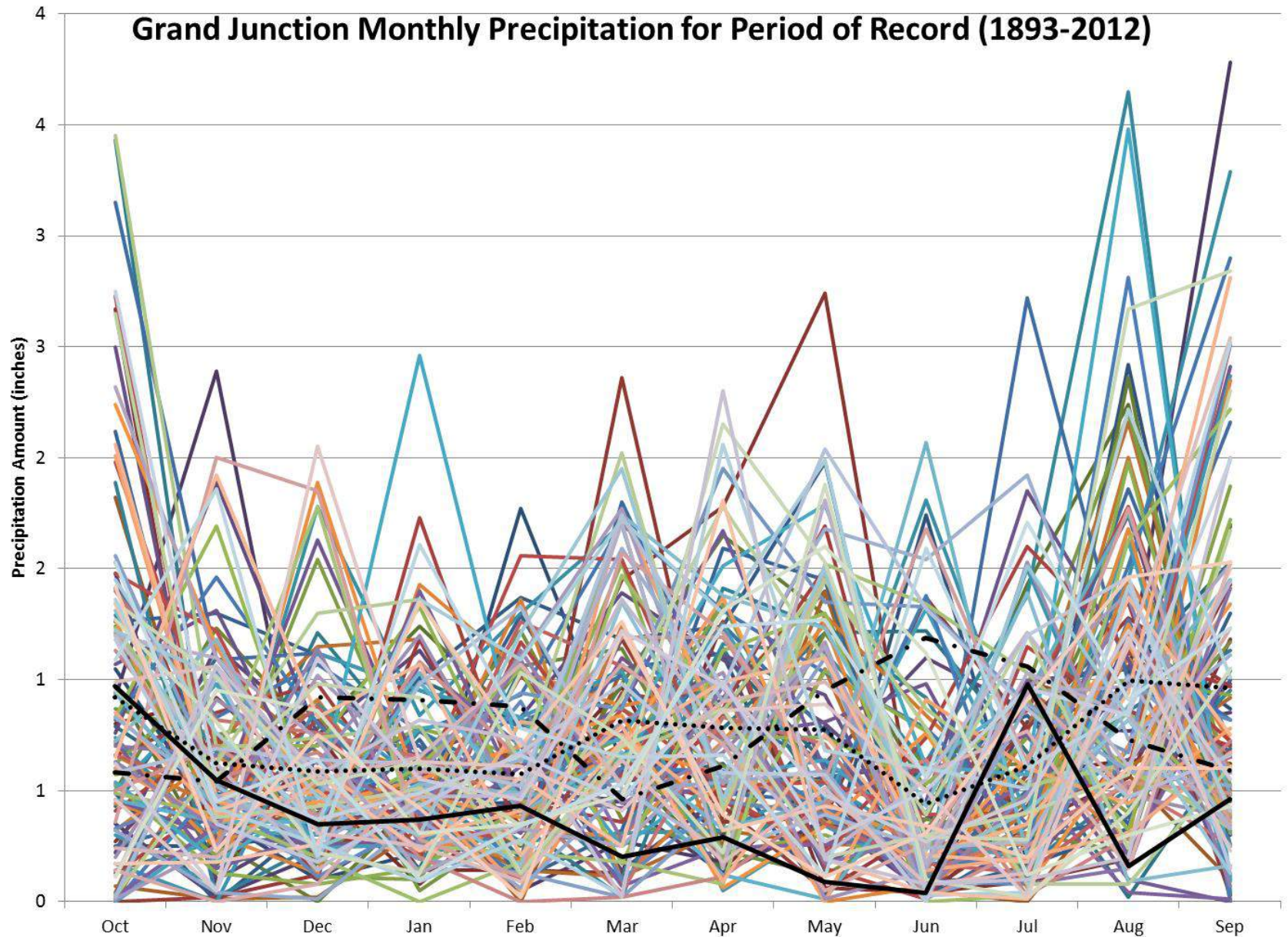
Water Year Average Precipitation for Selected Stations
E-W transect along I-70



Year-to-Year Variations in Precipitation are Huge



No two years are ever the same

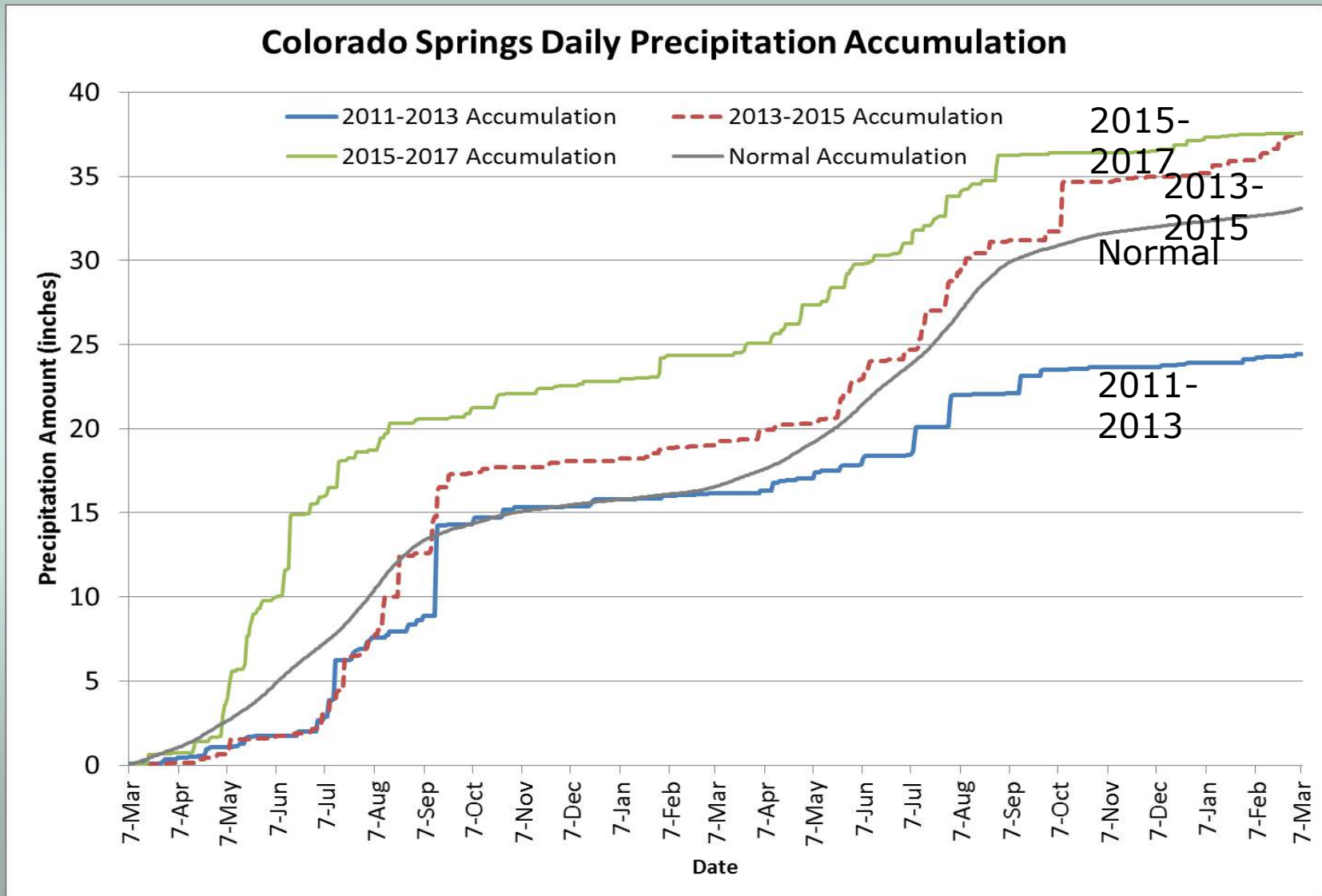


**A few storm systems each year make
the difference**



Photo Credit: Henry Reges

2-year daily precip. accumulation graphs (Note the impact of a few large storms)



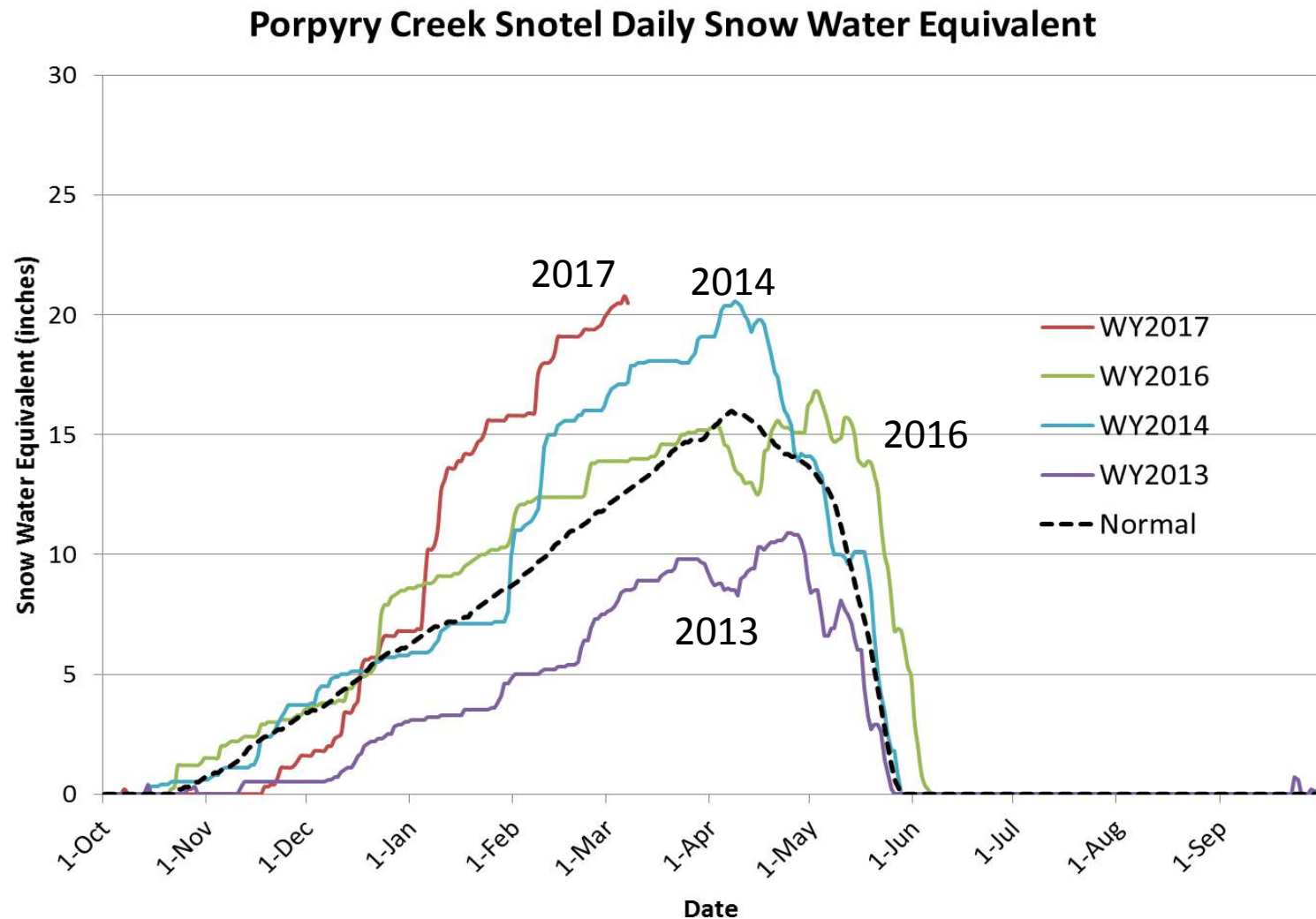
**We'll still get some of this
moisture as snow**



**Much of our surface water
comes from
Mountain Snowmelt**

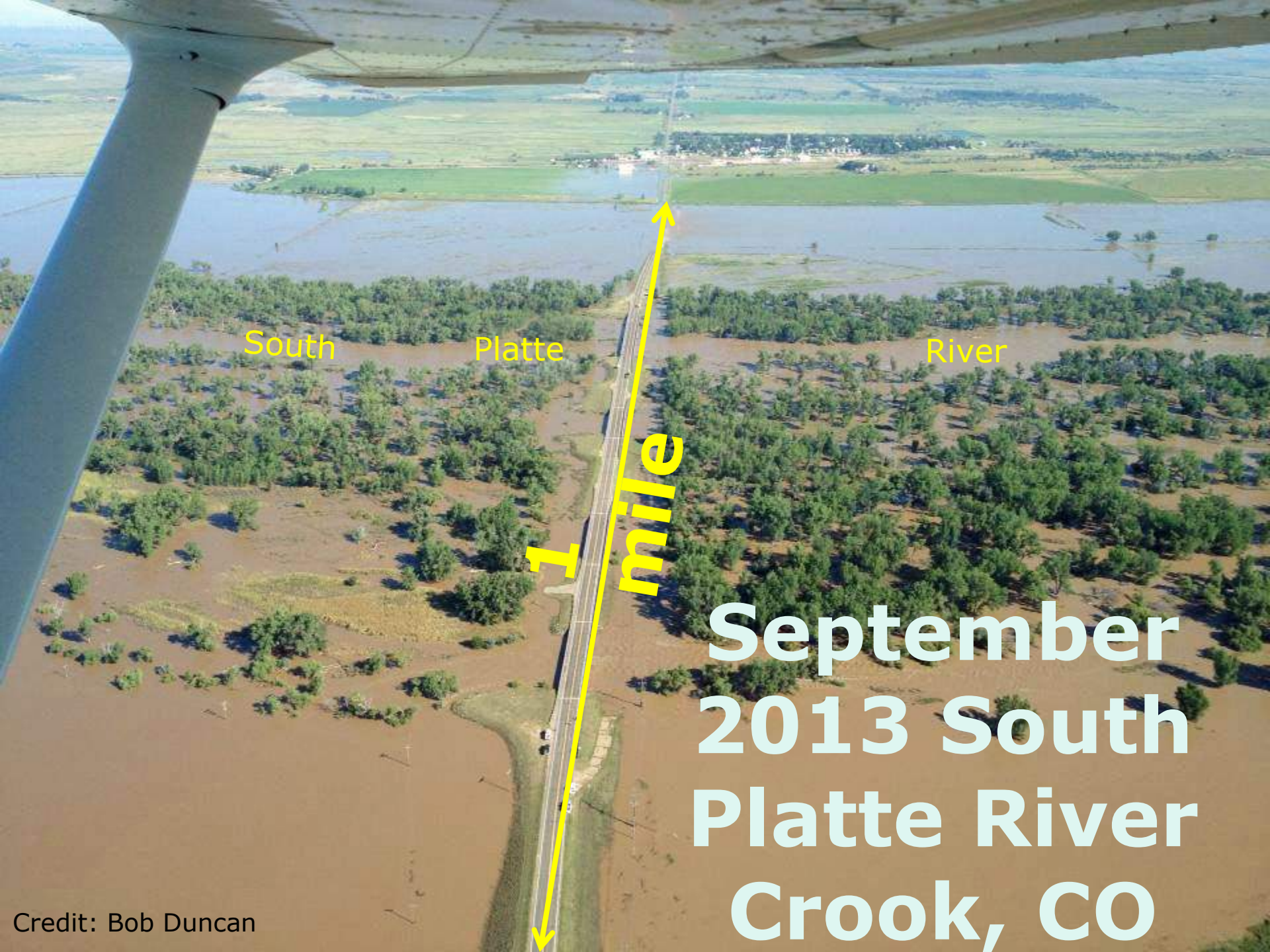


We're doing well so far this year, but will it continue



Sometimes we get ooo much





South

Platte

River

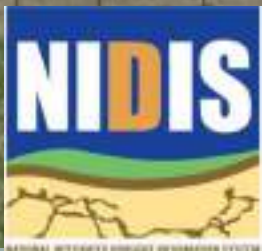
1 mile

**September
2013 South
Platte River
Crook, CO**

Was that forecast?



But often too little





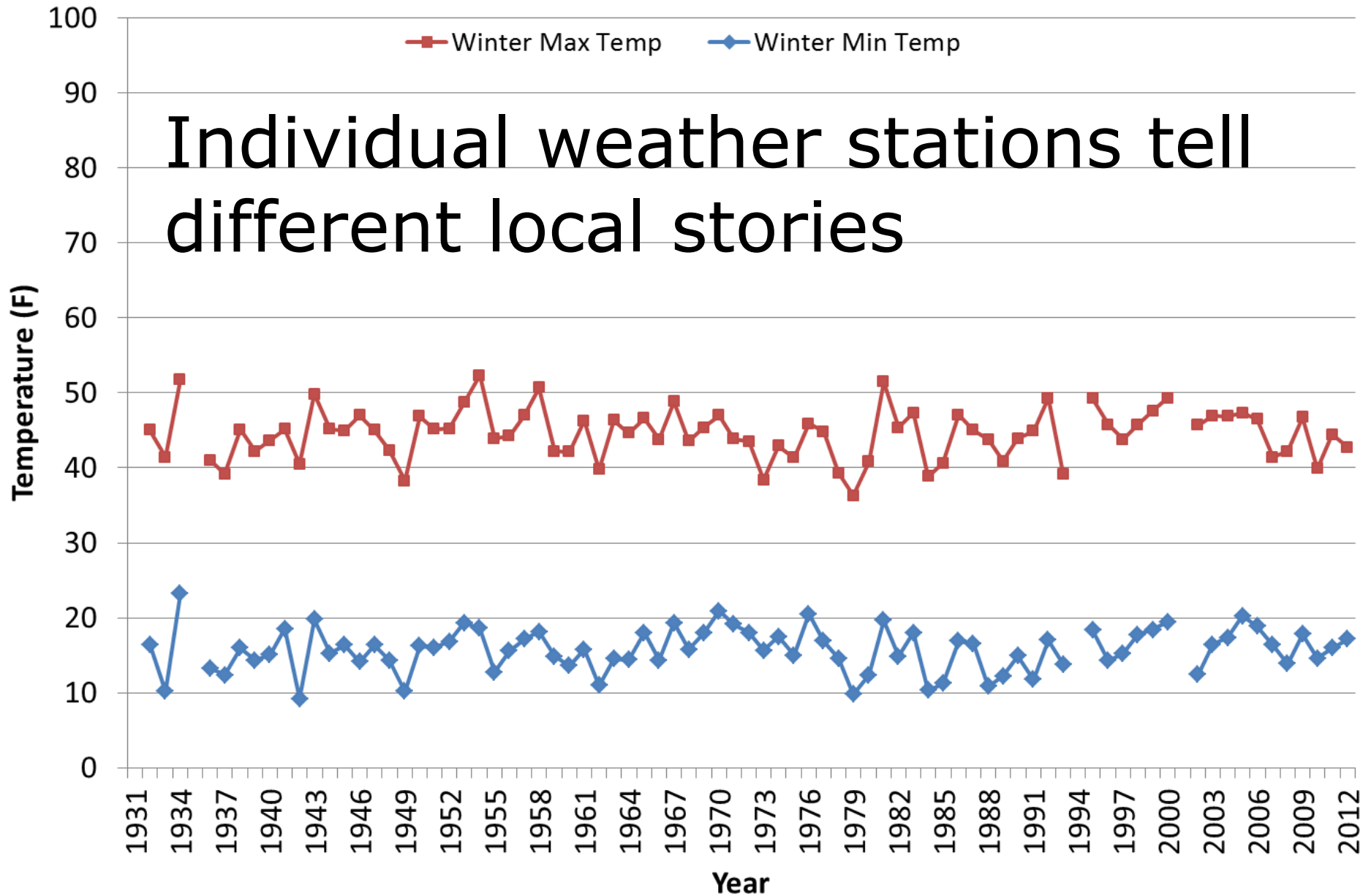
Paonia Reservoir
August 2012

A scenic landscape featuring a range of mountains with patches of snow under a clear blue sky. A full moon is visible in the upper right. The foreground is dark with silhouettes of trees.

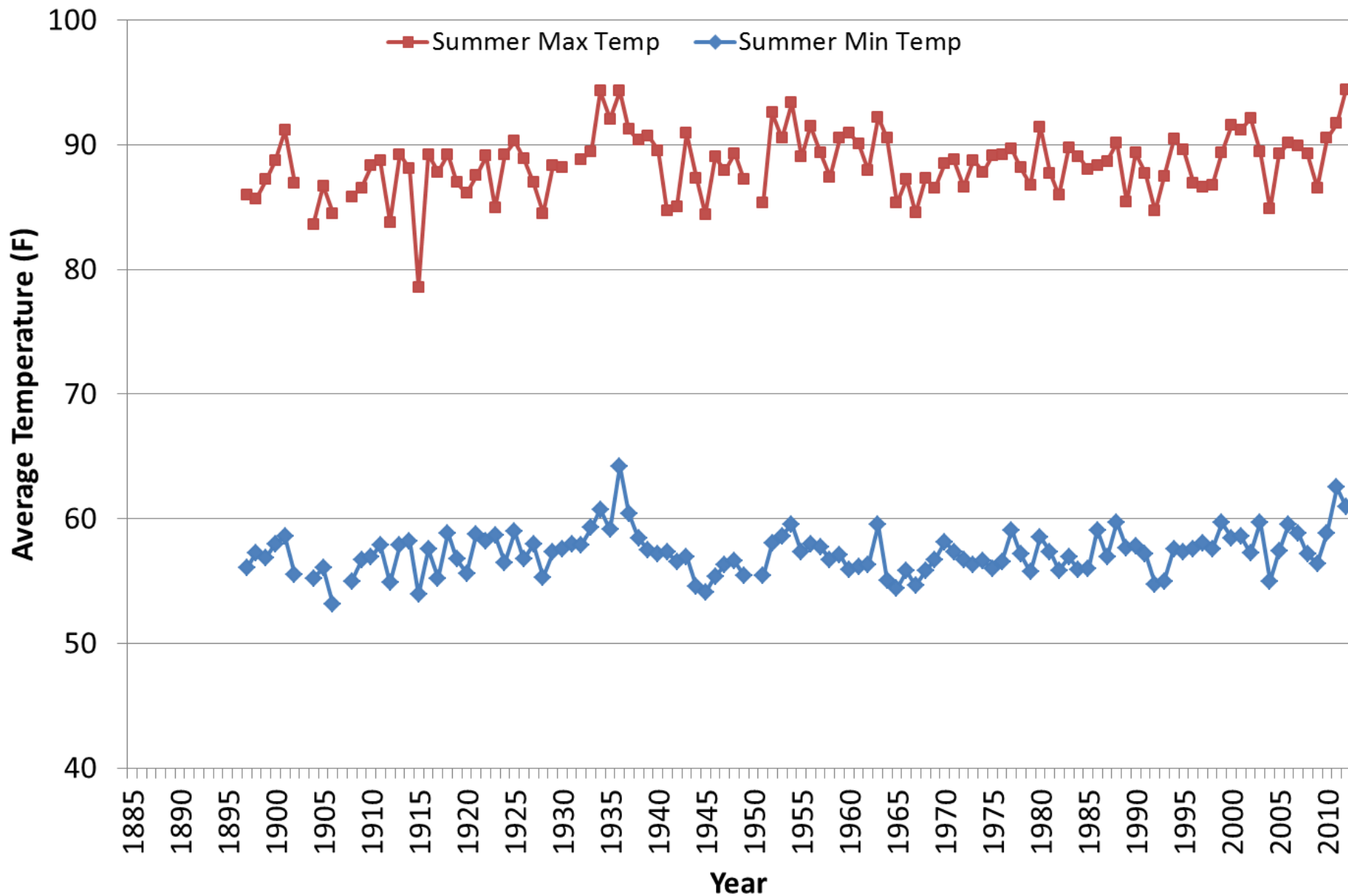
**What do our long term
data tell us about
changing temperatures**

Waterdale Coop Average Winter Temperature

Individual weather stations tell different local stories



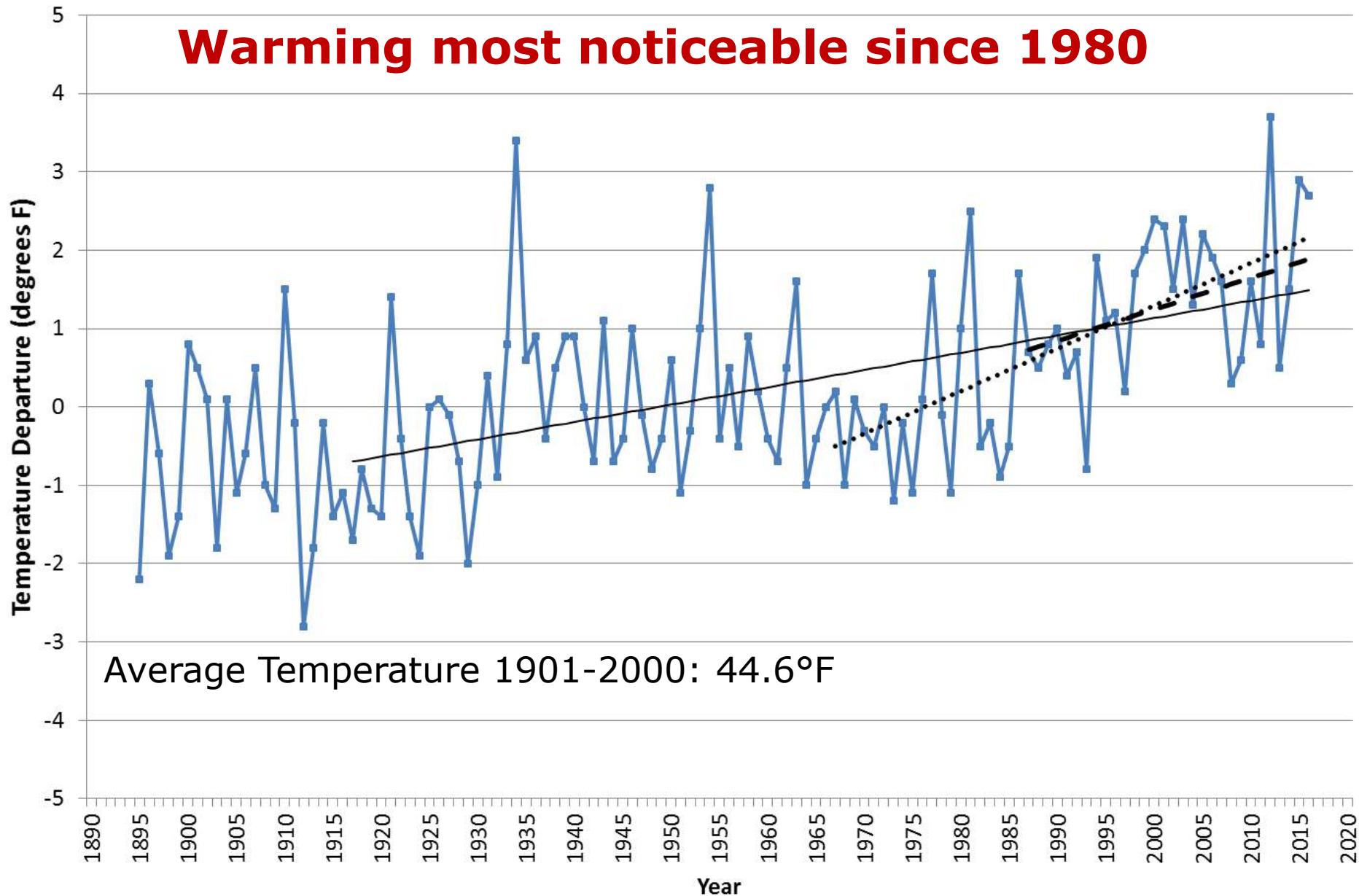
Cheyenne Wells, CO Average Summer Temperature



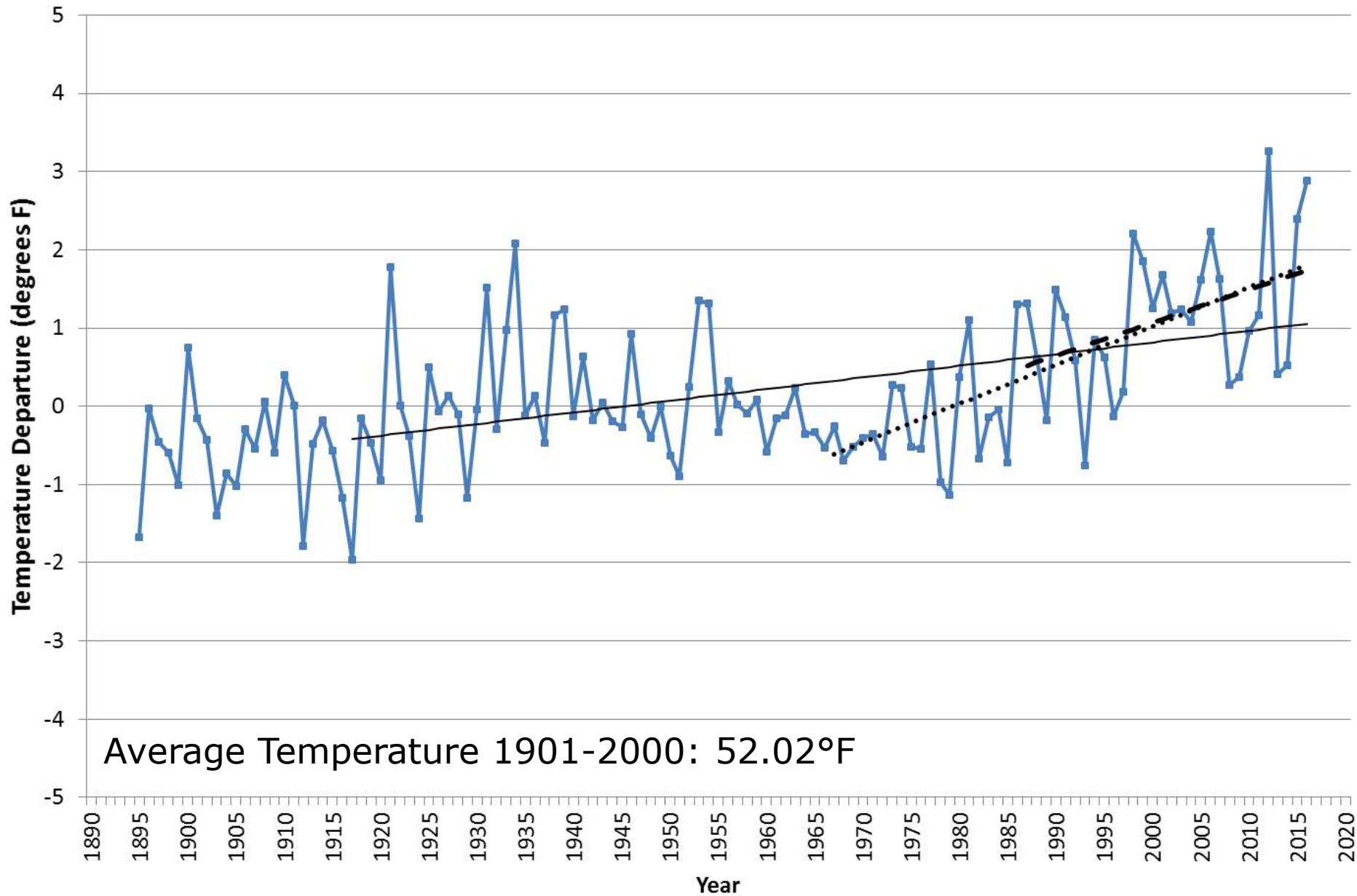
But average things together
and -- -- --

Colorado Temperature Departure from Average

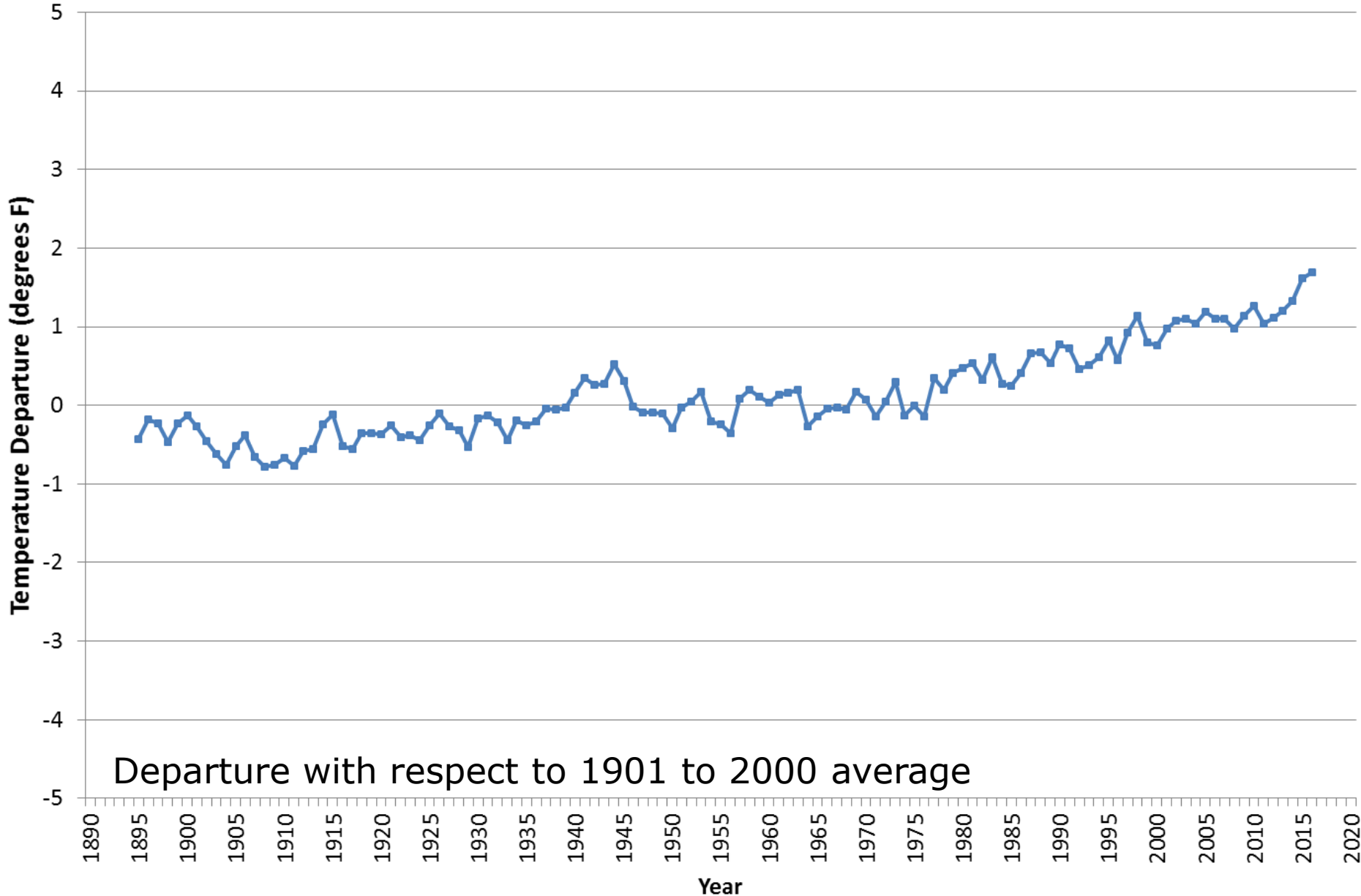
Warming most noticeable since 1980



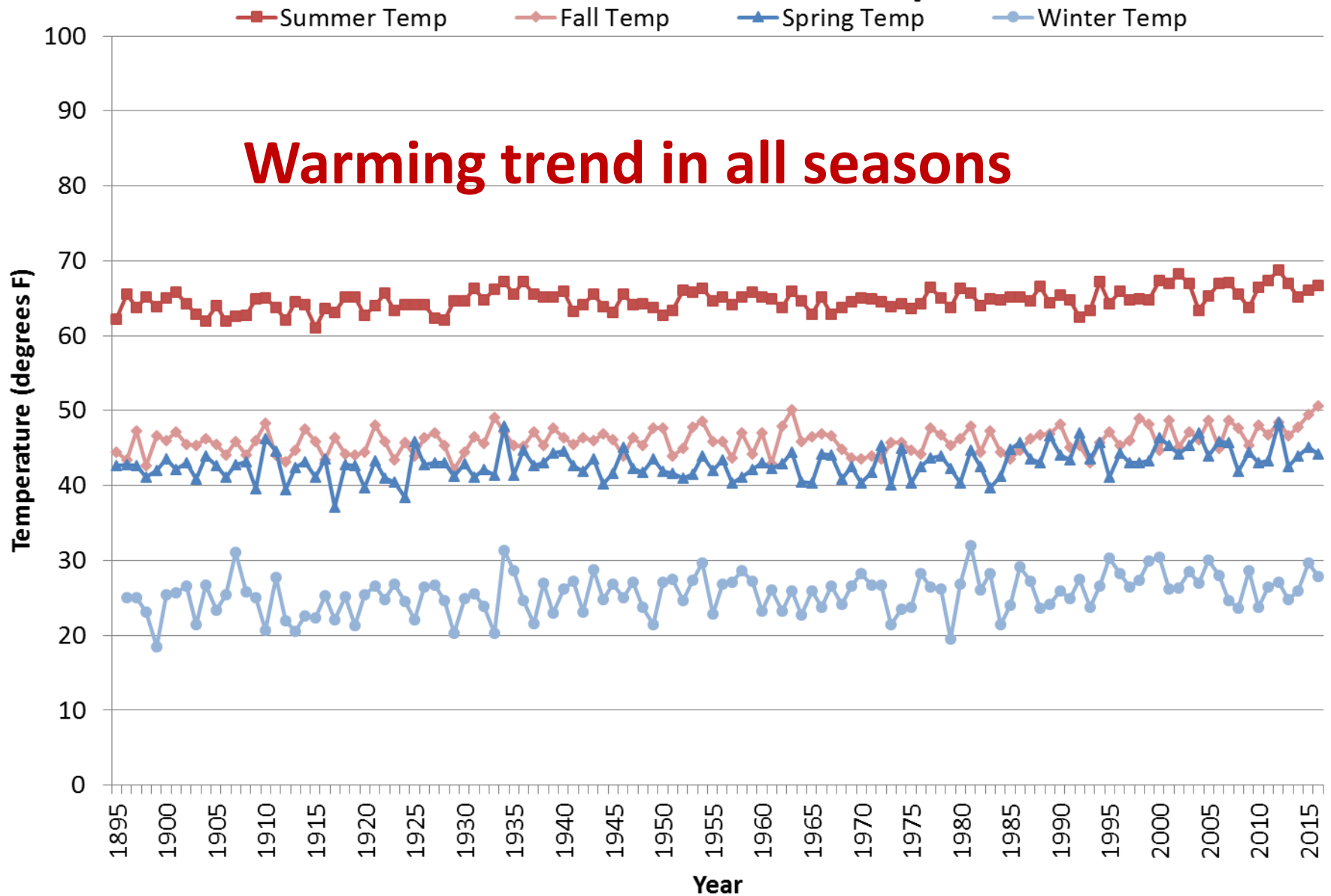
U.S. Temperature Departure from Average



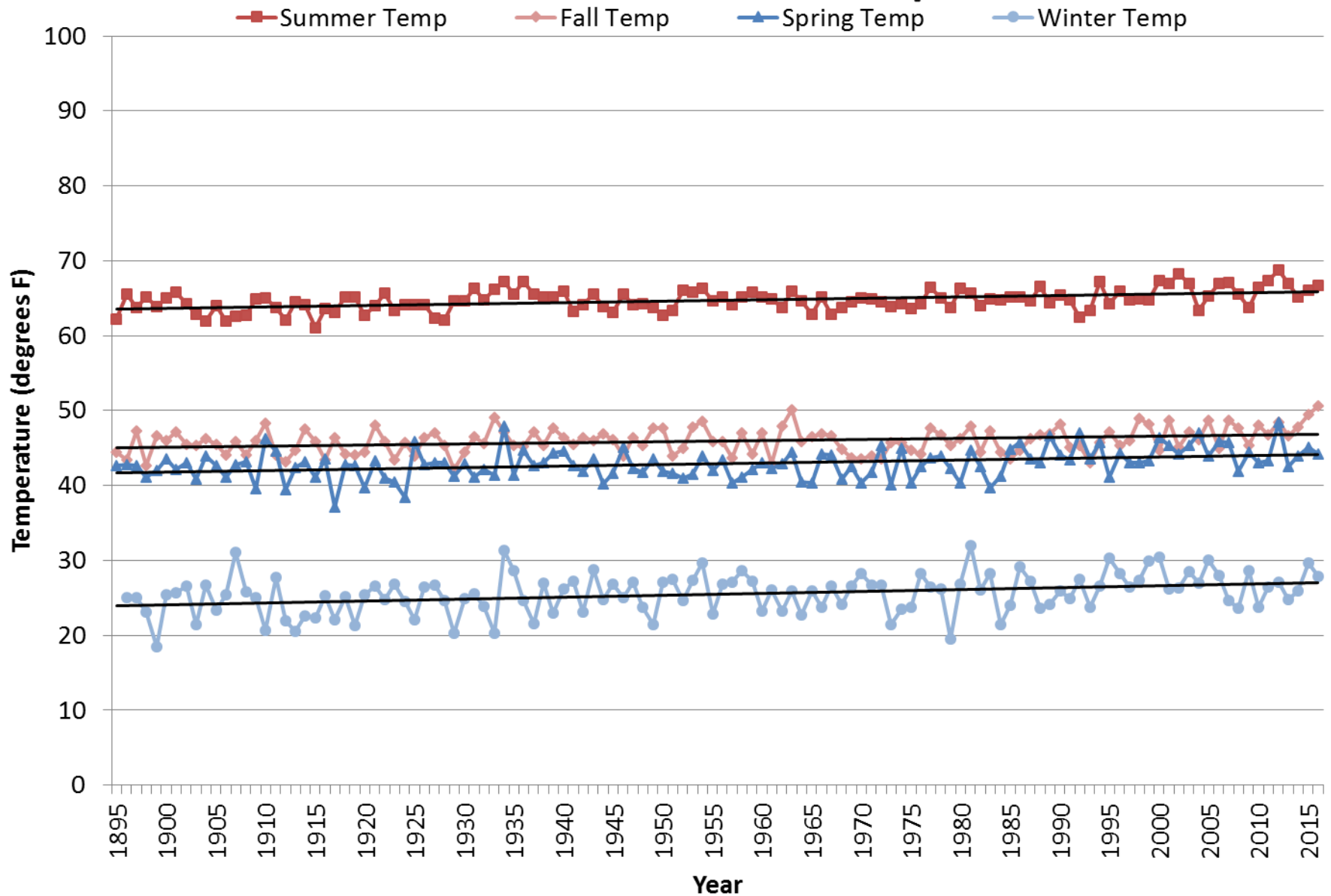
Global Temperature Departure from Average



Colorado Statewide Seasonal Temperature

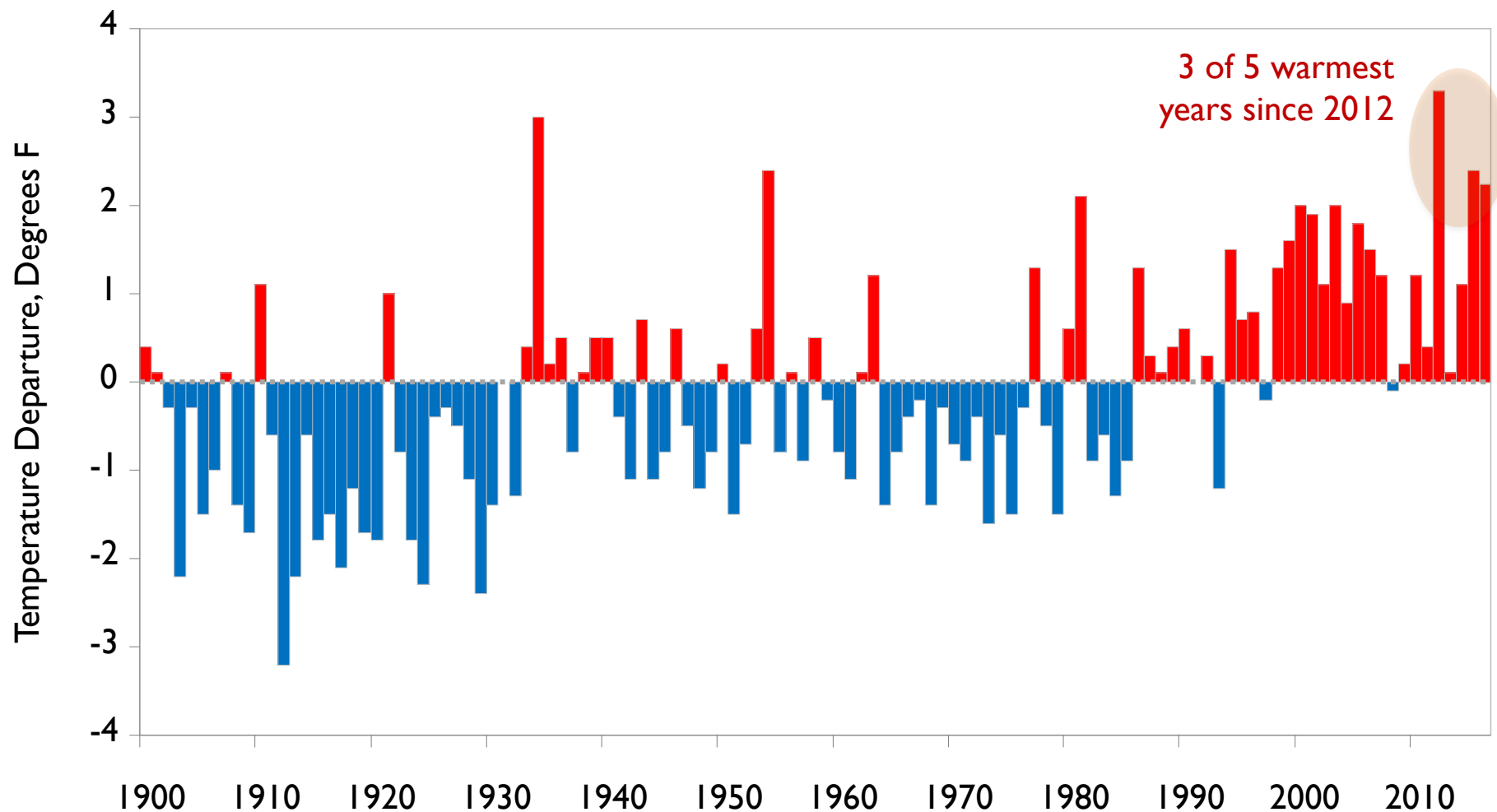


Colorado Statewide Seasonal Temperature



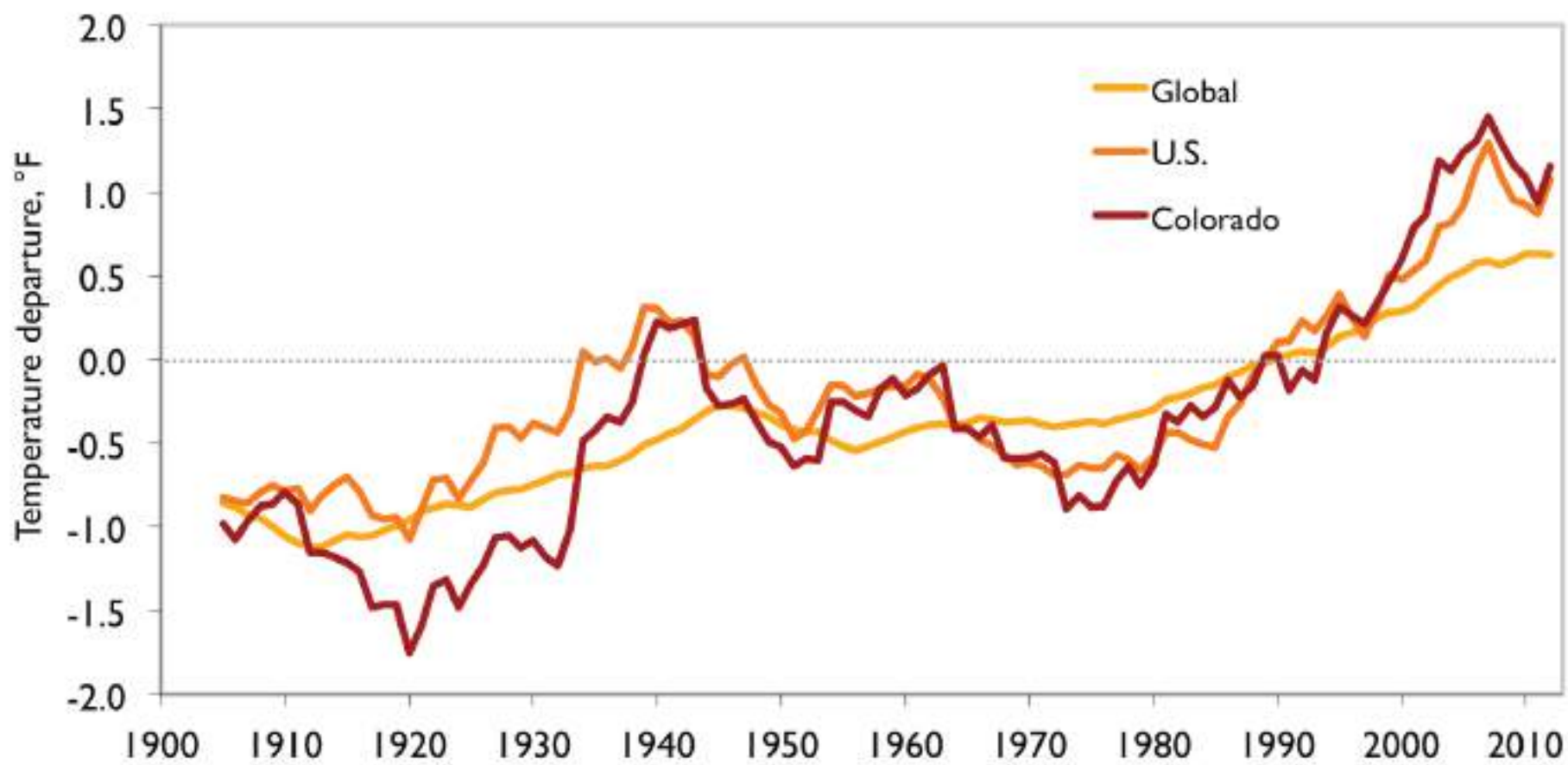
Expand the scale, and then
the trends catch your
attention more

Colorado statewide annual temperatures have warmed by 2°F in past 30 years



Western Water Assessment, CIRES, University of Colorado Boulder; Data: NOAA NCEI

Observed

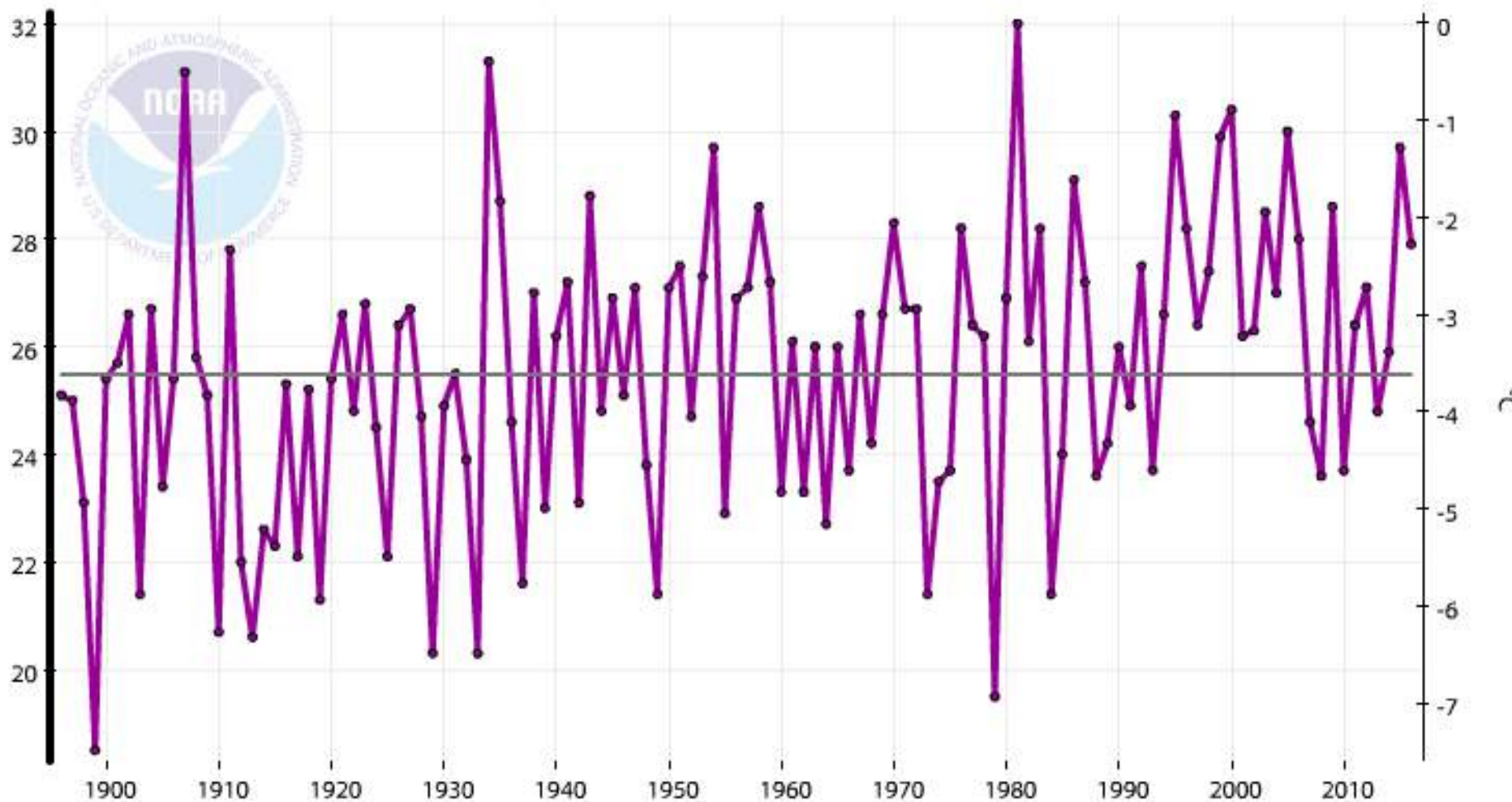


Winter (DJF) Statewide Temperatures 1895-2016

Colorado, Average Temperature, December-February

— 1901-2000
Mean: 25.5°F

—●— Avg Temperature

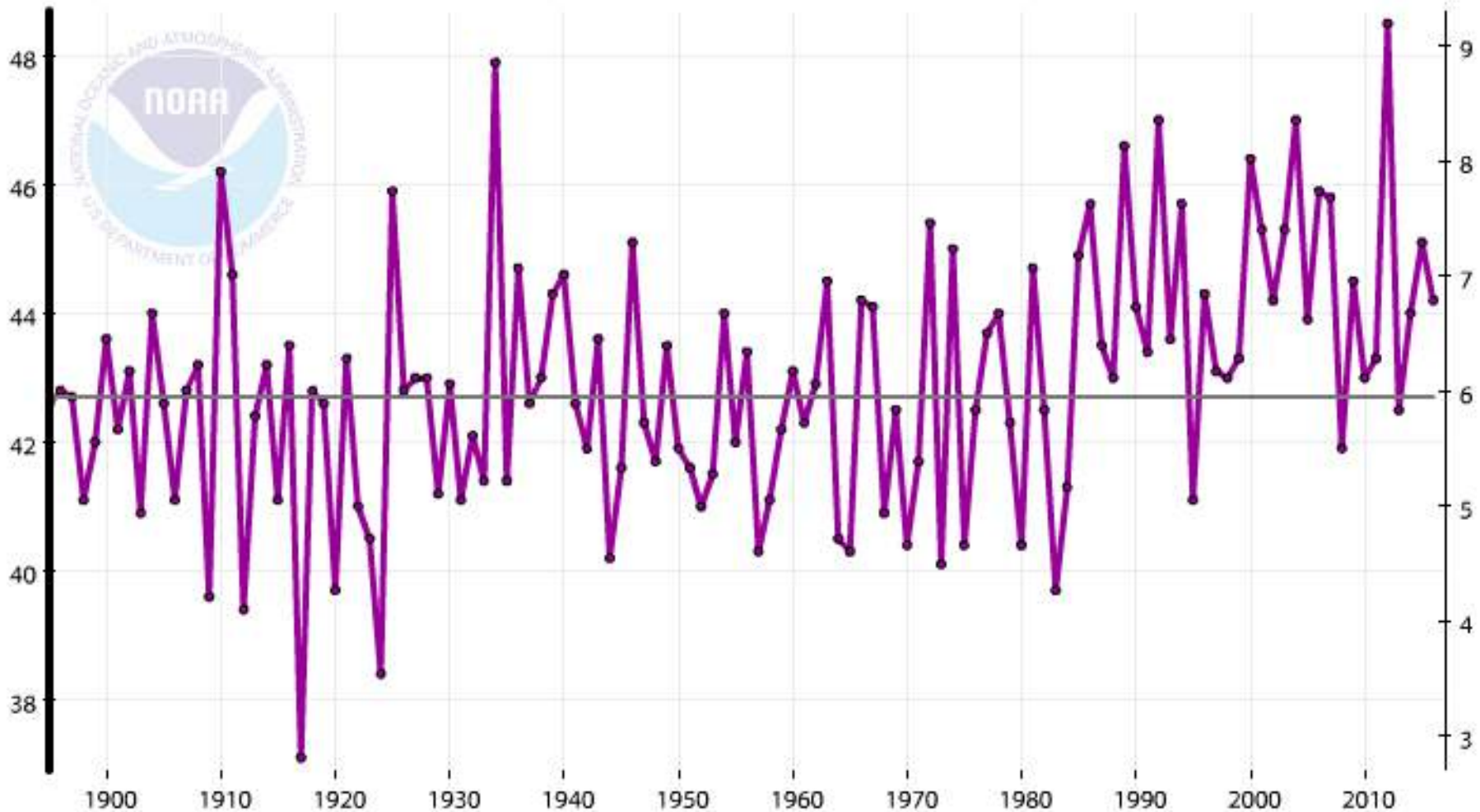


Spring (MAM) Statewide Temperatures 1895-2016

Colorado, Average Temperature, March-May

— 1901-2000
Mean: 42.7°F

—●— Avg Temperature

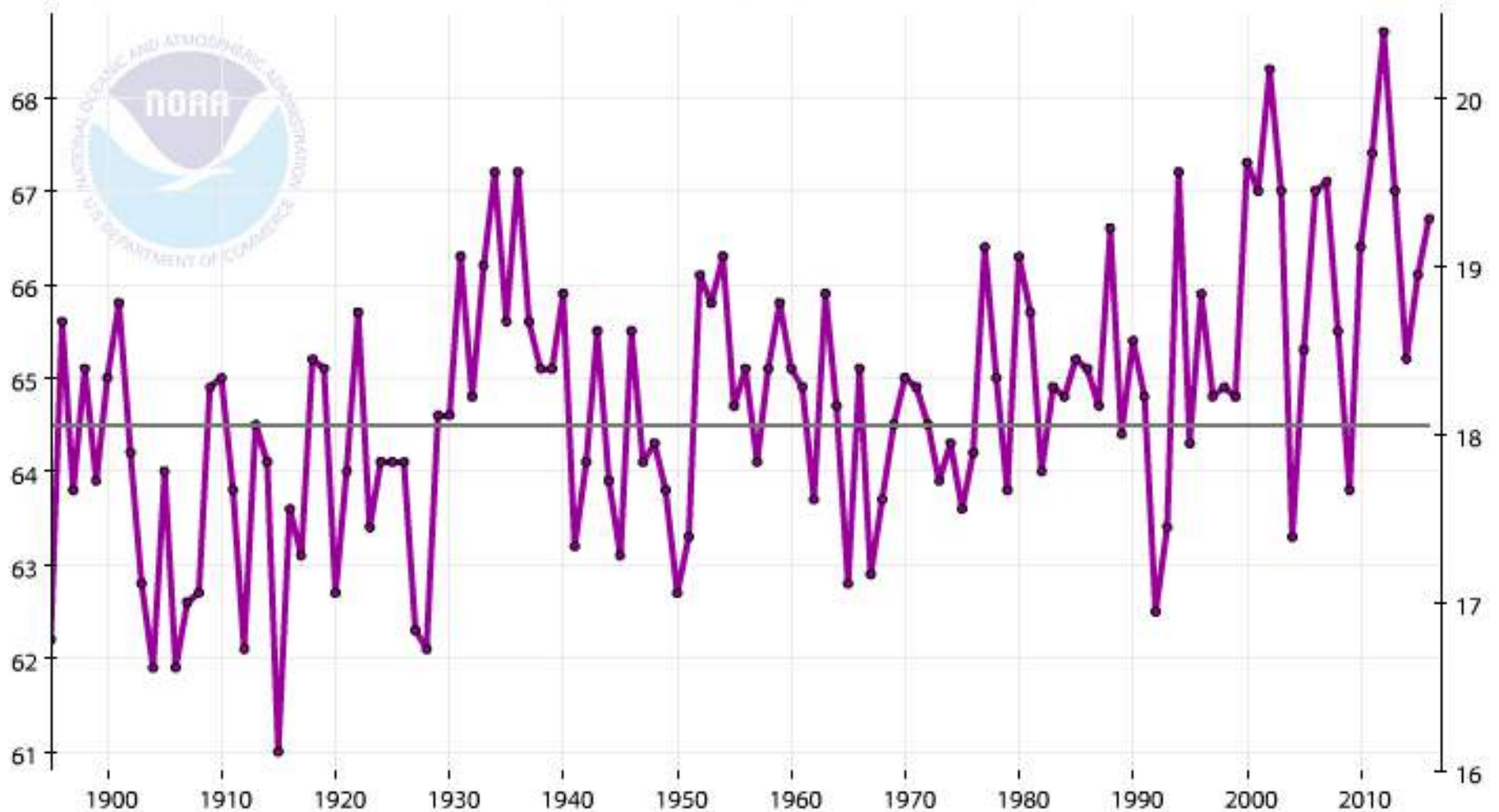


Summer (JJA) Statewide Temperatures 1895-2016

Colorado, Average Temperature, June-August

— 1901-2000
Mean: 64.5°F

—●— Avg Temperature

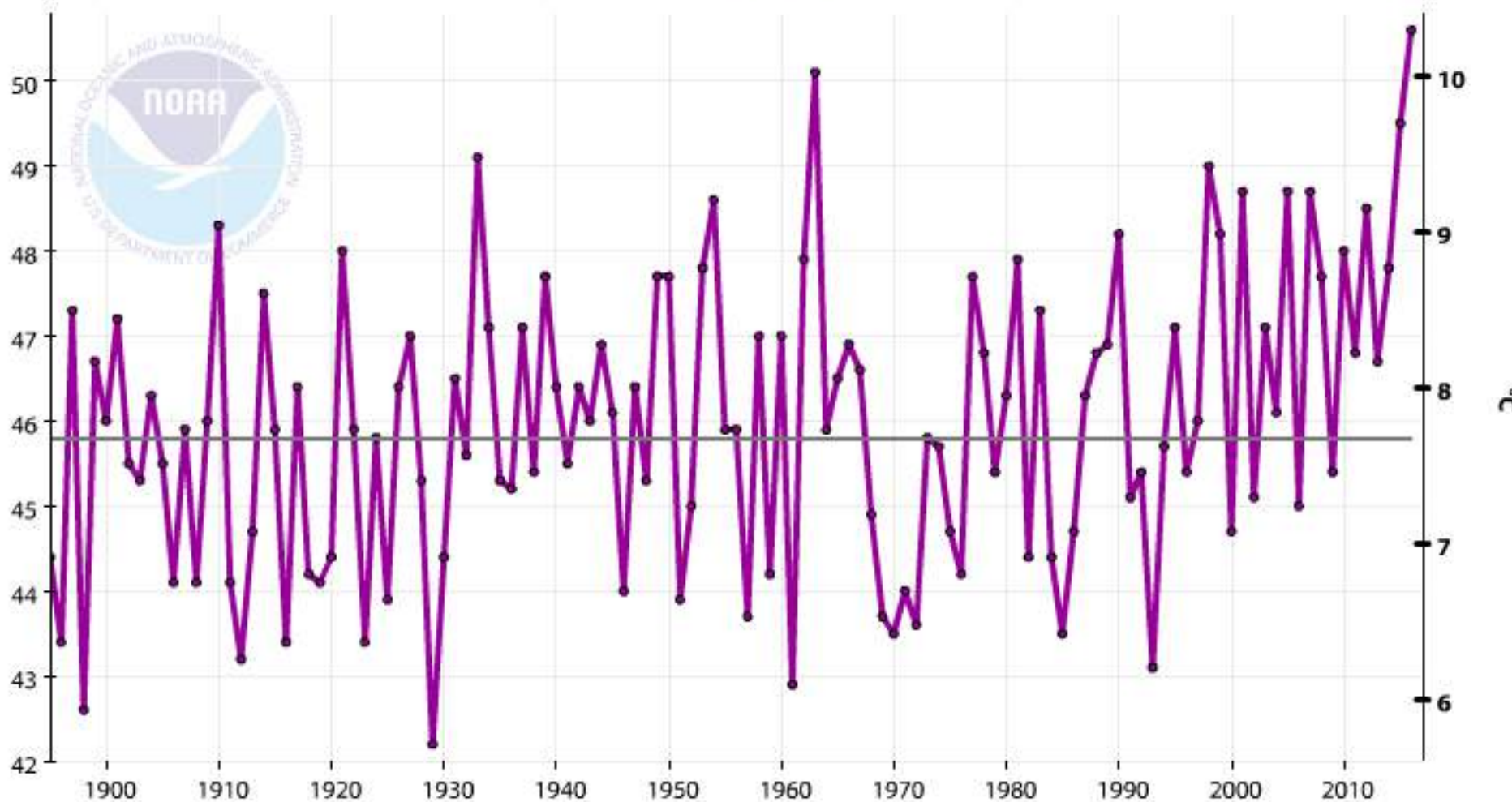


Fall (SON) Statewide Temperatures 1895-2016

2016 Warmest on Record

Colorado, Average Temperature, September-November

— 1901-2000 Mean: 45.8°F —●— Avg Temperature

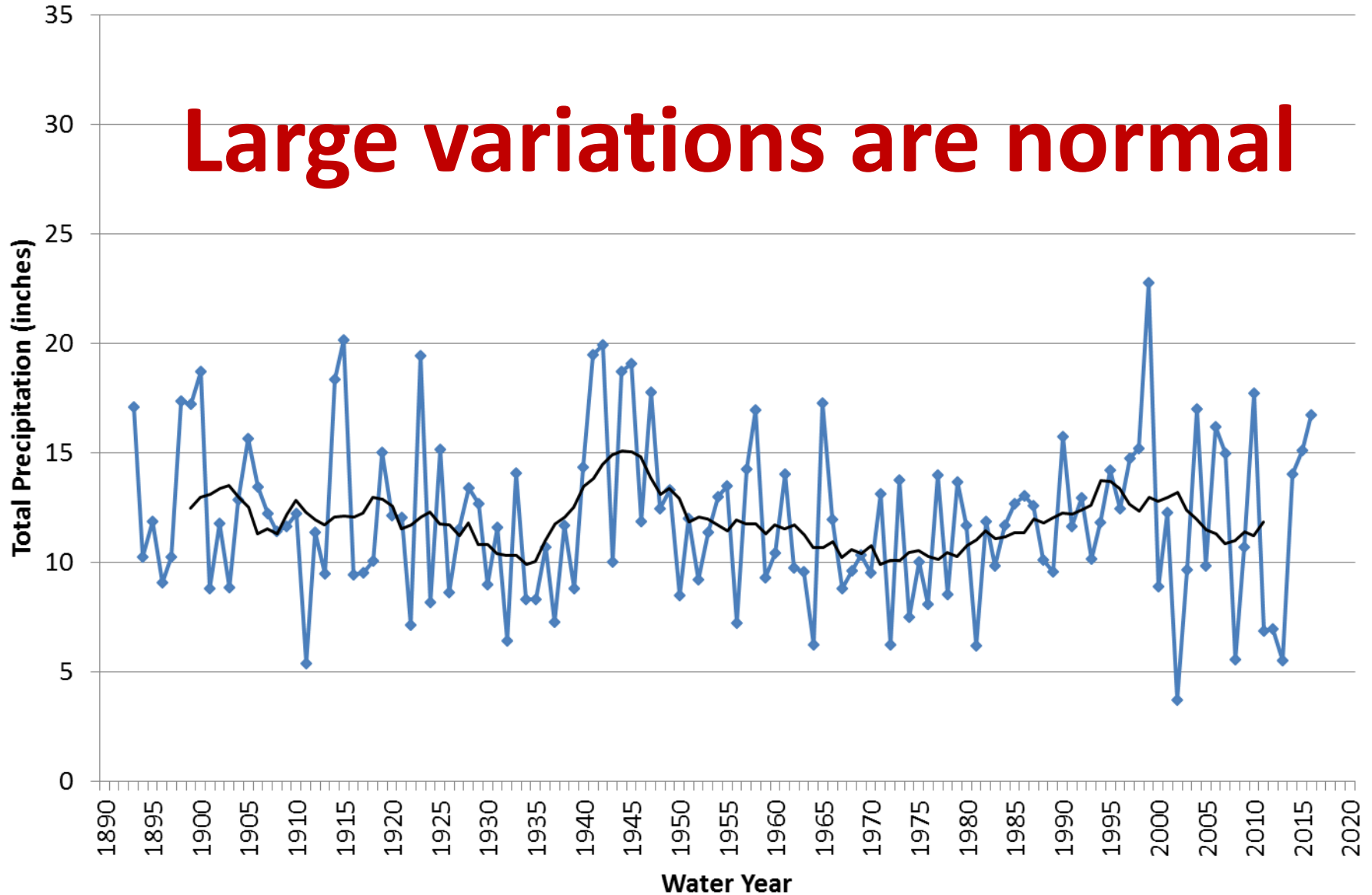


What about precipitation ??

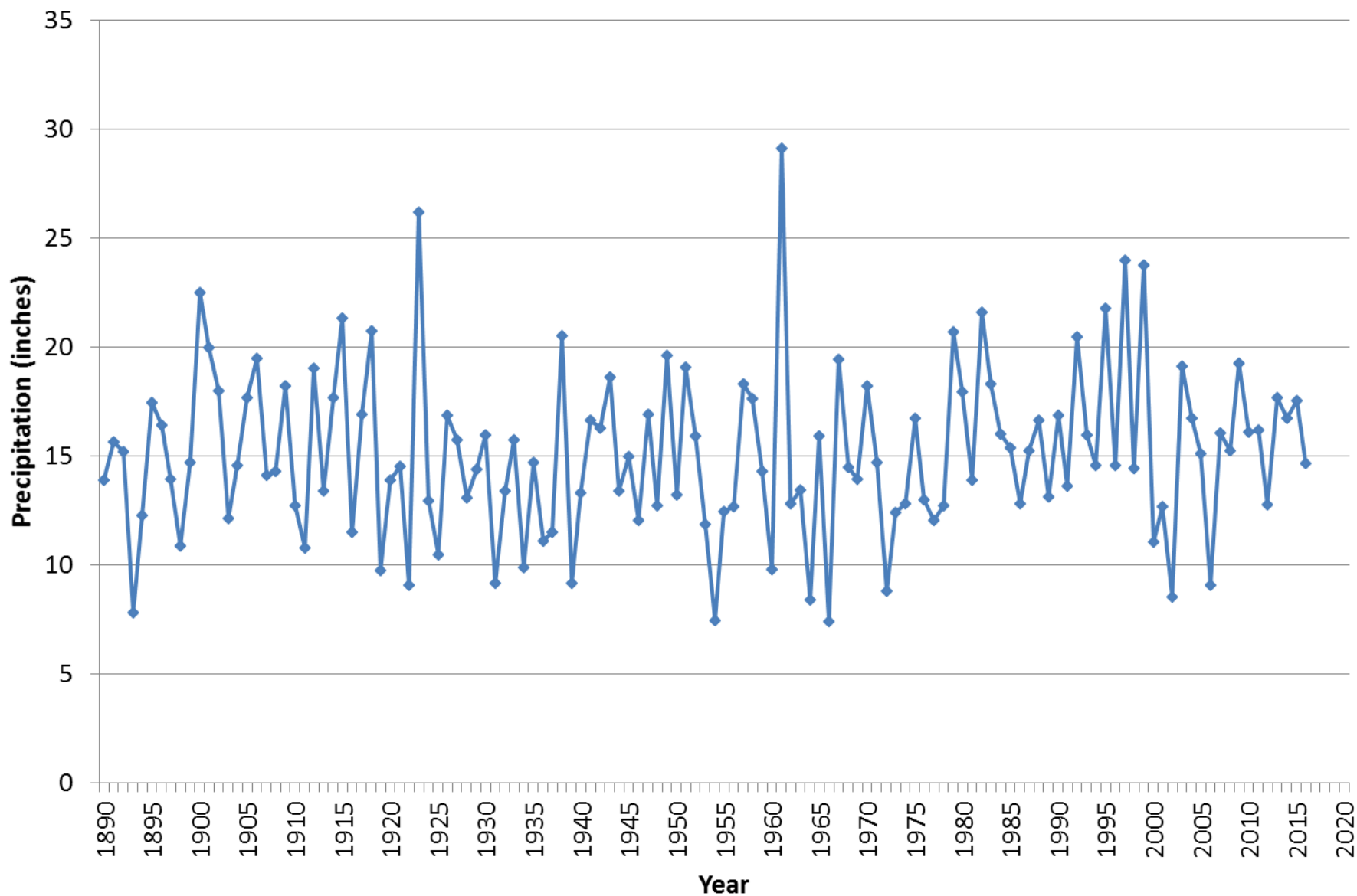


Rocky Ford, CO Water Year Precipitation

Large variations are normal

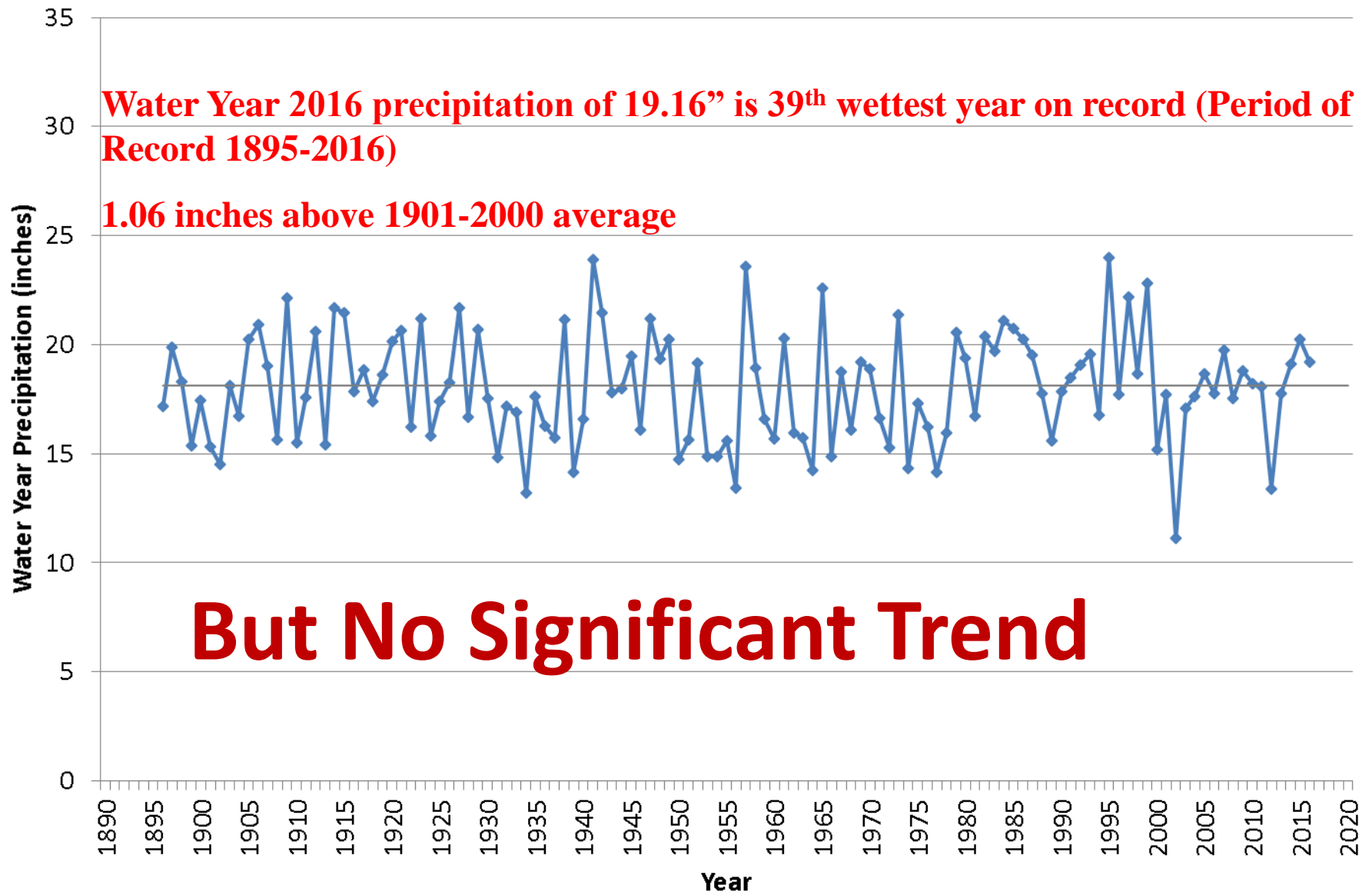


Fort Collins, CO Water Year (Oct-Sep) Precipitation



Colorado Precipitation in Historic Perspective

Statewide Water Year Precipitation

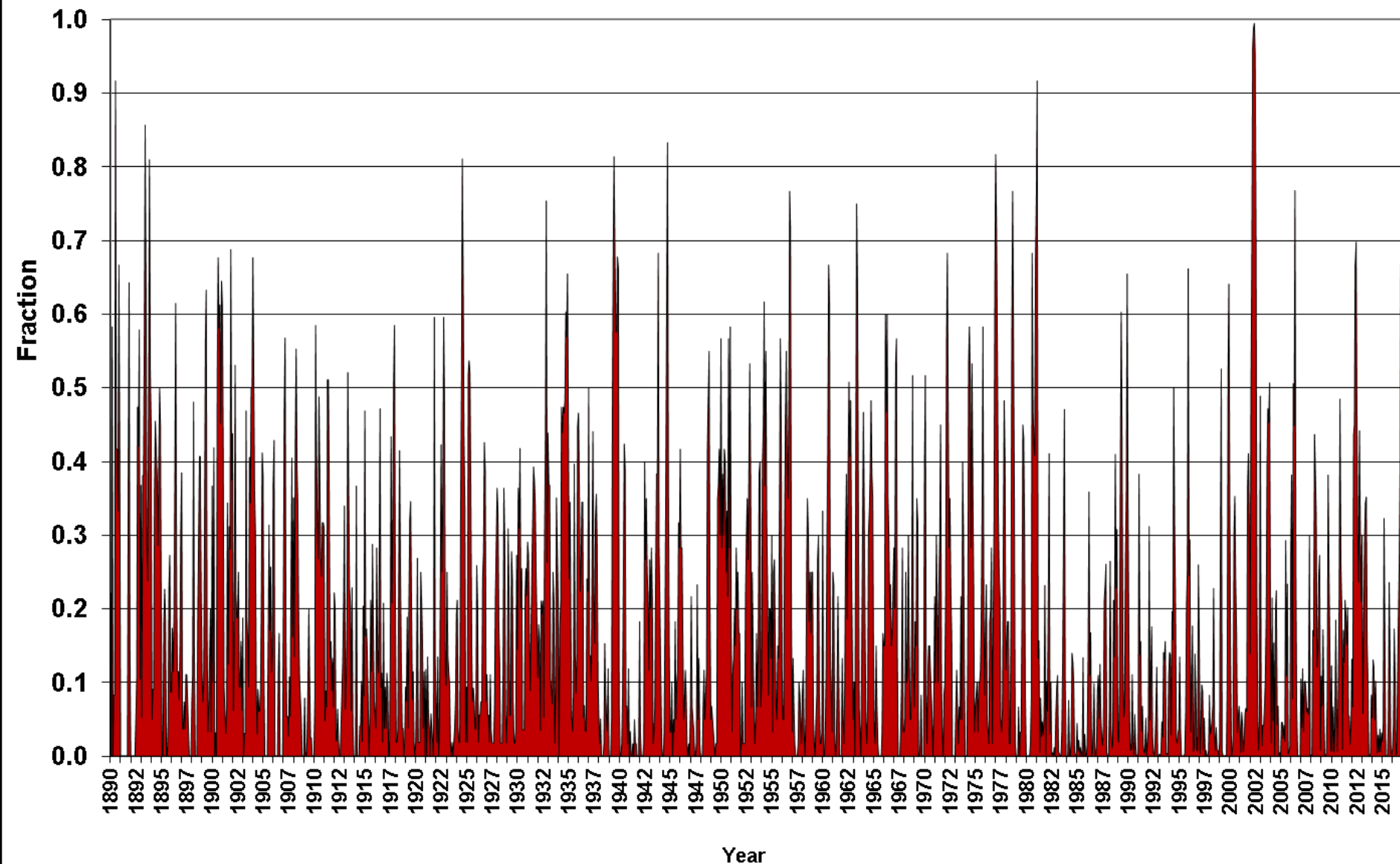




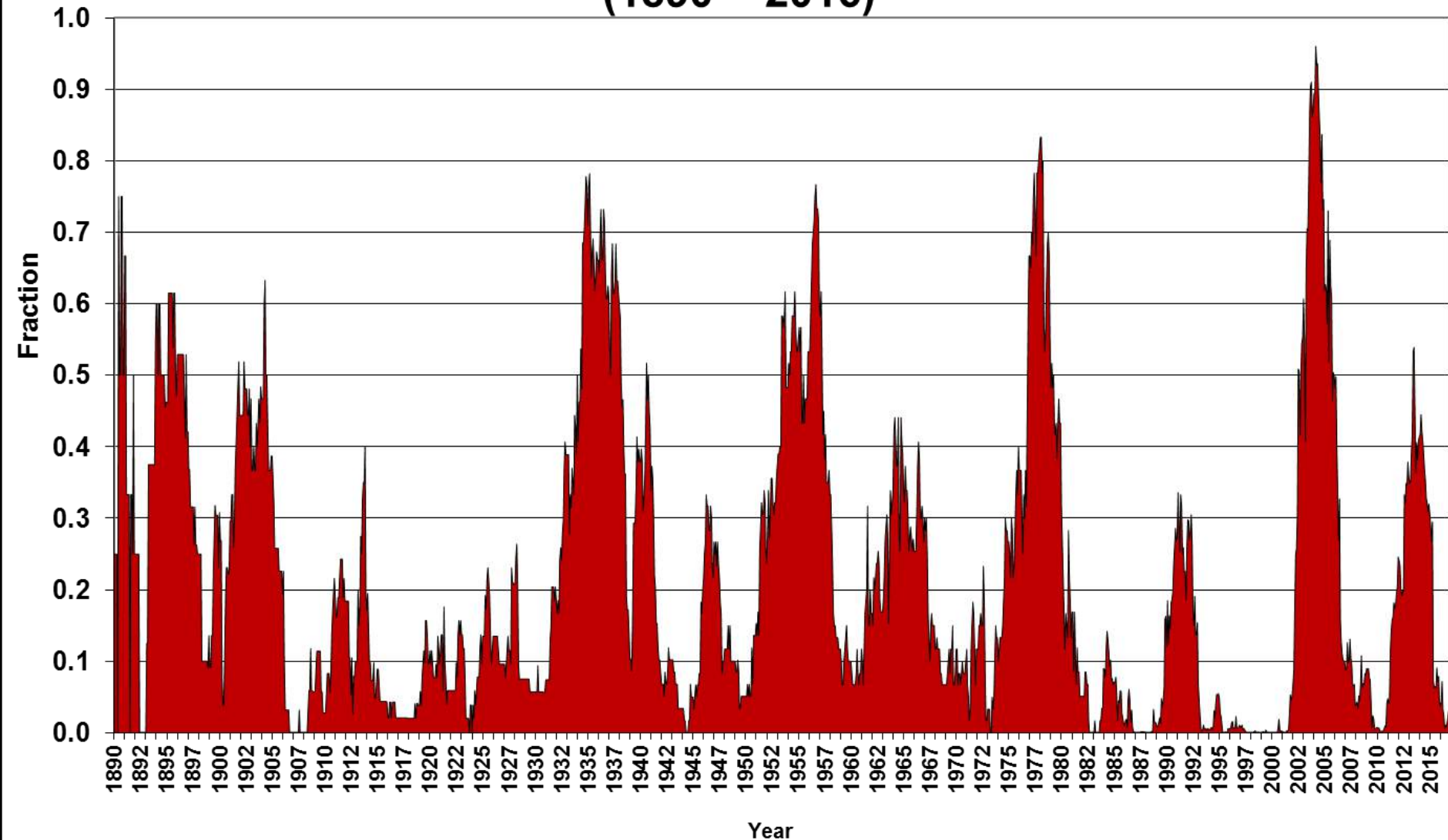
**Drought never leaves us
alone for long**

Photo by Lyric Lucero
2013 Manzanola, CO

Fraction of Colorado in Drought Based on 3-month SPI (SPI<-1) 1890-2016



Fraction of Colorado in Drought Based on 48 month SPI (SPI < -1) (1890 - 2016)



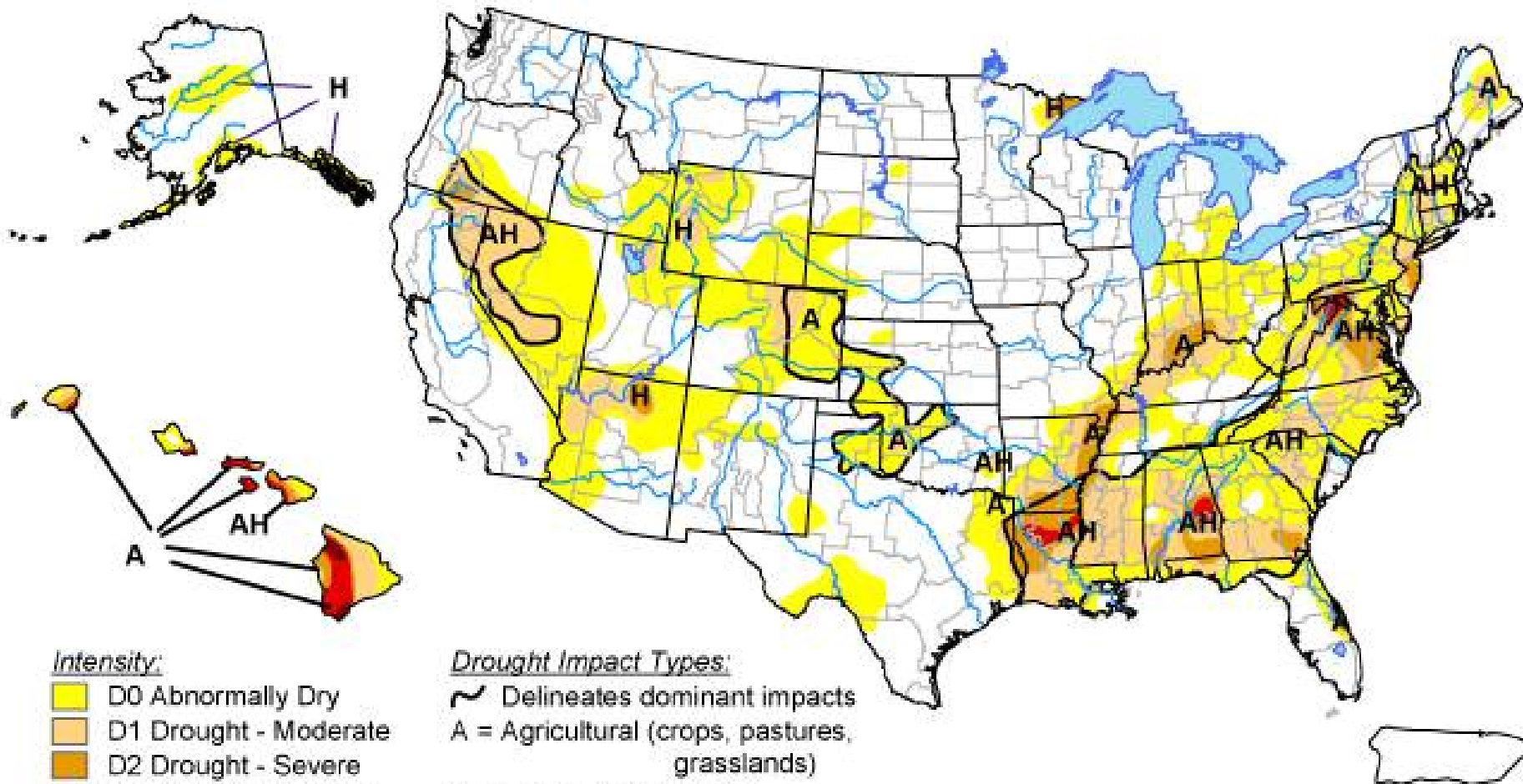
**Thoughts about drought:
We're all vulnerable but southern
Colorado seems particularly prone**



U.S. Drought Monitor

September 28, 2010

Valid 8 a.m. EDT



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

- ~ Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

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

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



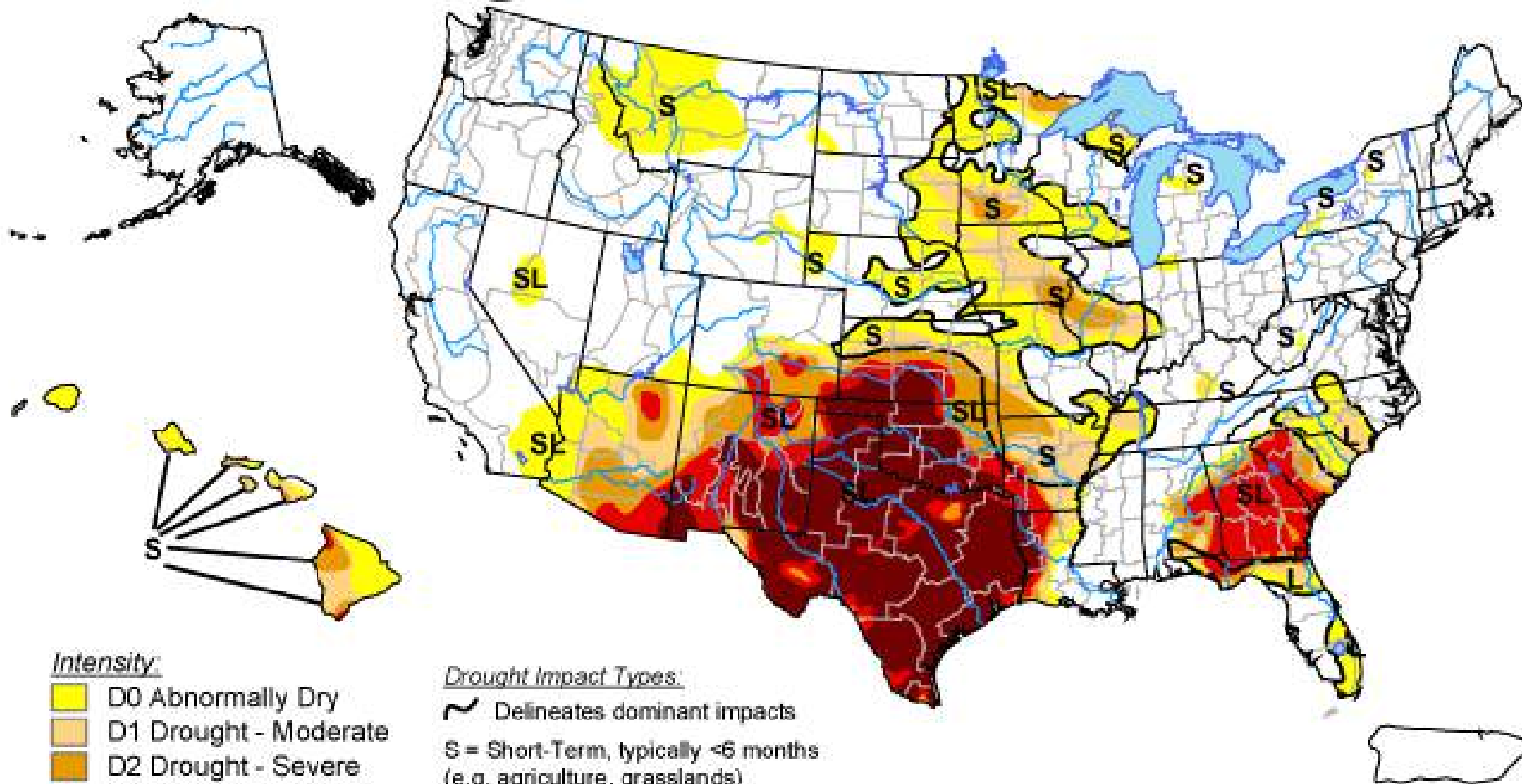
Released Thursday, September 30, 2010

Author: Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

U.S. Drought Monitor

October 4, 2011

Valid 8 a.m. EDT



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

- Delineates dominant impacts
- S = Short-Term, typically <6 months
(e.g. agriculture, grasslands)
- L = Long-Term, typically >6 months
(e.g. hydrology, ecology)

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

<http://droughtmonitor.unl.edu/>



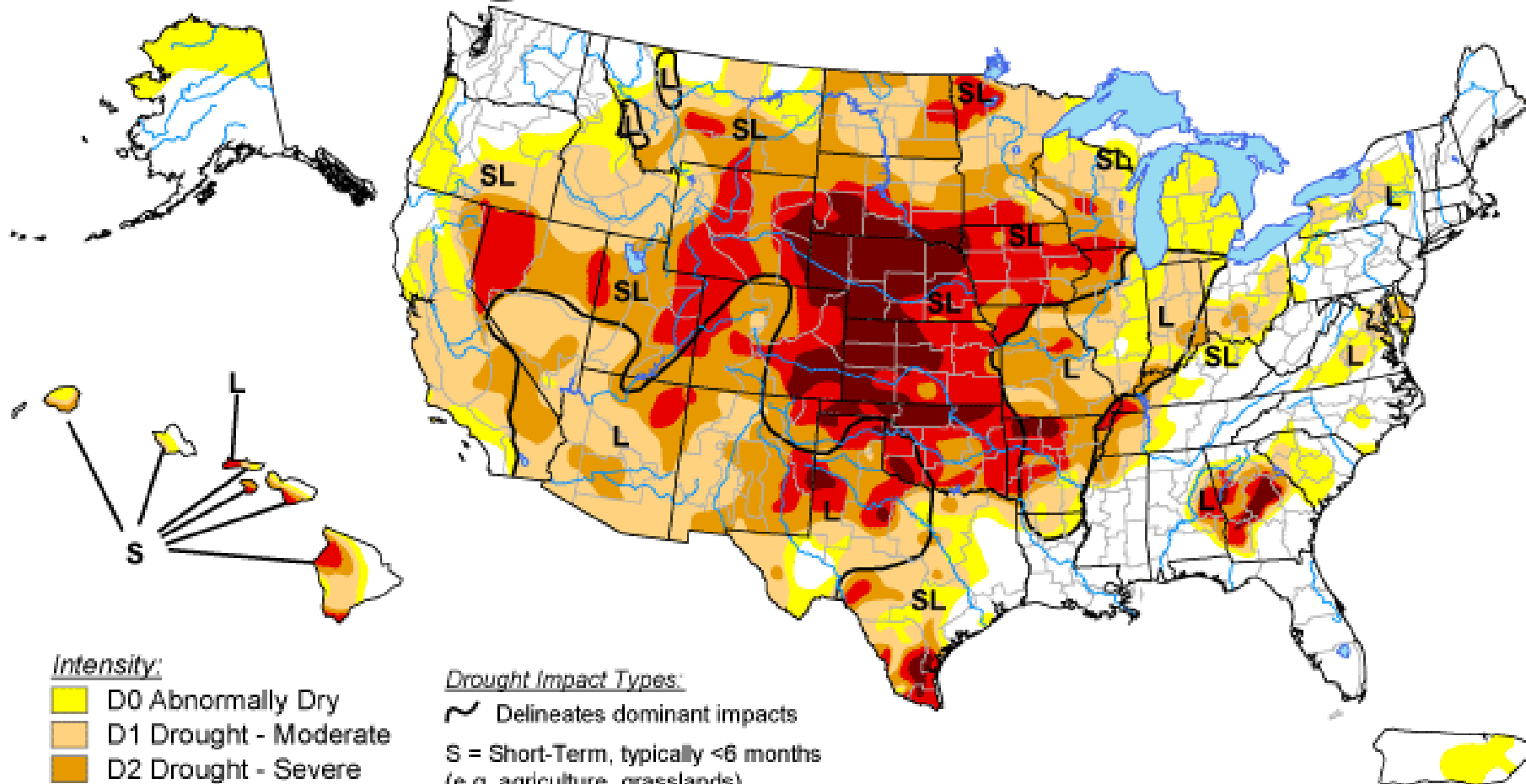
Released Thursday, October 6, 2011

Author: Rich Tinker, CPC/NCEP/NWS/NOAA

U.S. Drought Monitor

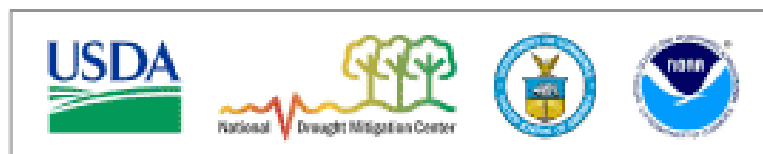
October 2, 2012

Valid 7 a.m. EDT



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

<http://droughtmonitor.unl.edu/>



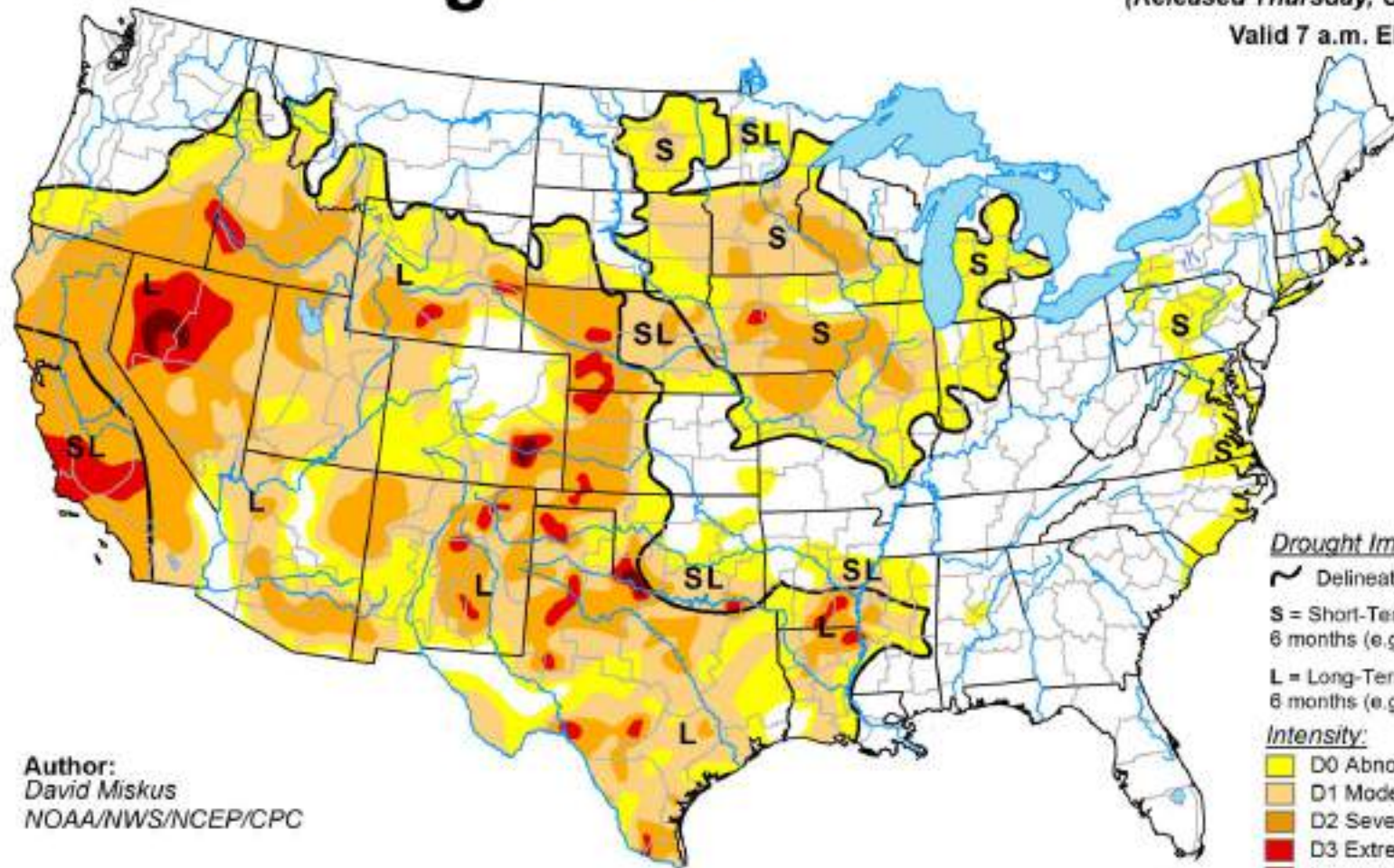
Released Thursday, October 4, 2012
Author: Anthony Artusa, NOAA/NWS/NCEP/CPC

U.S. Drought Monitor

October 1, 2013

(Released Thursday, Oct. 3, 2013)

Valid 7 a.m. EDT



Author:
David Miskus
NOAA/NWS/NCEP/CPC

Drought Impact Types:

~ Delineates dominant impacts

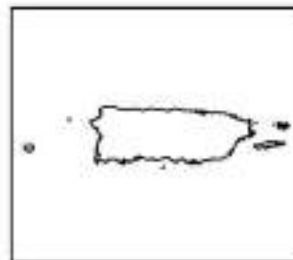
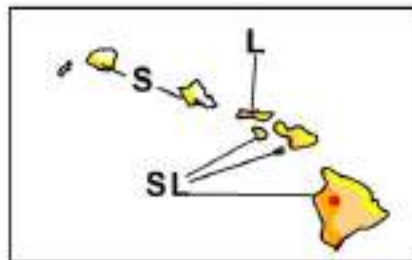
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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



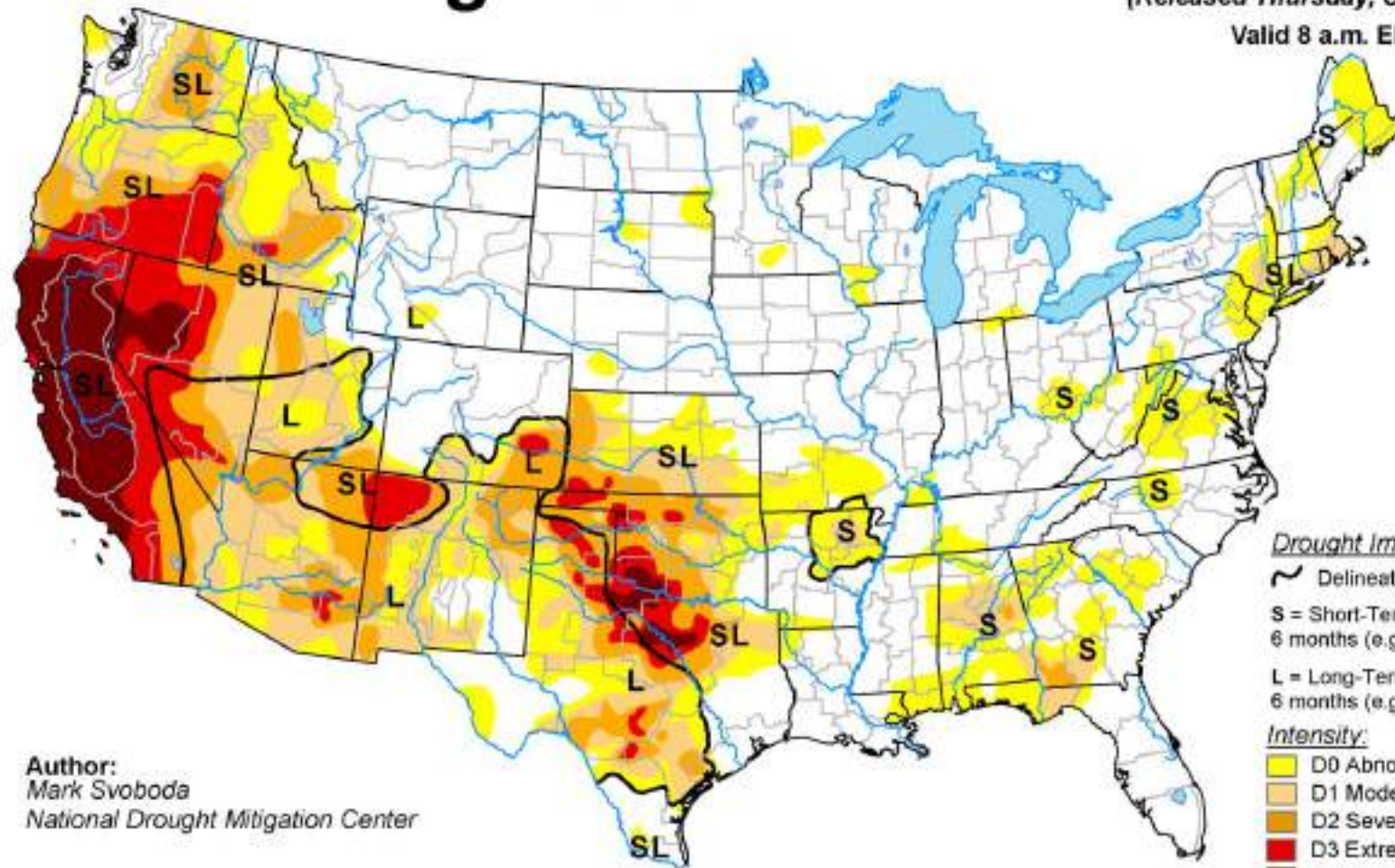
<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor

October 7, 2014

(Released Thursday, Oct. 9, 2014)

Valid 8 a.m. EDT



Author:
Mark Svoboda
National Drought Mitigation Center

Drought Impact Types:

~ Delineates dominant impacts

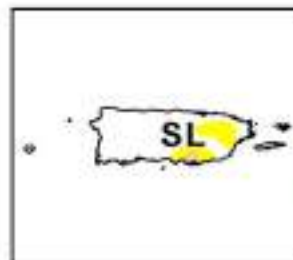
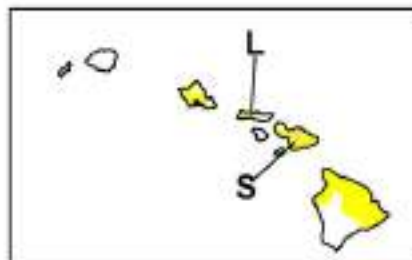
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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



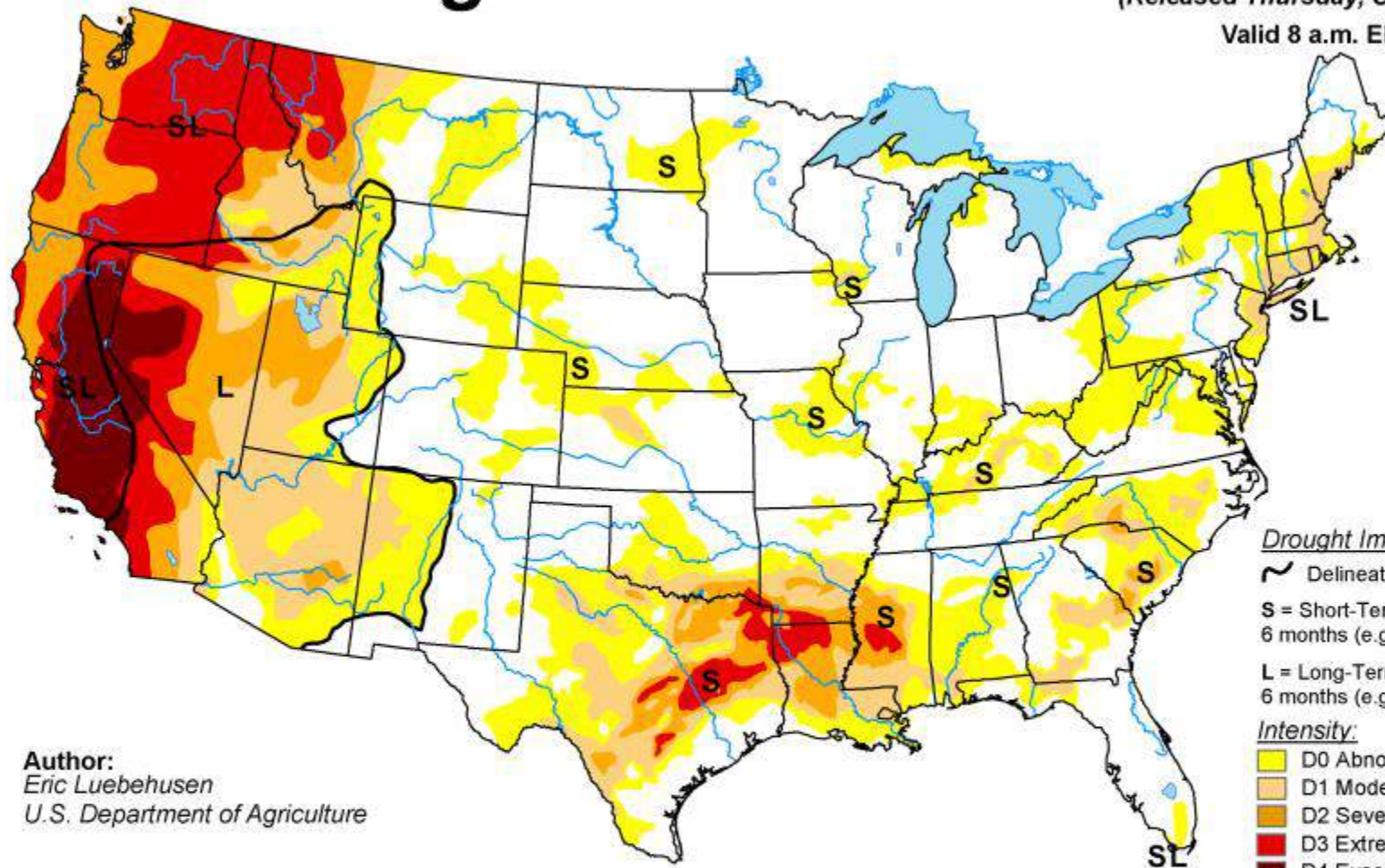
<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor

September 29, 2015

(Released Thursday, Oct. 1, 2015)

Valid 8 a.m. EDT



Author:
Eric Luebehusen
U.S. Department of Agriculture

Drought Impact Types:

~ Delineates dominant impacts

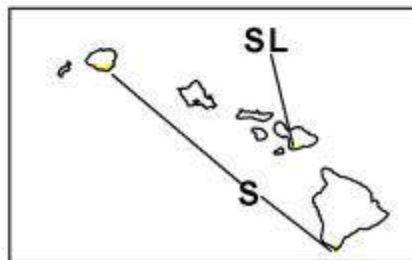
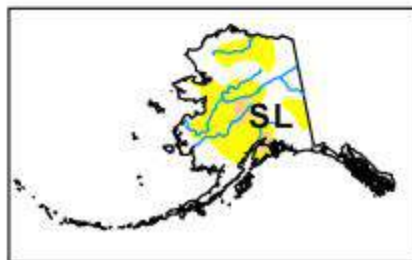
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought

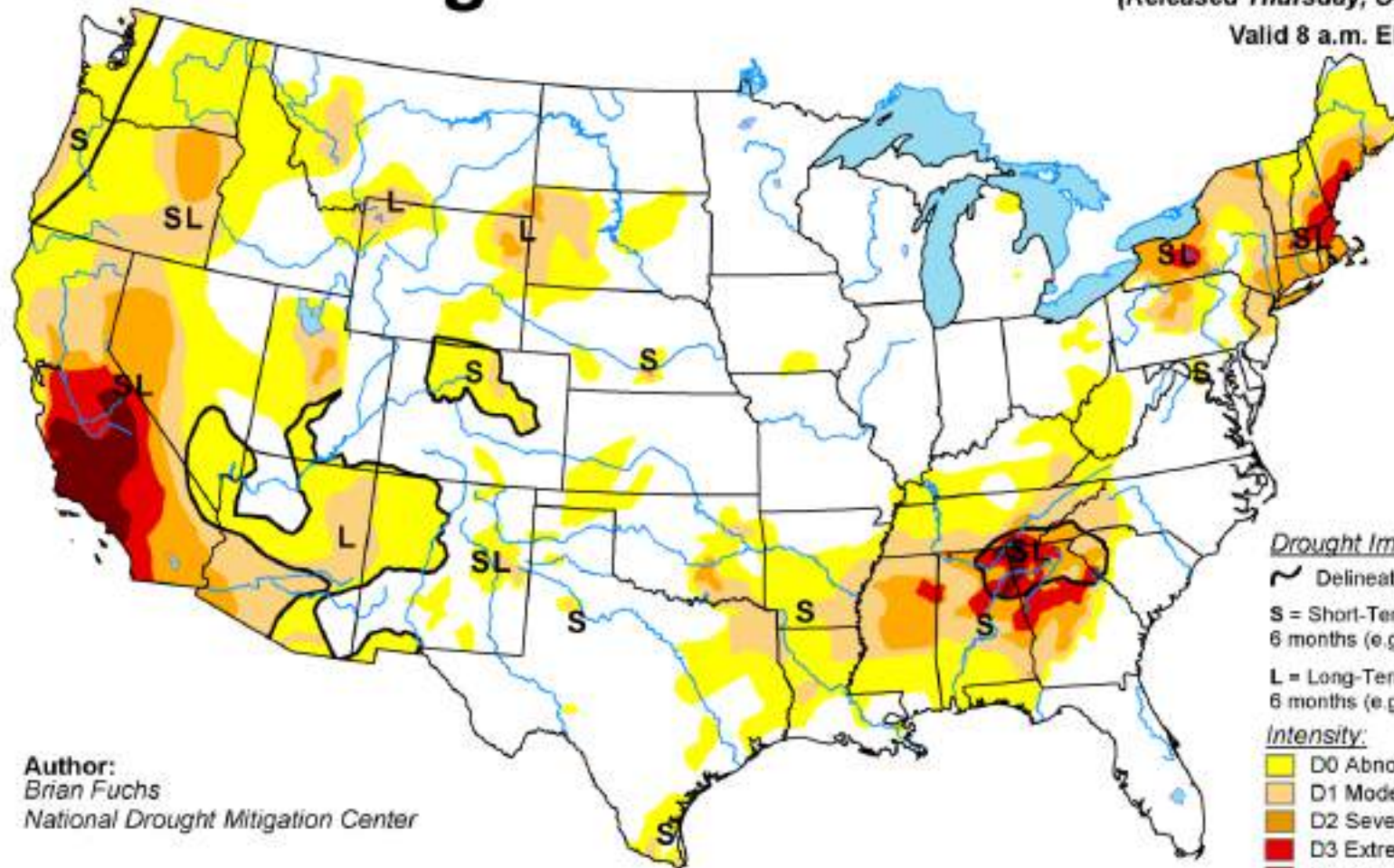
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.



<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor

October 11, 2016
(Released Thursday, Oct. 13, 2016)
Valid 8 a.m. EDT



Author:
Brian Fuchs
National Drought Mitigation Center

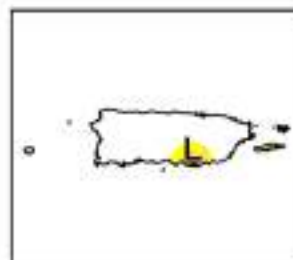
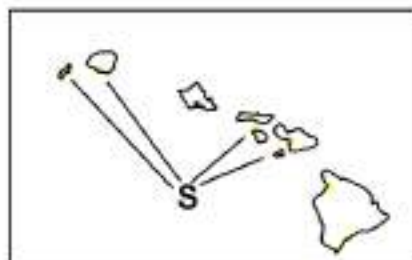
Drought Impact Types:

- ~ Delineates dominant impacts
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought

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

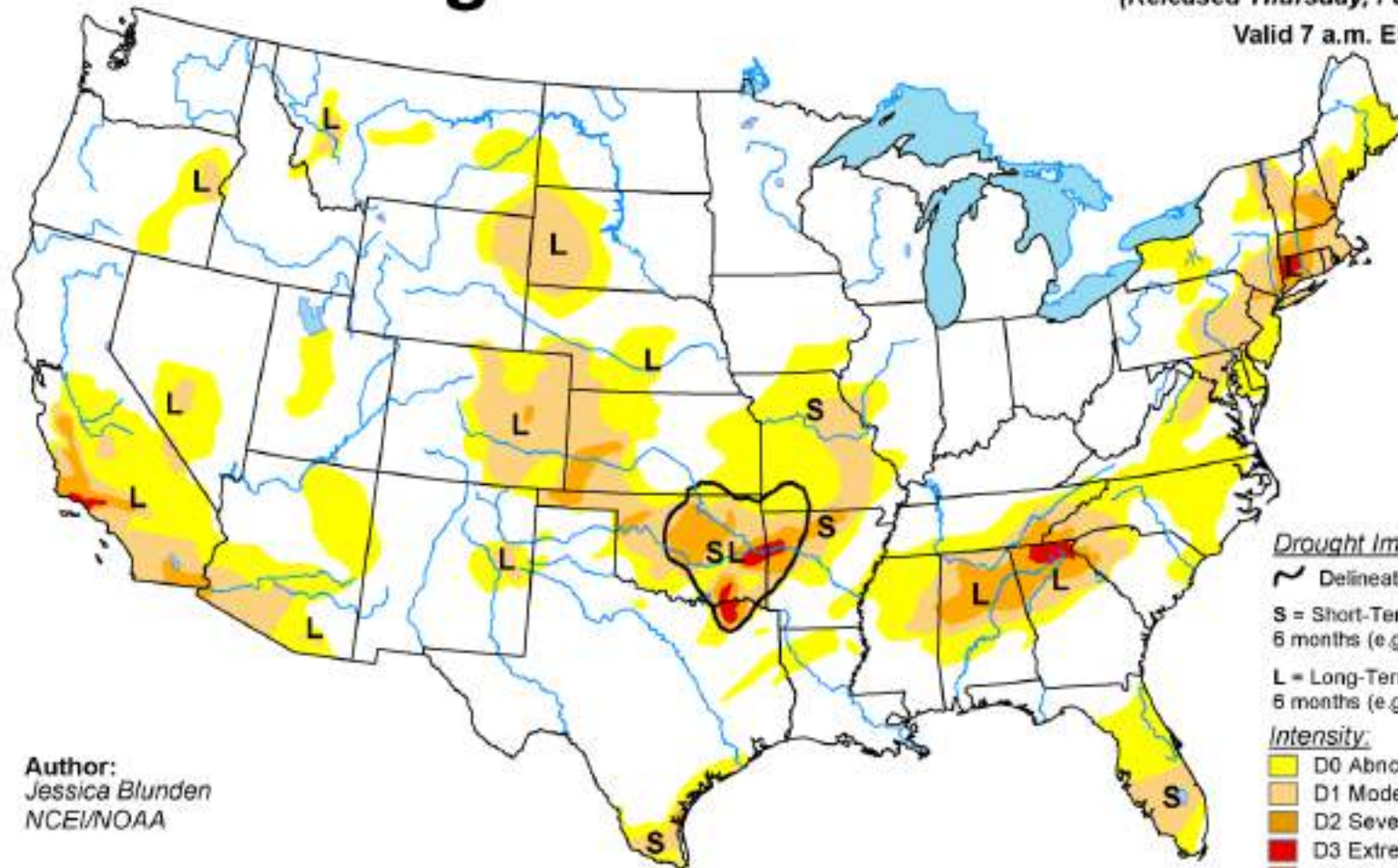


<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor

February 14, 2017
(Released Thursday, Feb. 16, 2017)

Valid 7 a.m. EST



Author:
Jessica Blunden
NCEI/NOAA

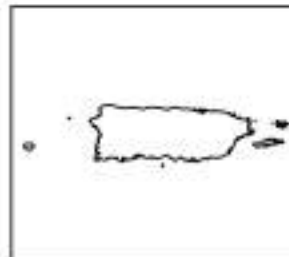
Drought Impact Types:

- ~ Delineates dominant impacts
- S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
- L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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



<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor






Total U.S.

February 28, 2017
 (Released Thursday, Mar. 2, 2017)
 Valid 7 a.m. EST

Drought Conditions (Percent Area)

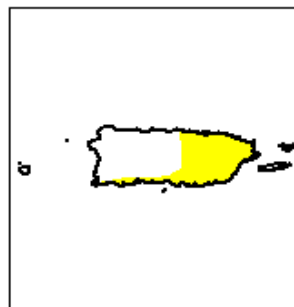
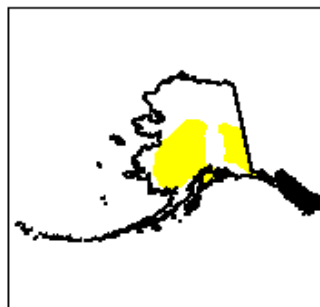
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	66.02	33.98	11.77	3.07	0.41	0.00
Last Week 2/21/2017	68.43	31.57	11.52	2.77	0.28	0.00
3 Months Ago 11/29/2016	51.45	48.55	26.29	13.87	7.23	2.24
Start of Calendar Year 1/3/2017	59.70	40.30	18.83	7.21	2.63	0.80
Start of Water Year 9/27/2016	61.21	38.79	15.85	6.77	2.67	0.97
One Year Ago 3/1/2016	71.41	28.59	12.07	6.51	3.39	1.83

Intensity:

 D0 Abnormally Dry	 D3 Extreme Drought
 D1 Moderate Drought	 D4 Exceptional Drought
 D2 Severe Drought	

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

Author:
 Richard Heim
 NCEI/NOAA

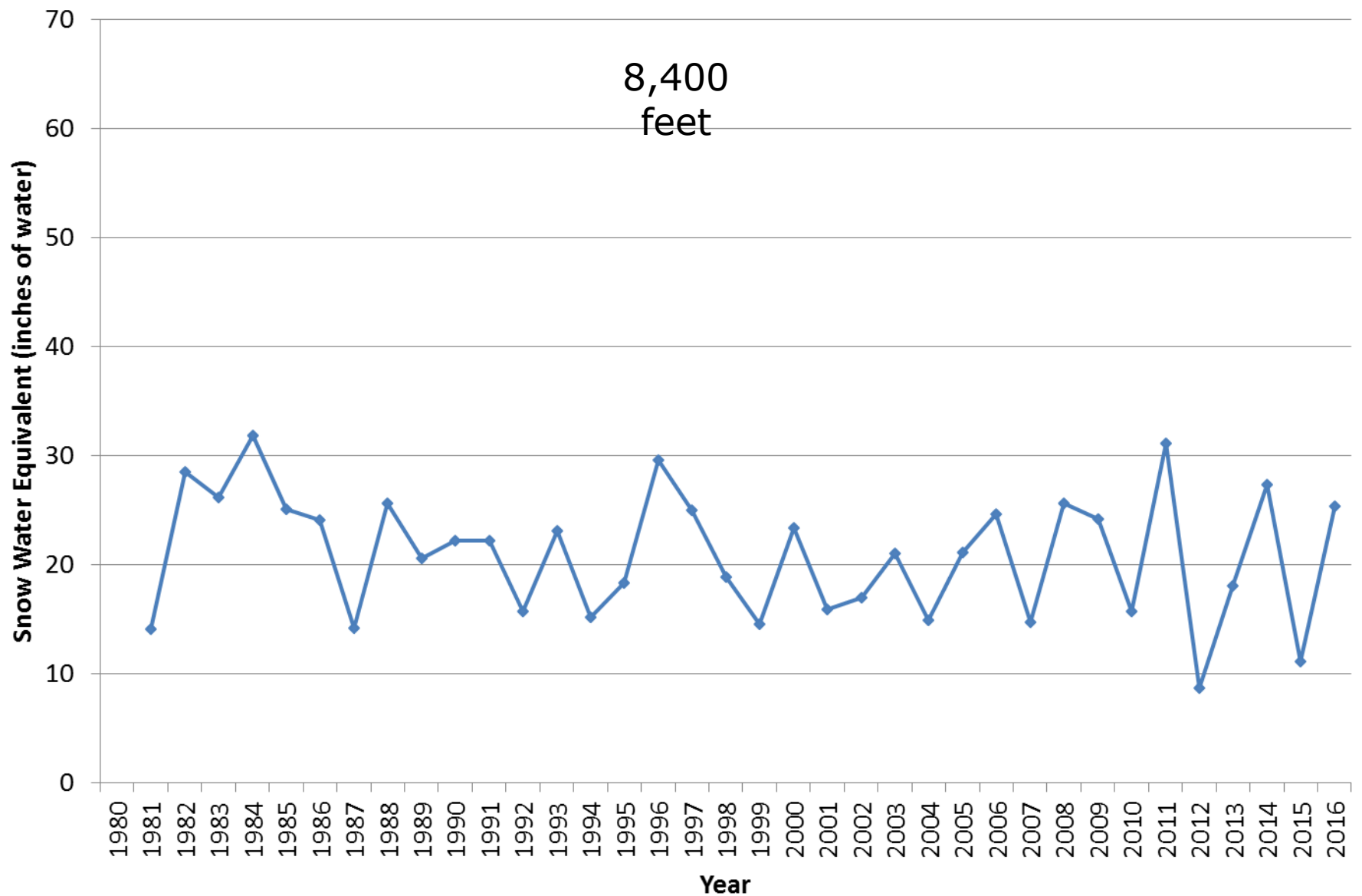


<http://droughtmonitor.unl.edu/>

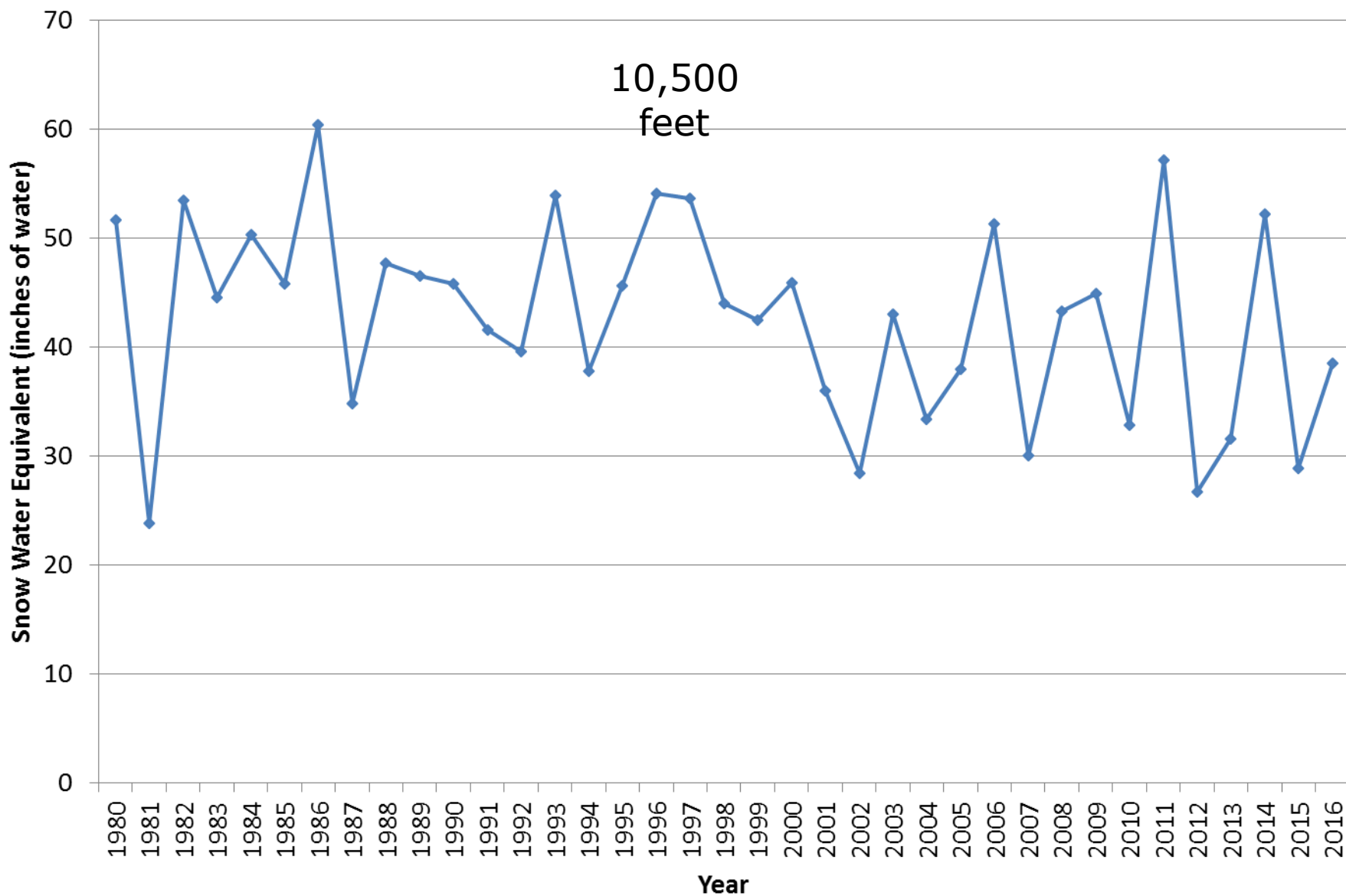
What about our mountain Snowpack?



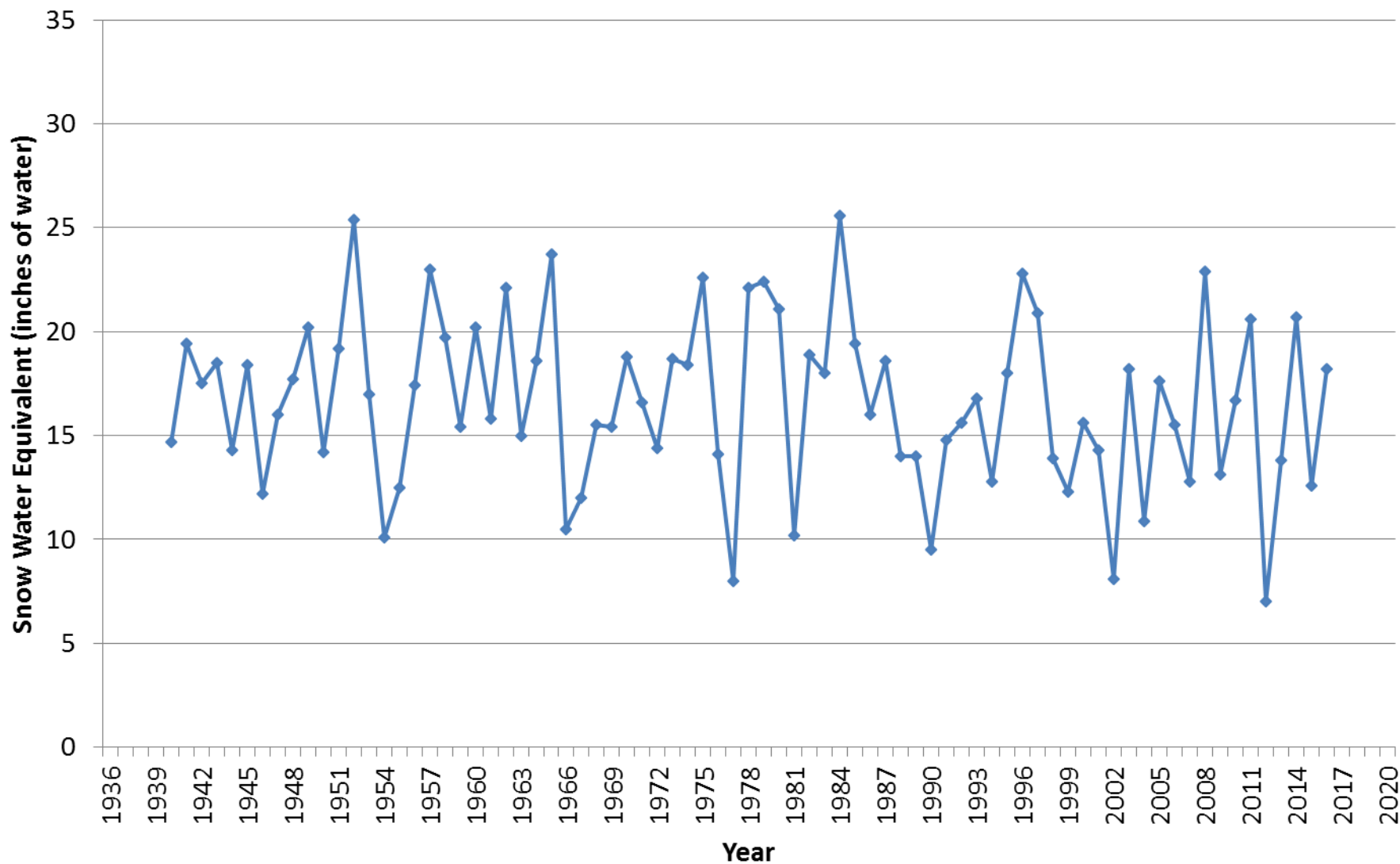
Dry Lake SNOTEL April 1 Snow Water Equivalent (in)



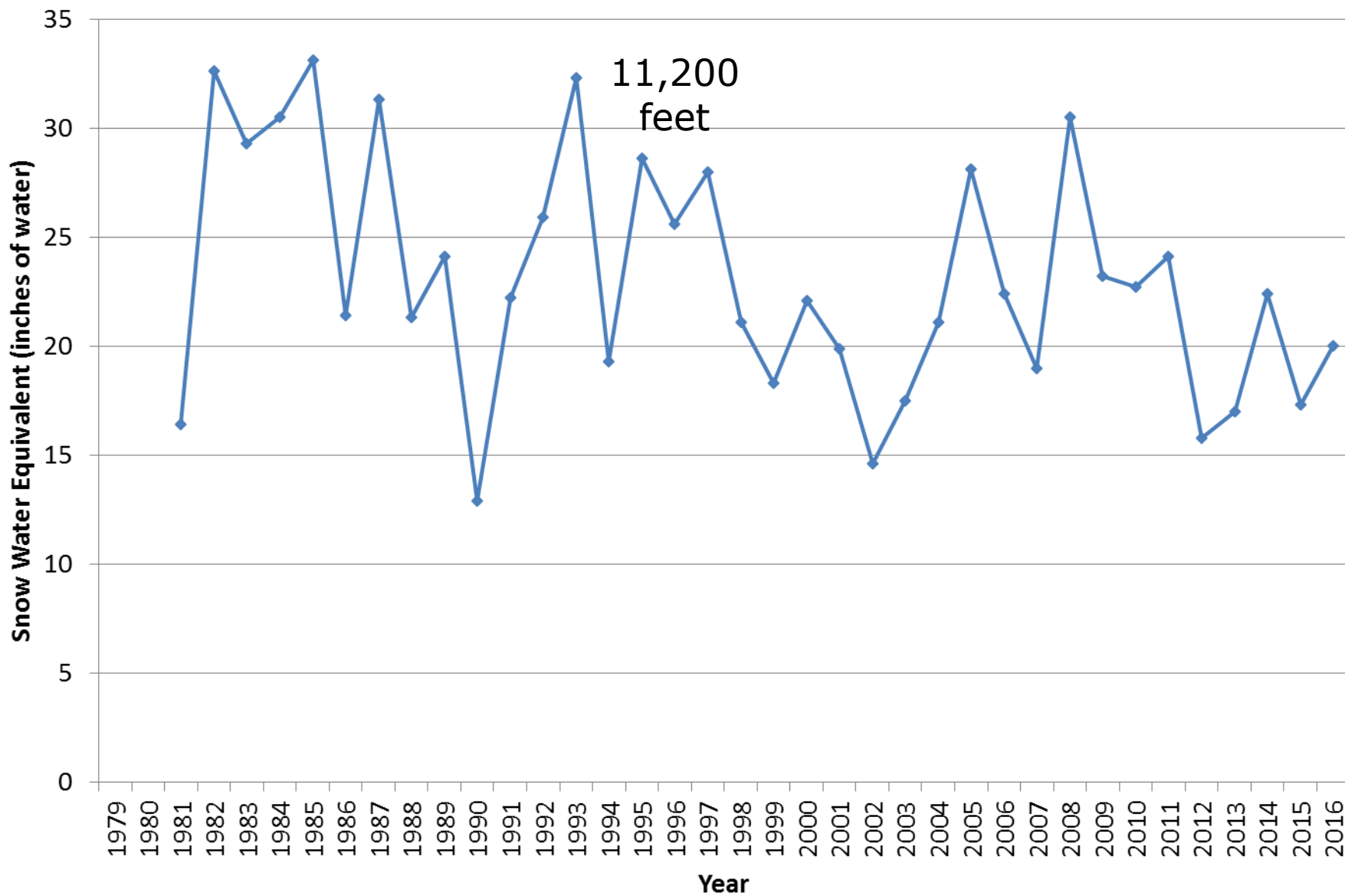
Tower SNOTEL April 1 Snow Water Equivalent (in)



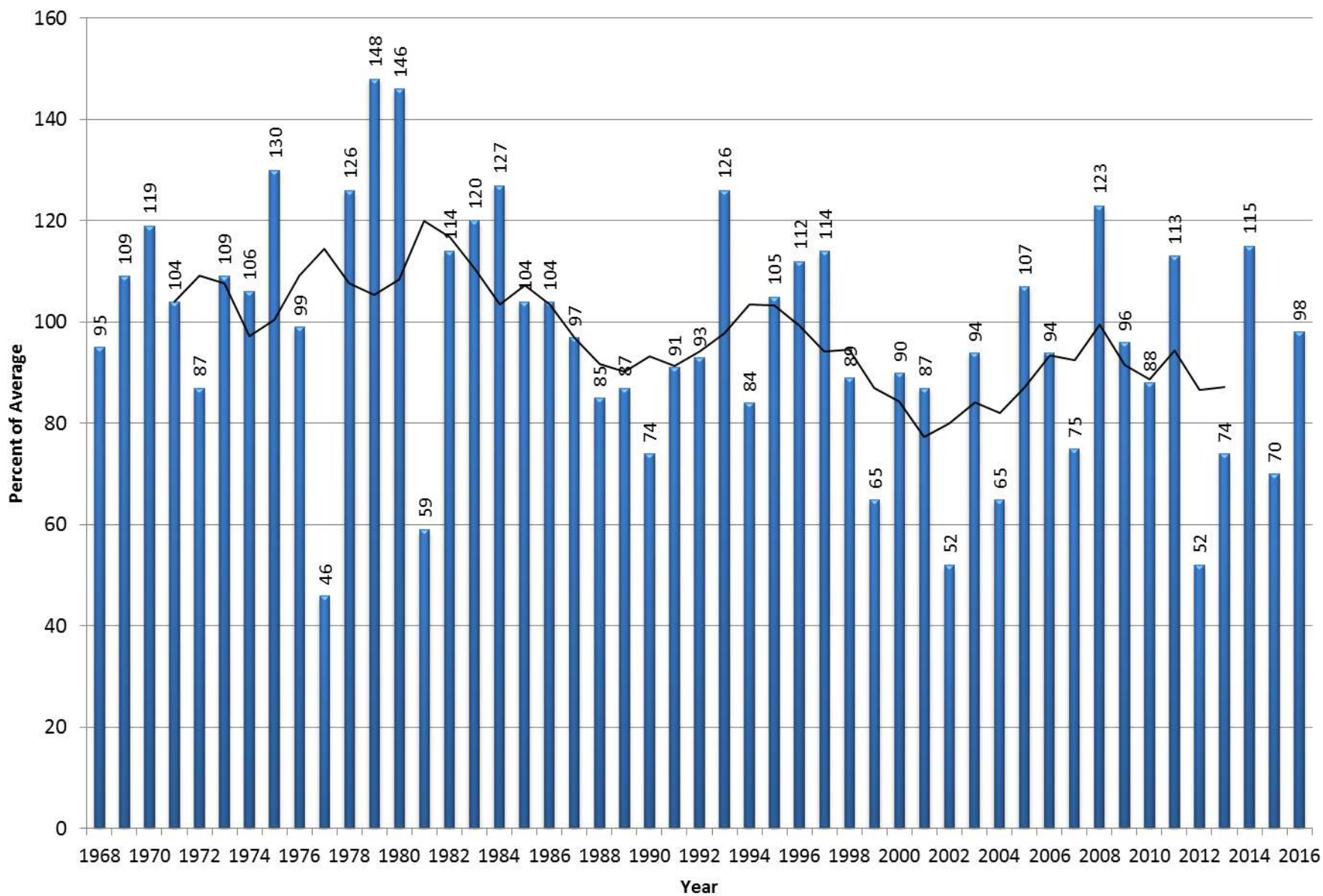
Porphyry Creek Snow Course April 1 Snow Water Equivalent



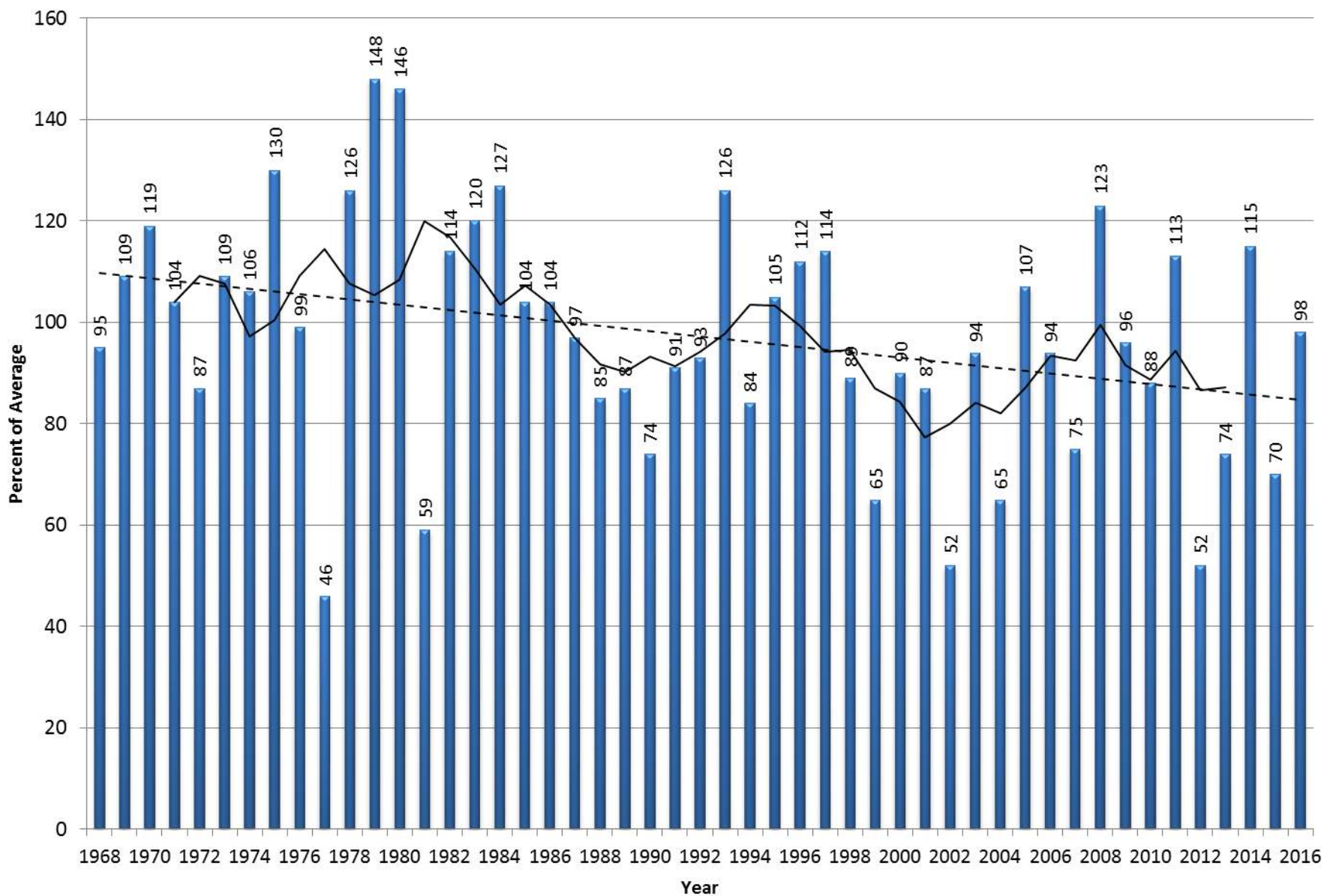
Red Mountain Pass April 1 Snow Water Equivalent (in)



April 1 Colorado Statewide Snowpack



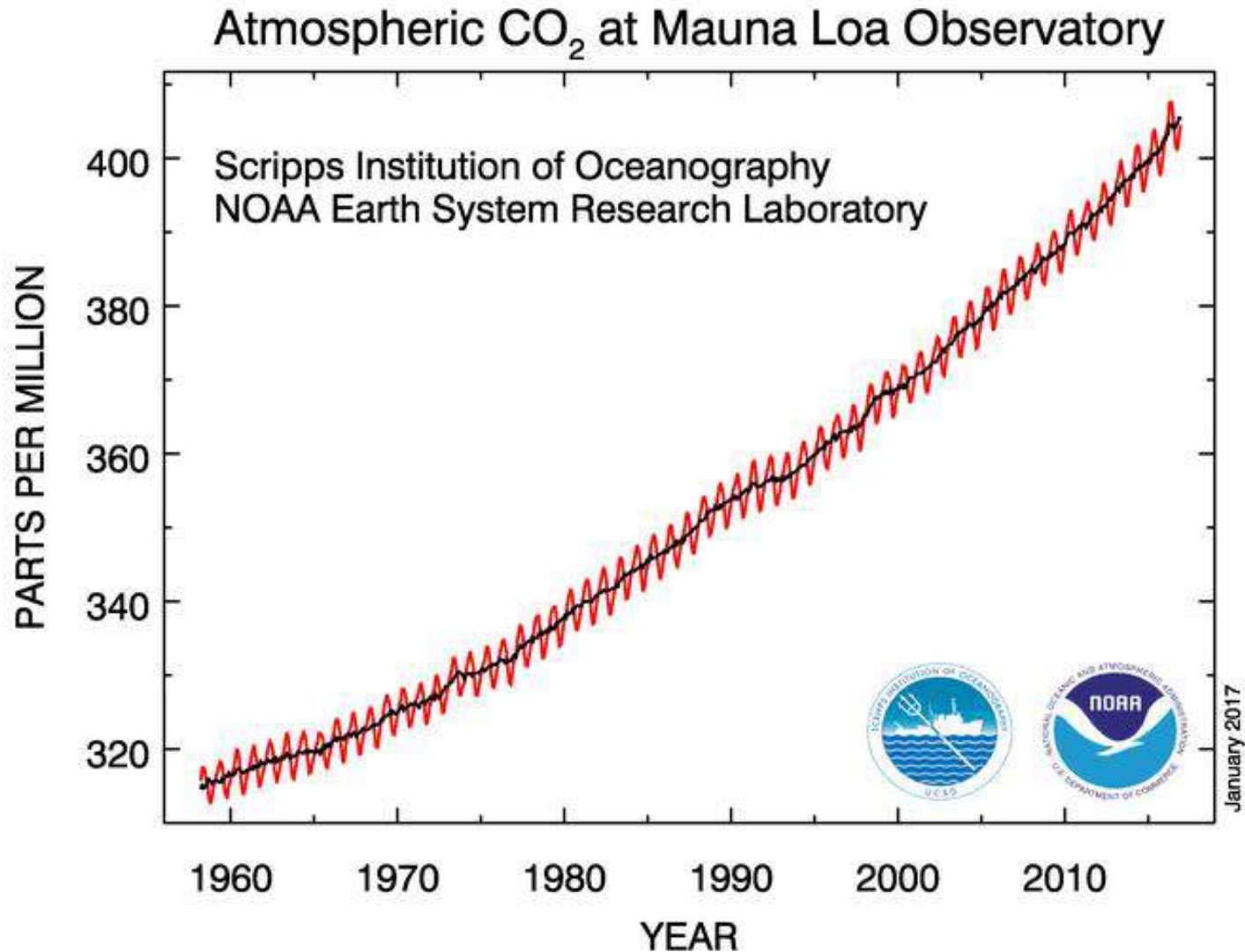
April 1 Colorado Statewide Snowpack



Summary

- We've got a great climate but with some interesting challenges.**
- Temperatures in Colorado are warming, especially since 1980**
- More really warm days, fewer really cold days**
- Trends in Colorado are similar to U.S and Globe**
- Growing season longer but irregular**
- No significant trends in precipitation yet**
- Recent drought episodes hotter**
- April 1 snowpack declining**

And then, there's this to think about



We don't see it
We don't smell it
It's just a minor fraction of
our atmosphere

and yet

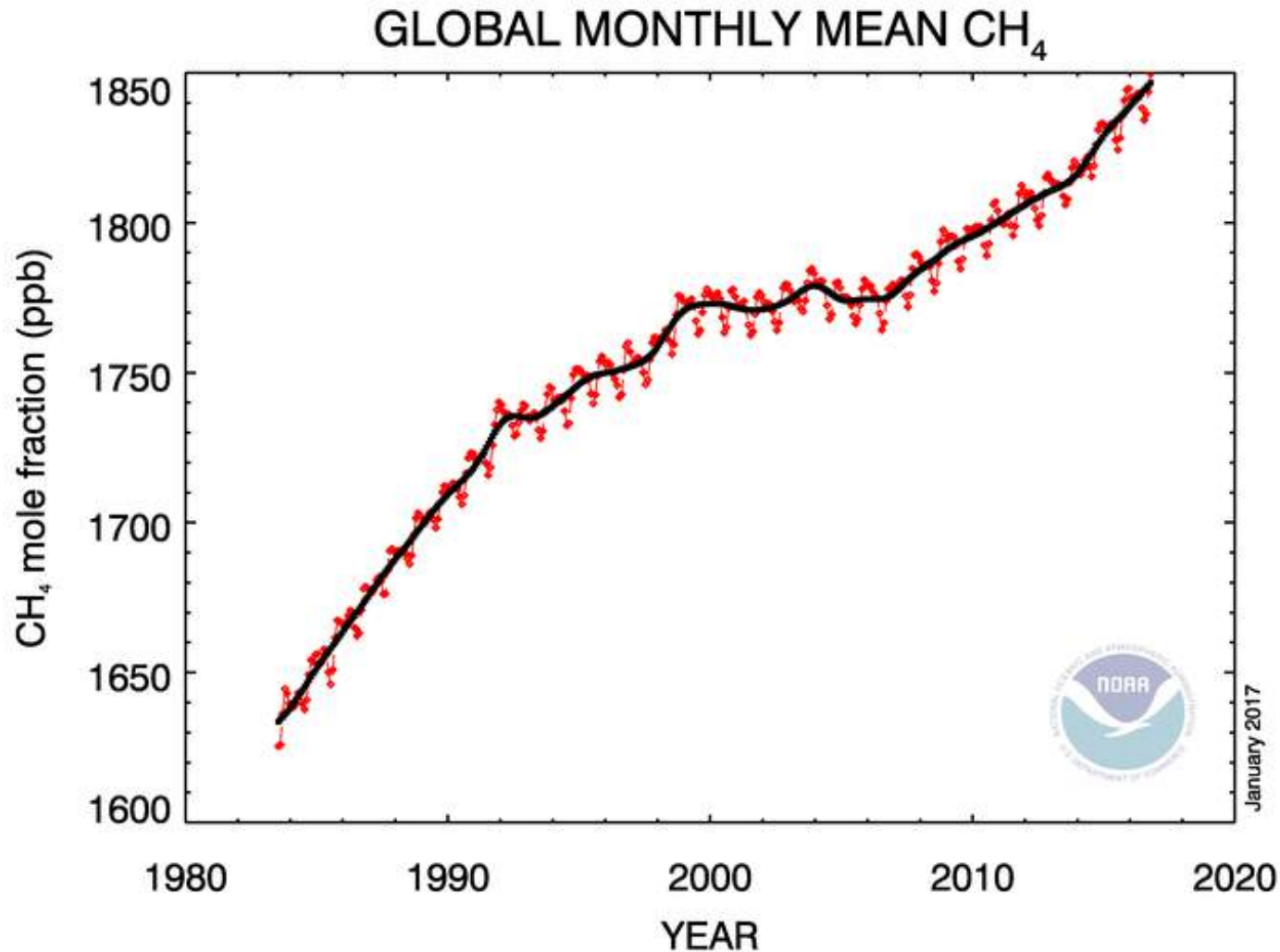
It may be a game changer

Global carbon emissions continue to increase

We have surpassed 400 parts per million of carbon dioxide in our atmosphere – highest level in the past 800,000 years

The rate of increase is still accelerating

And Methane too – what to do?



**These gases let sunshine into the
atmosphere with very little
attenuation**

**However, they trap heat energy in the
atmosphere**

Temperature (Annual)

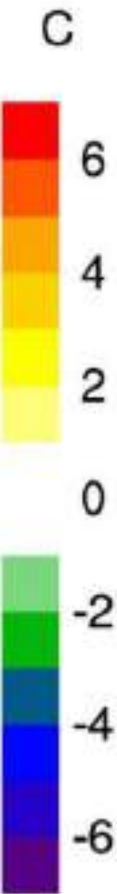
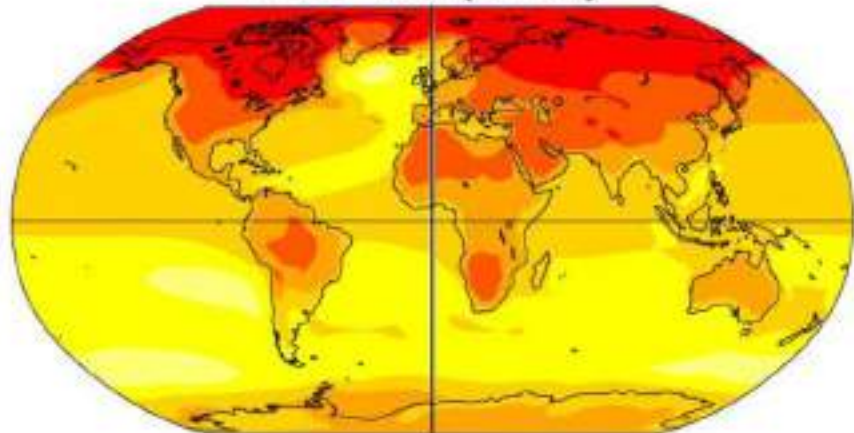
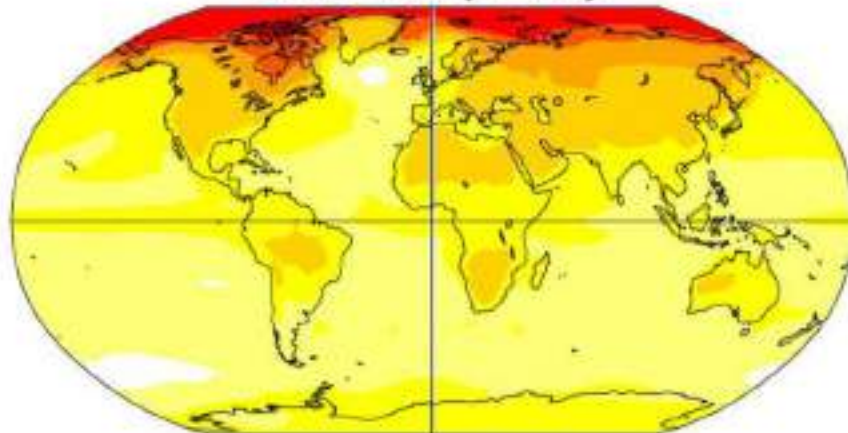
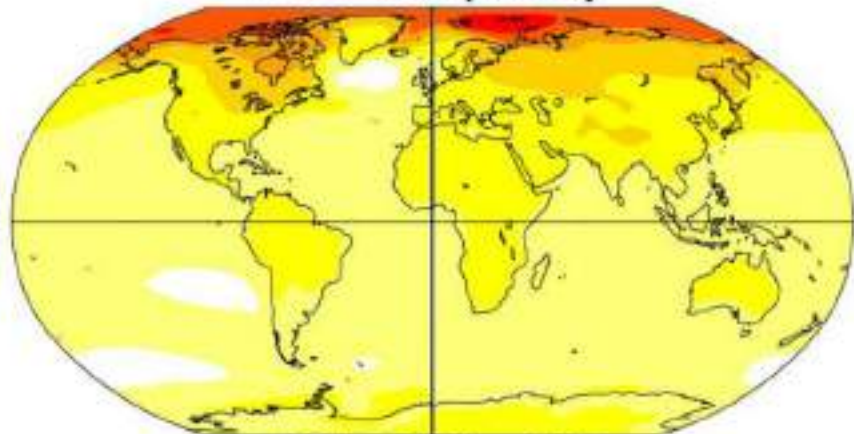
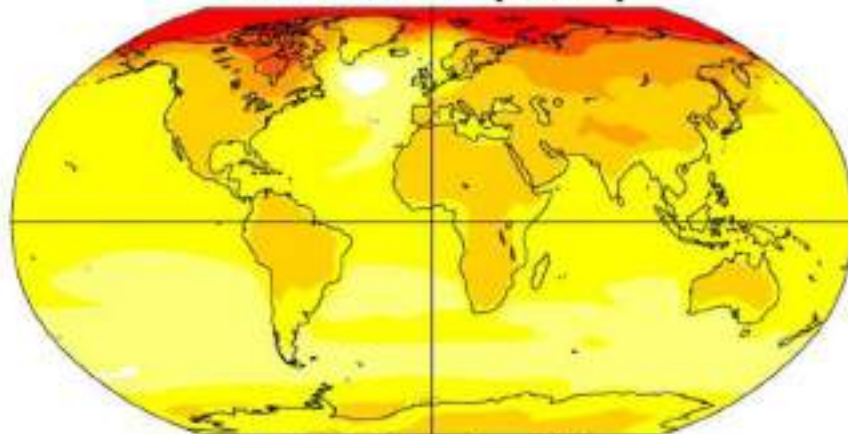
2081-2100 MINUS 1981-2000

SRES A1B (n=23)

RCP 4.5 (n=42)

RCP 6.0 (n=25)

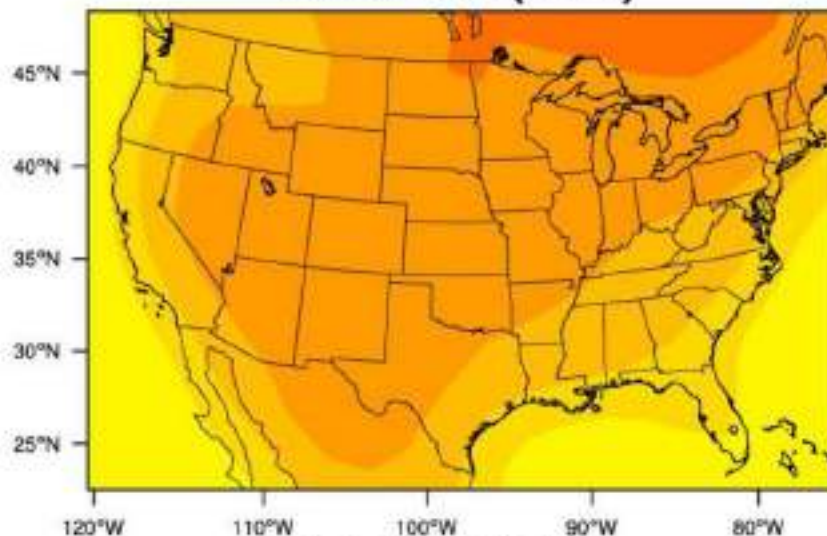
RCP 8.5 (n=39)



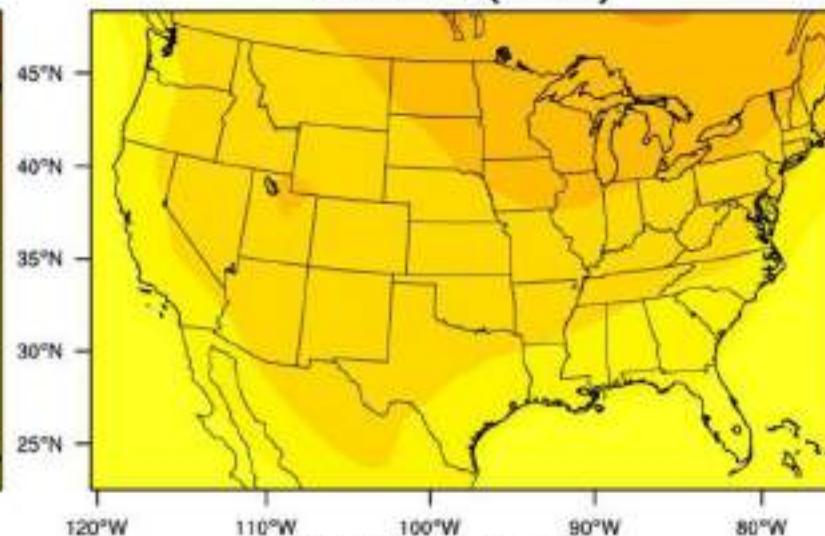
Temperature (Annual)

2081-2100 MINUS 1981-2000

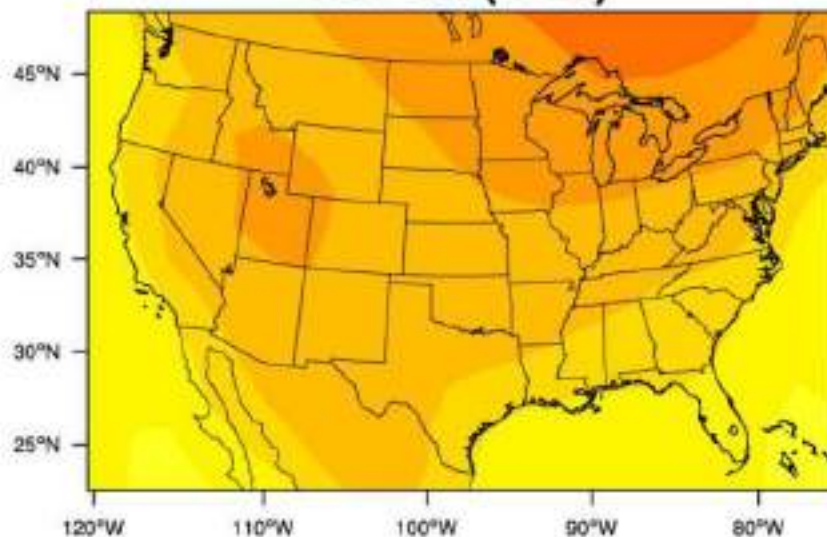
SRES A1B (n=23)



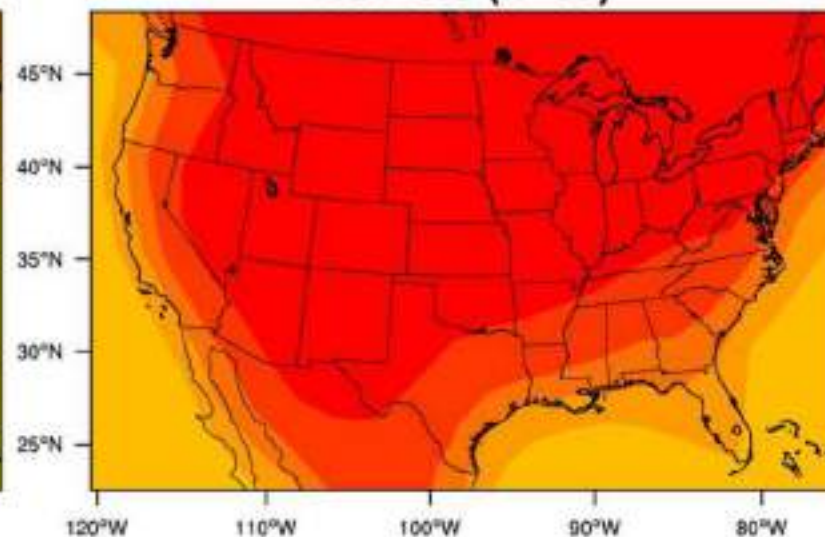
RCP 4.5 (n=42)



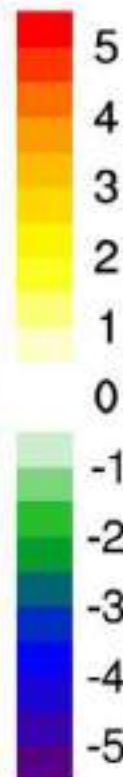
RCP 6.0 (n=25)



RCP 8.5 (n=39)



C

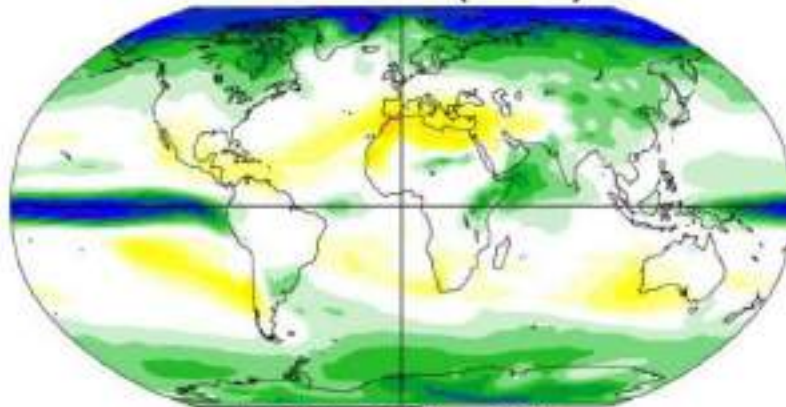


Globally, spatial pattern of change very similar between CMIP3 and CMIP5

Precipitation (Annual) 2081-2100 MINUS 1981-2000

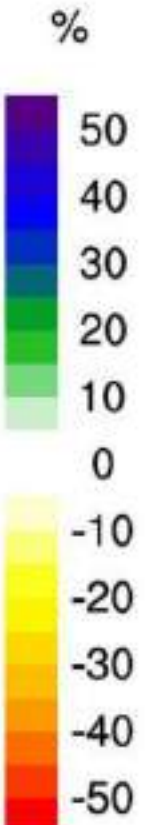
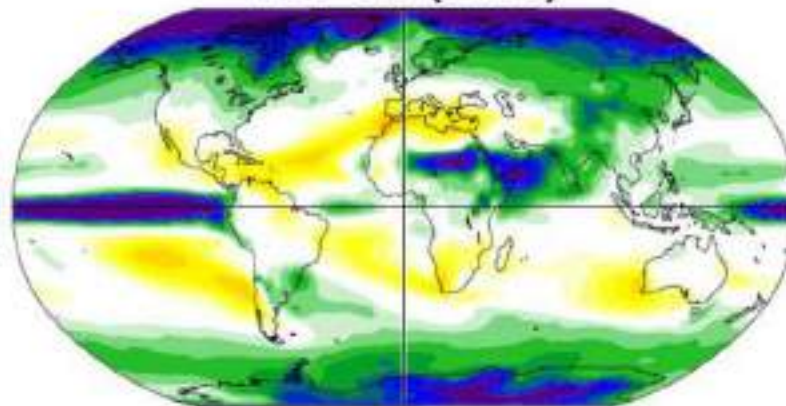
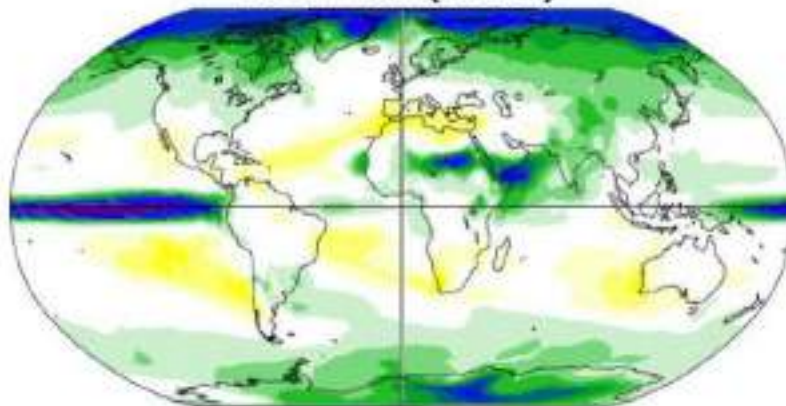
SRES A1B (n=23)

RCP 4.5 (n=42)



RCP 6.0 (n=25)

RCP 8.5 (n=39)



n = # of individual model ensembles (many more individual models in there)

- These similarities consistent at seasonal scales
- Magnitude of change is generally a function of the emission scenario

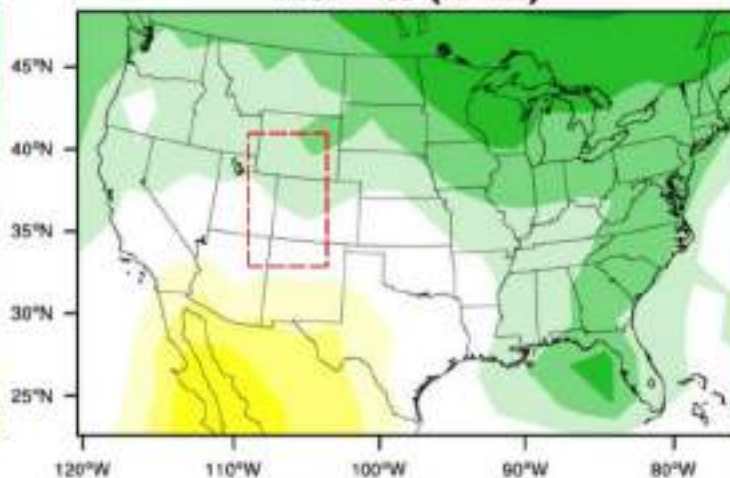
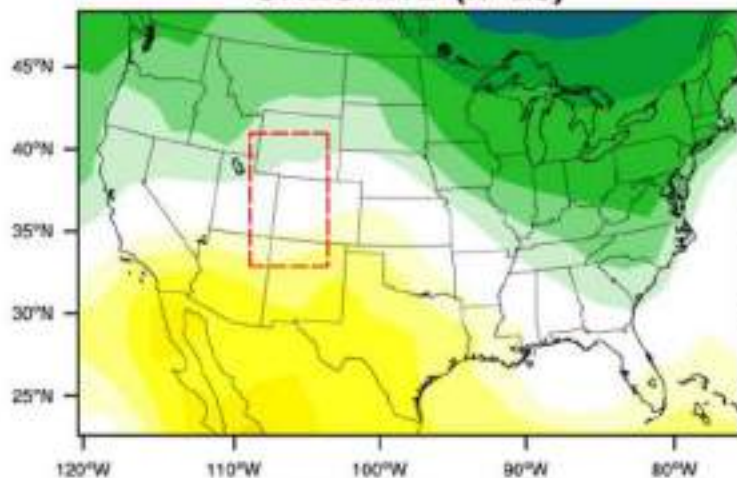
Zooming in onto the US....

Precipitation (Annual)

2081-2100 MINUS 1981-2000

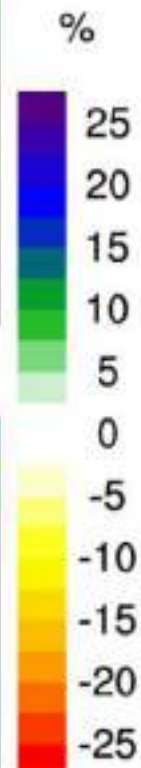
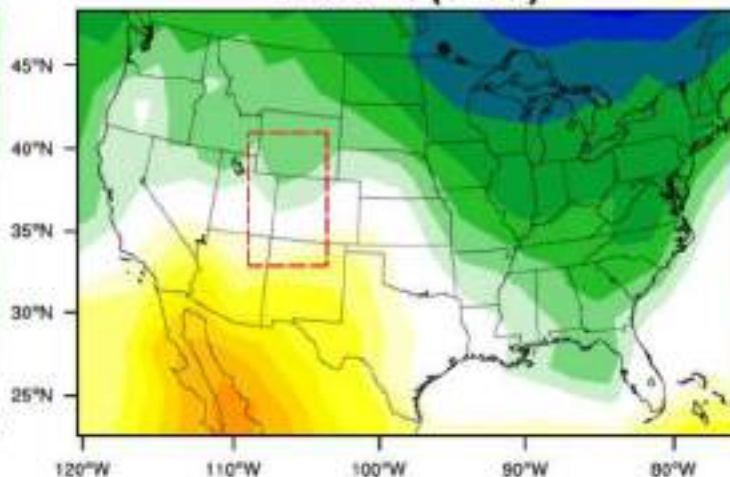
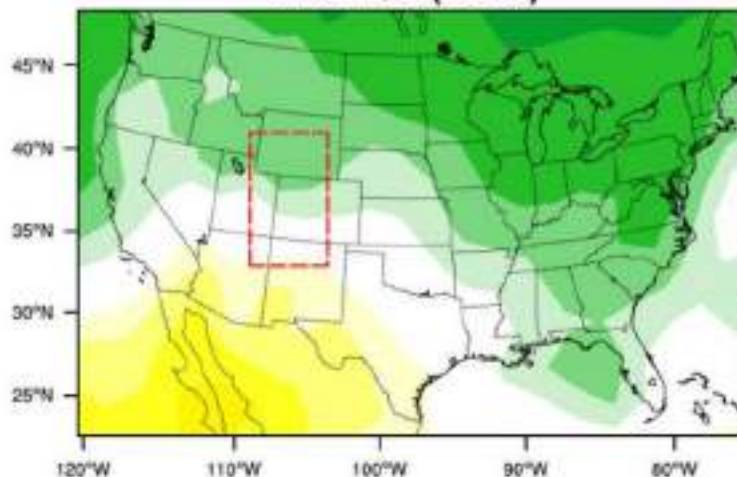
SRES A1B (n=23)

RCP 4.5 (n=42)



RCP 6.0 (n=25)

RCP 8.5 (n=39)



□ Broader scale patterns remain the same between CMIP3 and CMIP5 but some finer scale differences noticable. Are they significant for the Upper CO Basin??? **Model Reality???**

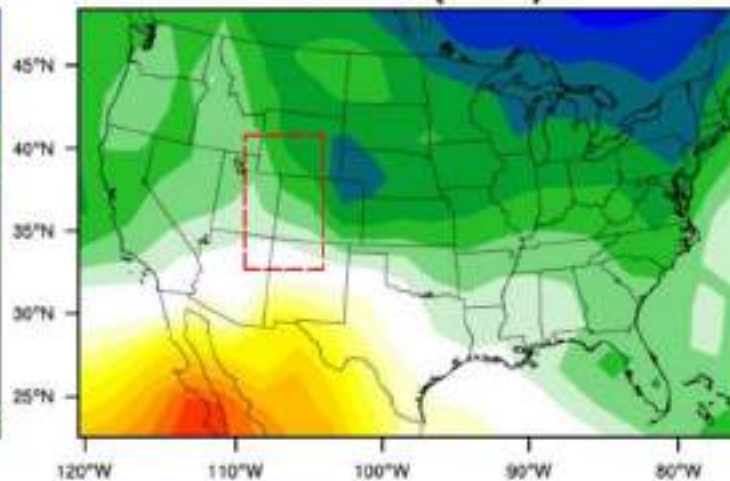
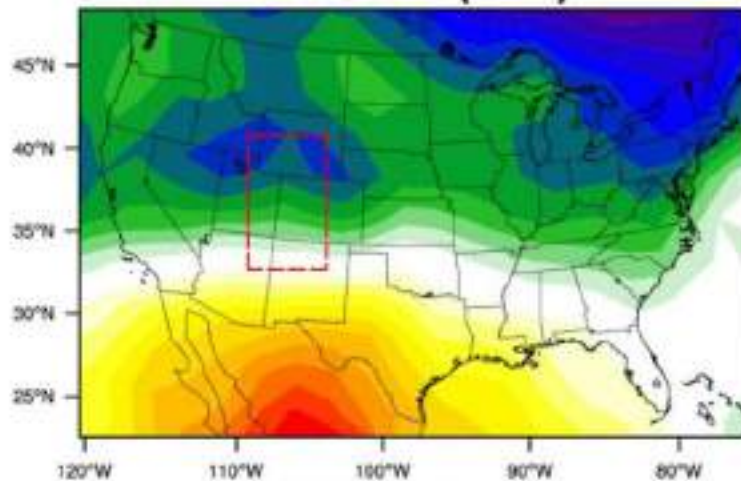
Winter precip....

Precipitation (DJF)

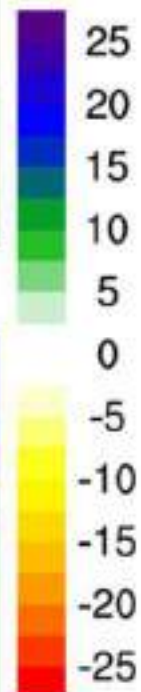
2081-2100 MINUS 1981-2000

SRES A1B (n=23)

RCP 4.5 (n=42)

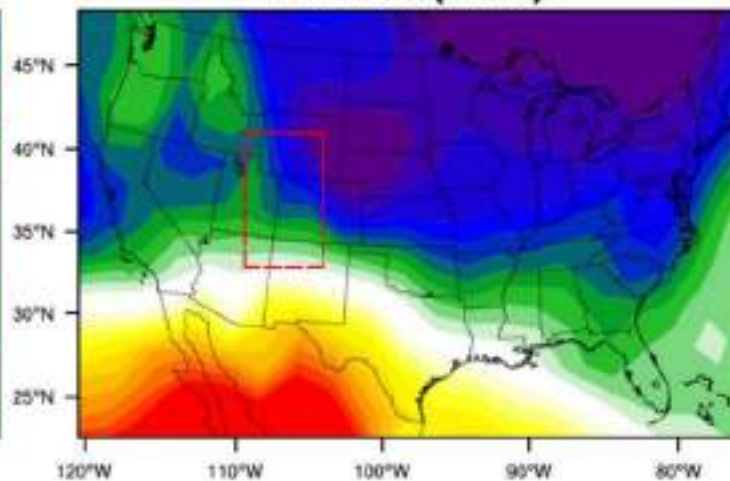
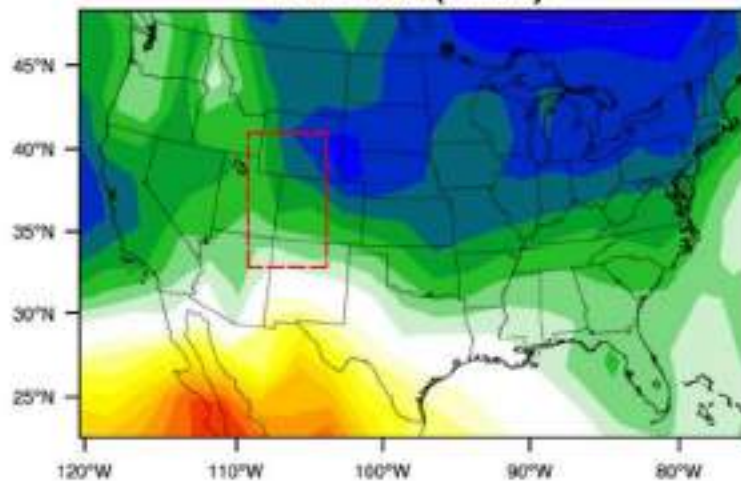


%



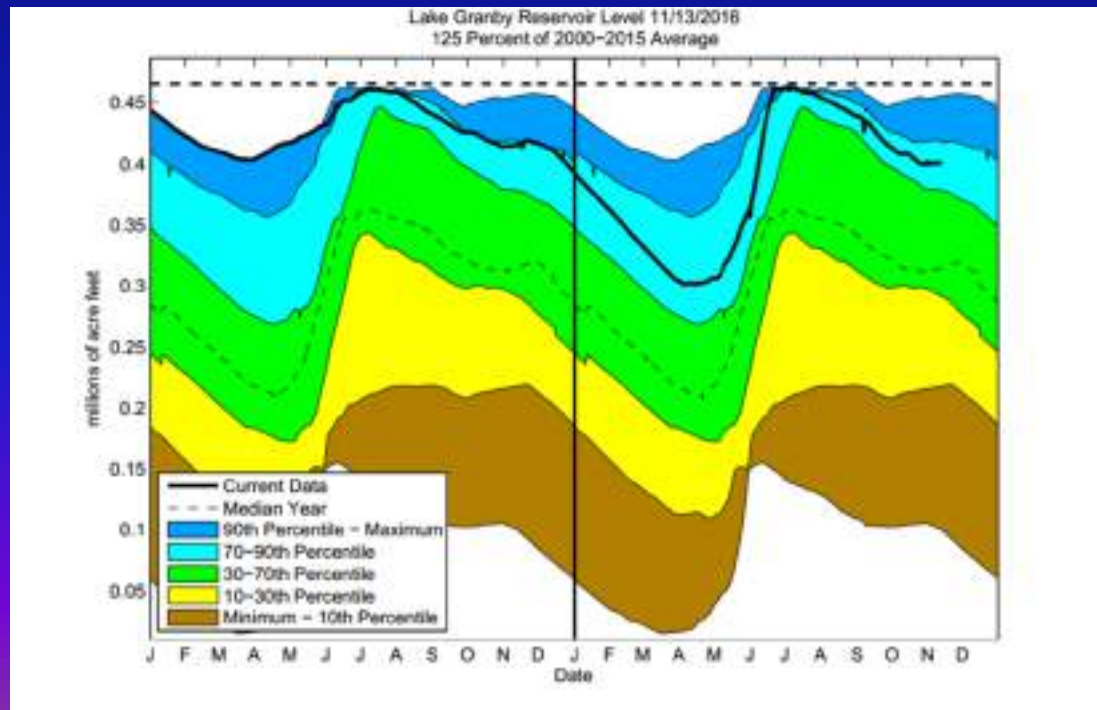
RCP 6.0 (n=25)

RCP 8.5 (n=39)



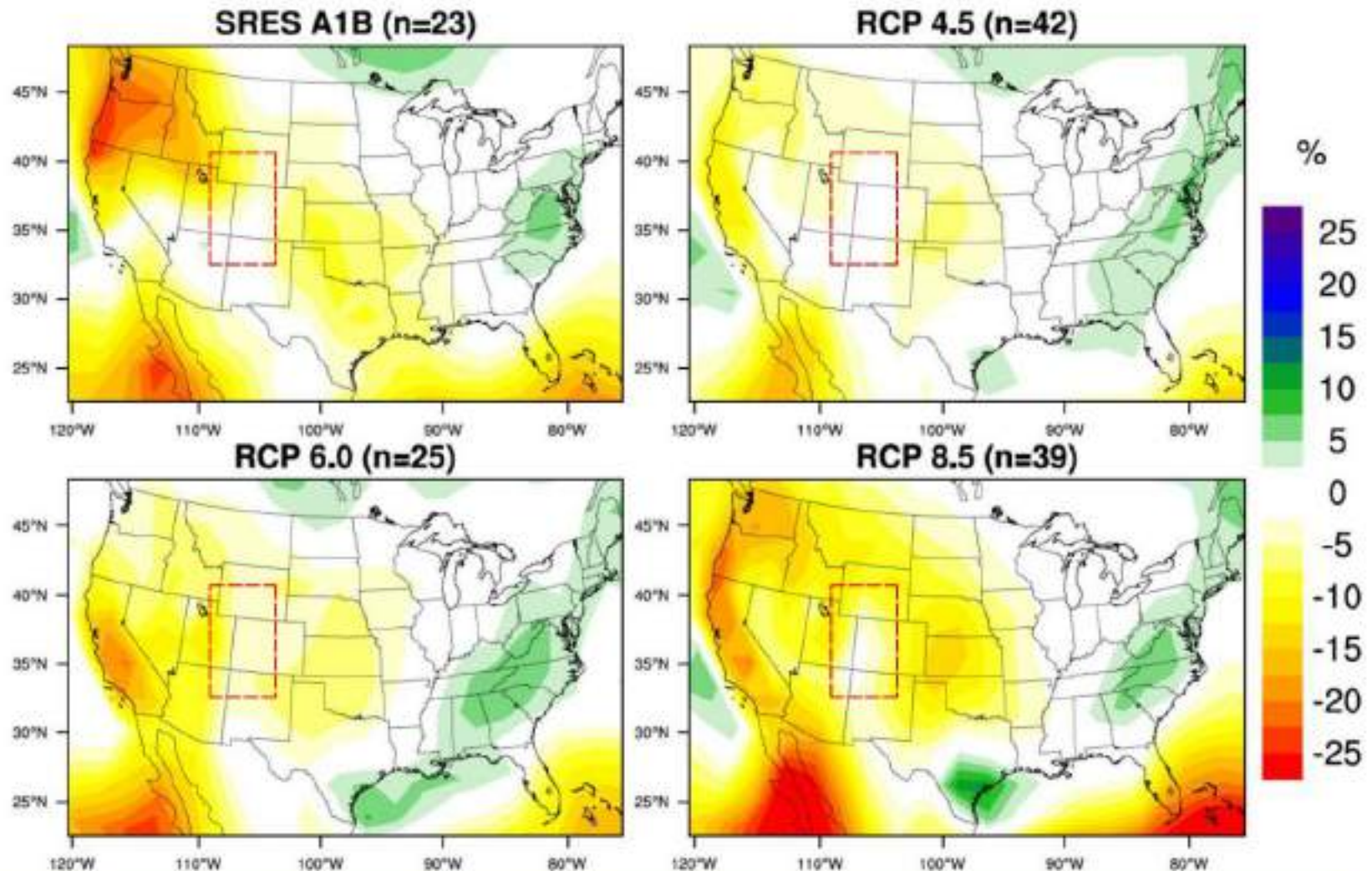
- ❑ Very similar increases between CMIP3 and CMIP5 for the Upper CO Basin. Enhanced increases under a higher emission scenario.

**So if you love
DATA
We can help**



Summer precip....

Precipitation (JJA) 2081-2100 MINUS 1981-2000

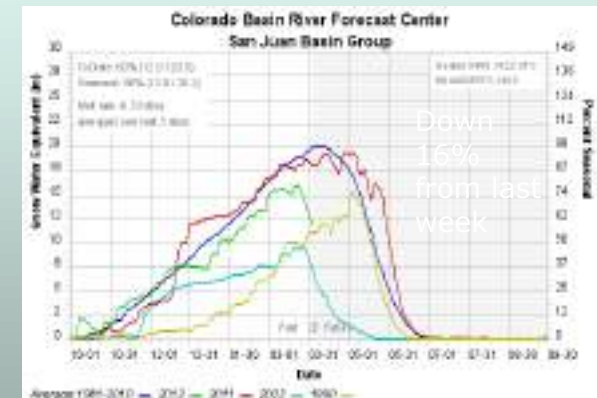
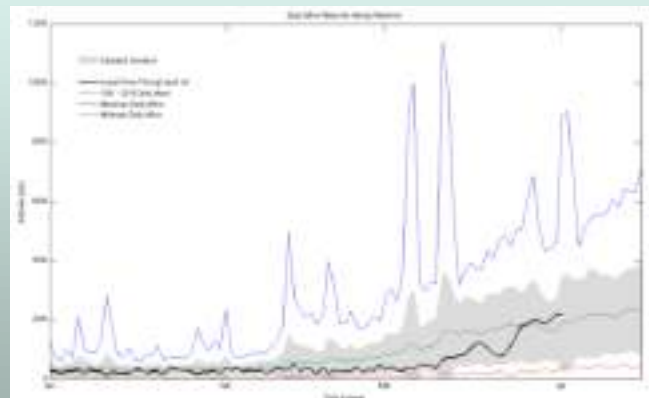
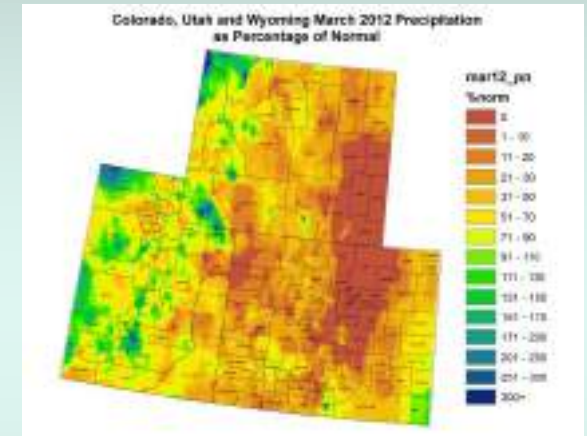
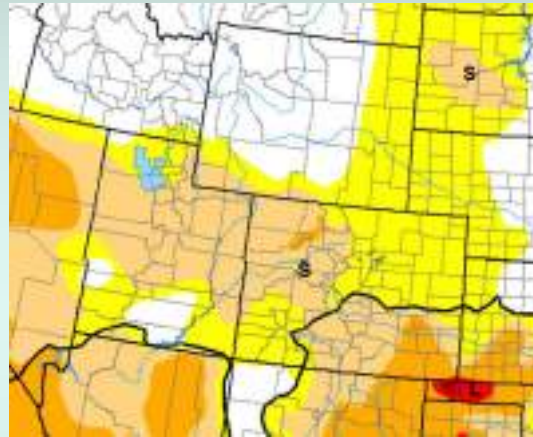
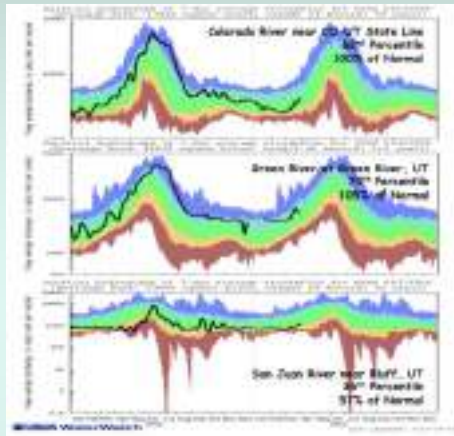


- Slightly greater decreases for US Southwest in CMIP5
- Summer time large scale atmospheric processes (e.g. monsoonal flows) still not adequately modeled

Vegetation responds to an atmosphere enriched with more carbon dioxide, even without changes in temperature or precip.



Weekly Climate and Water Supply updates Available



And we could use your help!



When in doubt, help us out!

Help measure and report rainfall!



THANKS to you who
measure or provide
support



Photos by H. Reges

CoCoRaHS

If you are interested in contributing your DOT
ON THE MAP, please join
the Community Collaborative Rain, Hail and
Snow Network

<http://www.cocorahs.org>

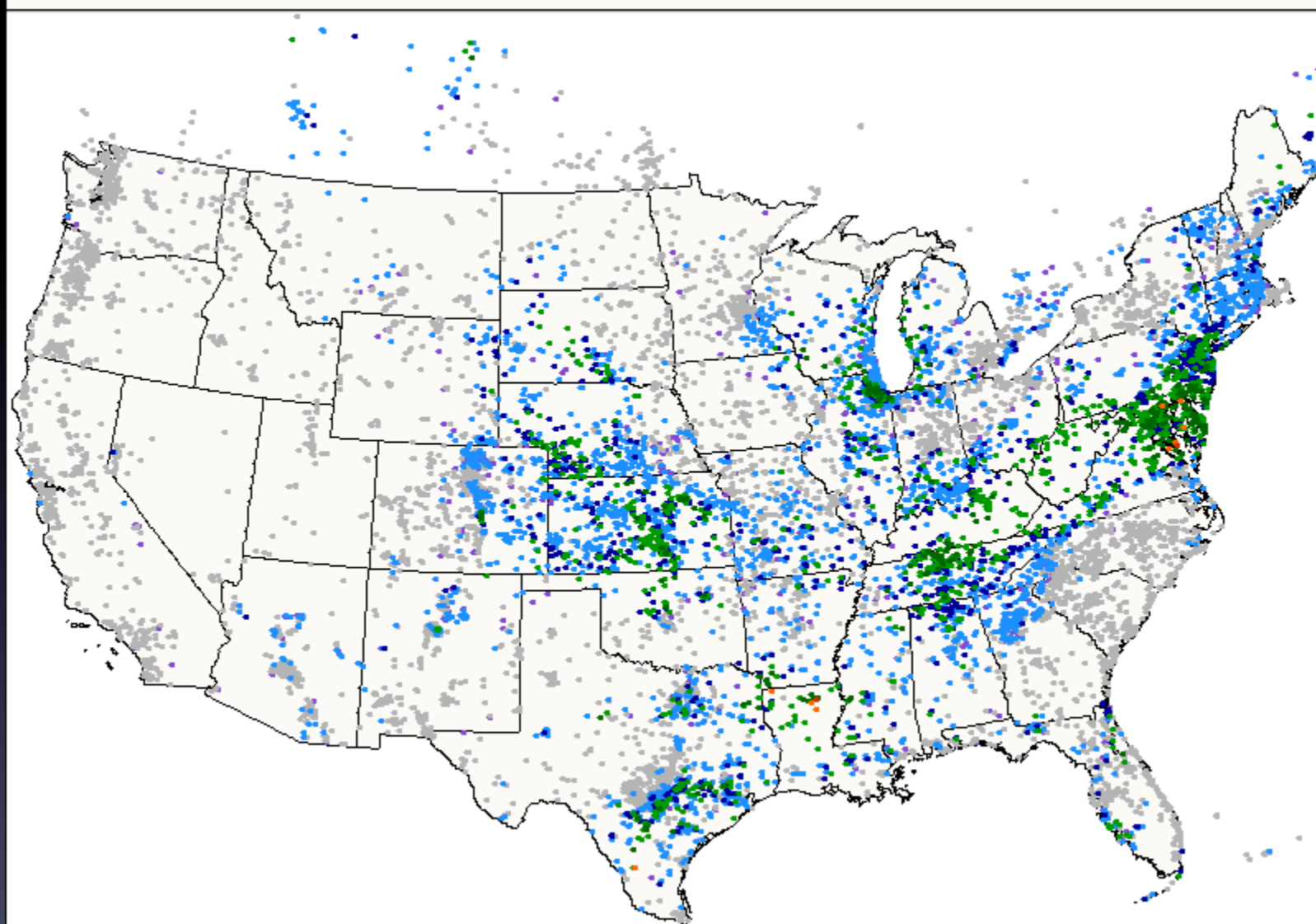
or see me today



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

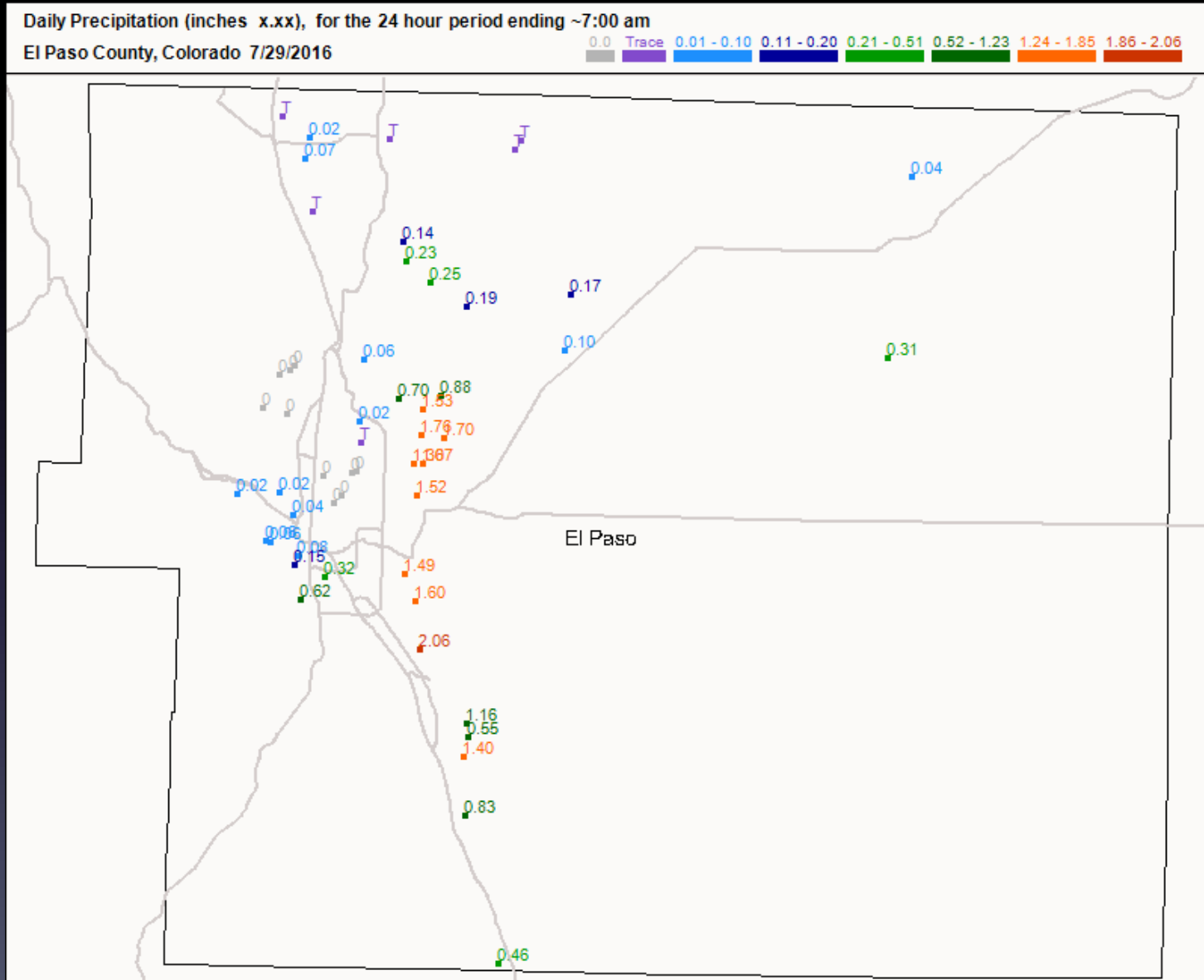
USA 7/29/2016

0.0 Trace 0.01 - 0.32 0.33 - 0.64 0.65 - 1.58 1.59 - 3.78 3.79 - 5.67 5.68 - 6.30



A Small Effort

A Great Value



**For information and to volunteer, visit
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www.cocorahs.org

OR SEE ME TODAY!



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