Westmap:
The Western Climate Mapping Initiative
An Update

Andrew Comrie[1], Kelly Redmond[2], Mary Glueck[1], Hauss Reinbold[3], Chris Daly[4]

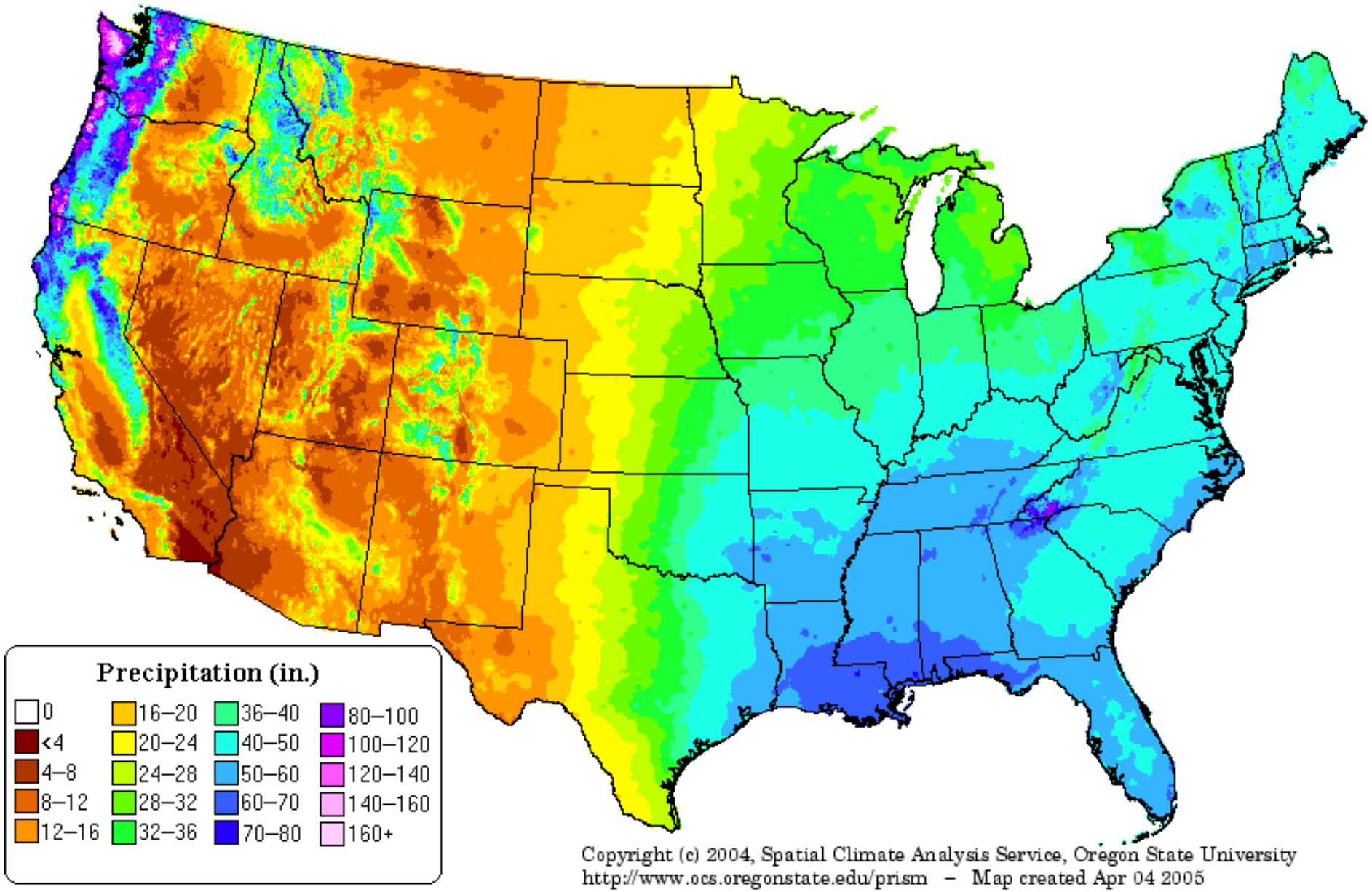
1 – University of Arizona,
2 – DRI / Western Regional Climate Center
3 – DRI / Climate Ecosystem & Fire Applications,
4 – OSU Spatial Climate Analysis Center

Supported by NOAA Climate Transition Program

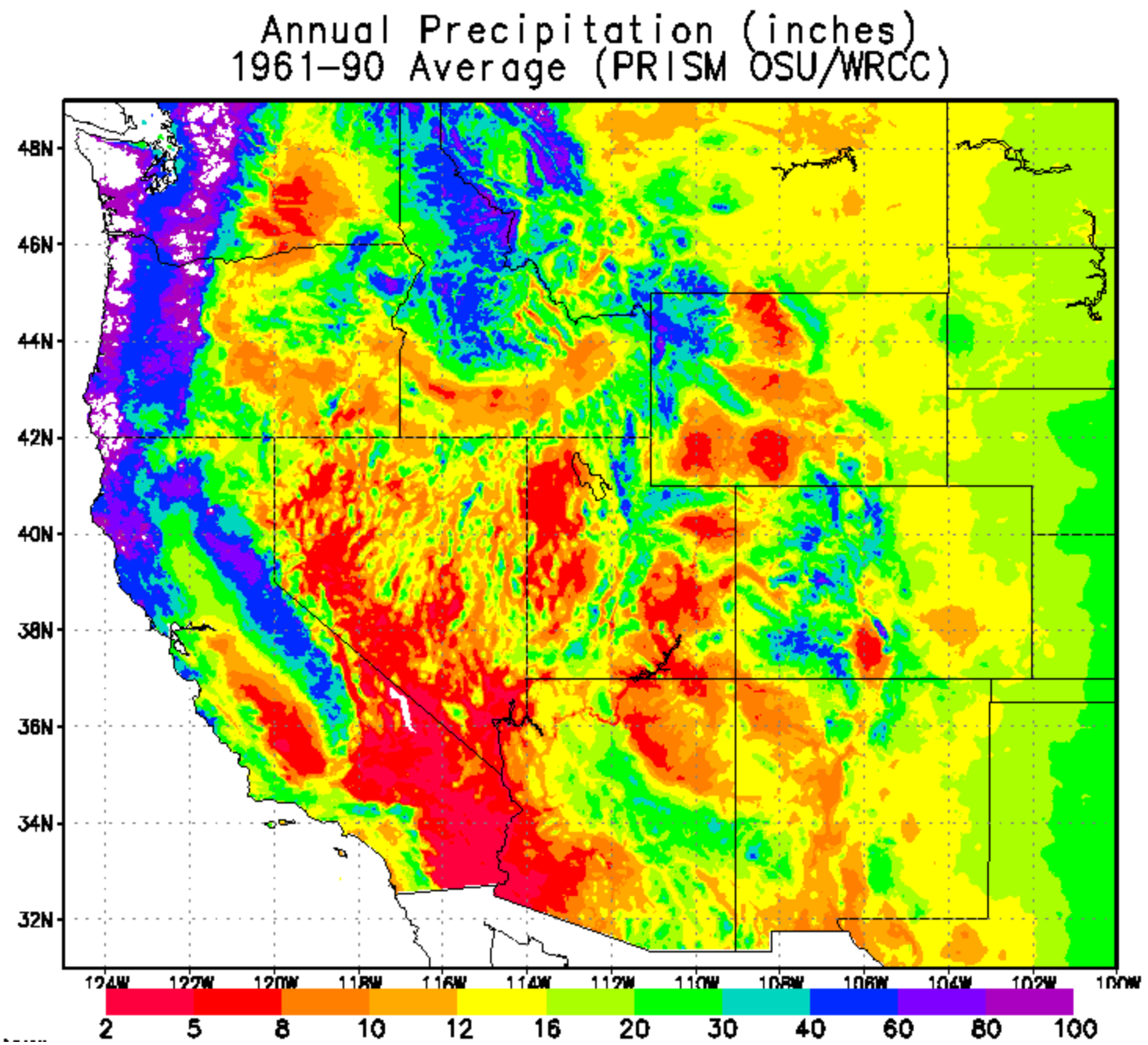
Climate Predictions Applications Science Workshop – CPASW
Tucson Arizona March 21-24, 2006

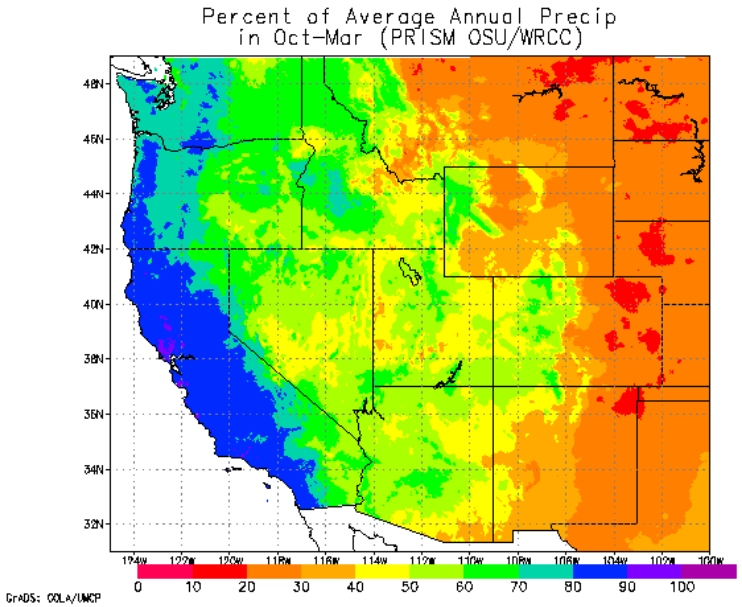
Western Regional
Climate Center

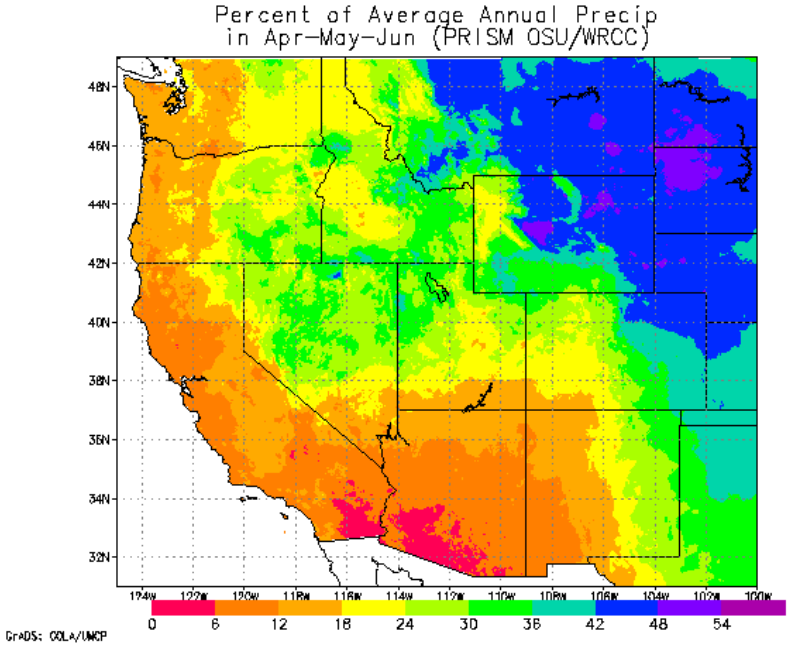
Precipitation: Annual Climatology (1971–2000)

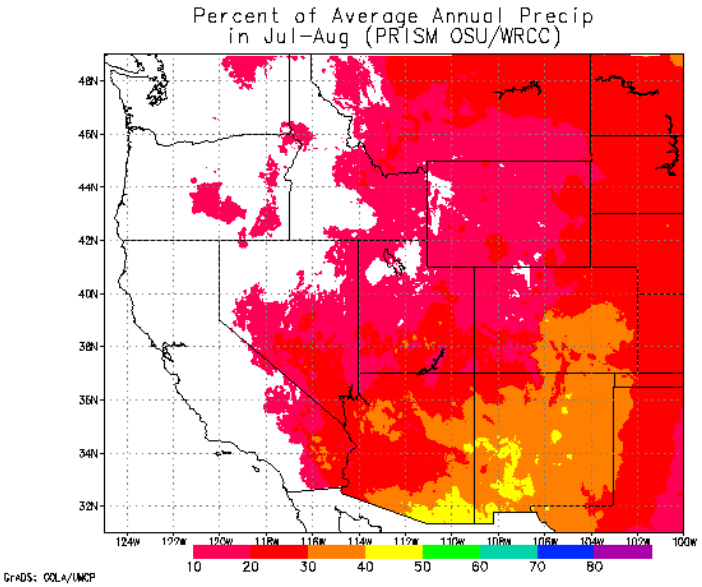


http://www.ocs.oregonstate.edu/prism – Map created Apr 04 2005


Annual Precipitation (inches)
1961–90 Average (PRISM OSU/WRCC)
48N
46N
44N
42N
40N
38N
36N
34N
32N
124W
122W
120W
118W
116W
114W
112W
110W
108W
106W
104W
102W
100W
2
5
8
10
12
16
20
30
40
60
80
100







Oct-Mar **Apr-May-June**

Fraction of Annual Total Precipitation, by Season

July-Aug

Climate Variability

Surface climate can be thought of in terms of three dimensional spatial patterns that are evolving in time.

In this particular version, those patterns are represented by a 4-km gridded monthly precipitation and temperature (Tmax, Tmin, Tave) data set, from previous OSU-SCAS projects using PRISM.

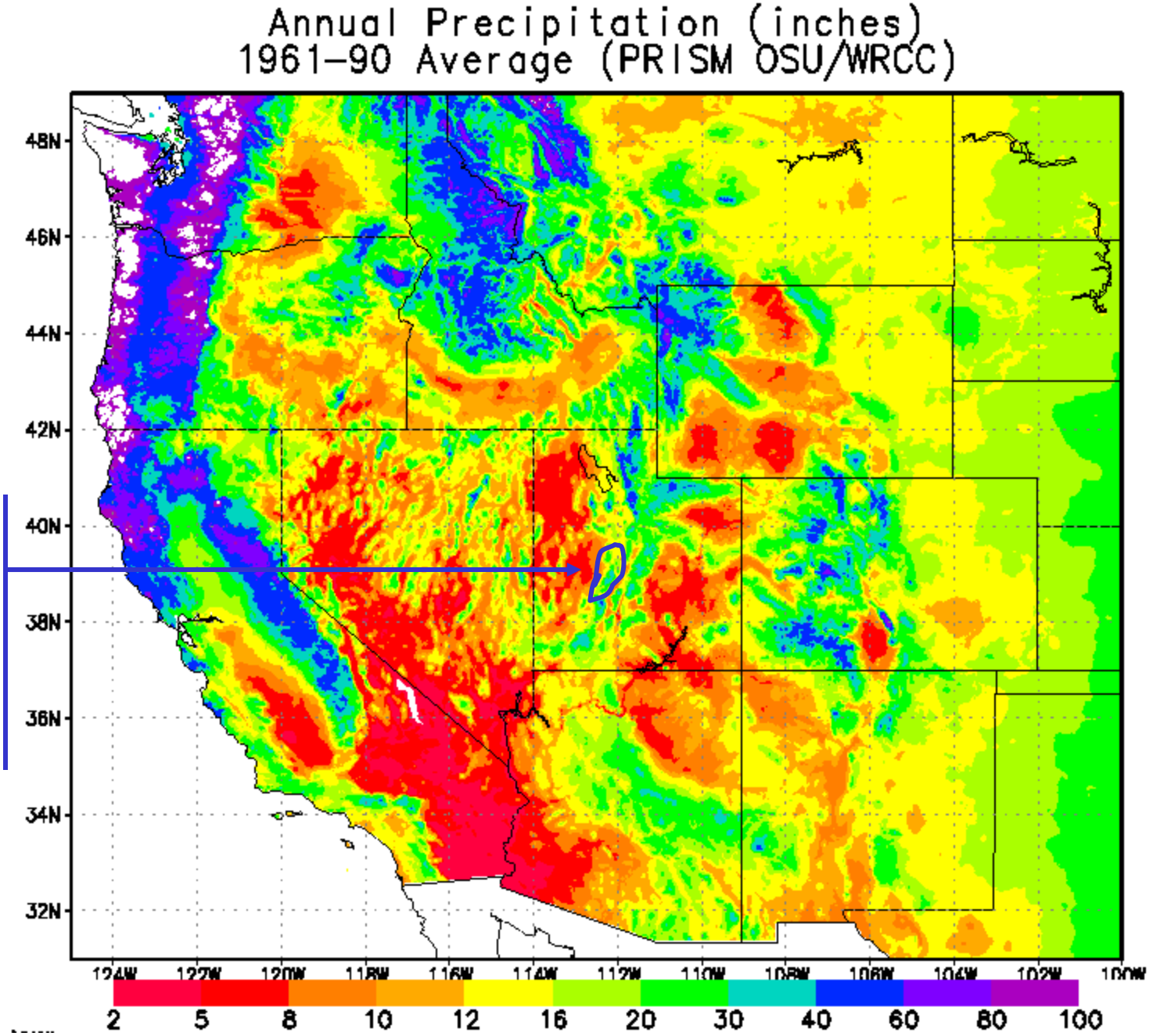
For the contiguous US, this consists of about 800,000 pixels with a 1300-month history (1895-present), or about a billion data values for each element. Increases as the square of the resolution.

Each pixel represents average spatial conditions for the average elevation of the pixel. Detail within the pixel can still be considerable and is not represented.

This project is concerned mainly with temporal behavior.

A typical question:

How has temp or precip in this area varied thru time?



Some Westmap Prehistory

There has been a longstanding need for:

- **Fine scale time histories extending for decades**
- **Principal climate elements: temp, precip, snow?, others?**
- **Arbitrarily shaped for spatial domains**
- **Credible values that accurately include elevation effects**

Recent possibilities

- **Availability of improved spatial mapping techniques**
- **Availability of improved access / distribution technology**
- **Emplacement of needed institutional infrastructure**
- **Improvements in coordination of data flow**

More history

Initial meeting took place in Tucson January 2003

Western Mapping Consortium Formed
Co-chairs: Andrew Comrie, Kelly Redmond, Chris Daly

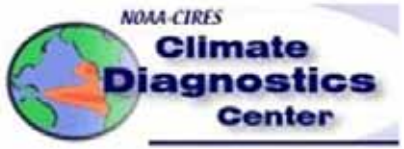
Membership

University of Arizona – Climate Assessment of the Southwest (UA)
Western Regional Climate Center (WRCC / DRI)
Spatial Climate Analysis Service – Oregon State University (OSU)
USDA Natural Resources Conservation Service (NRCS)
Scripps Institution of Oceanography – California Applications Program (Scripps/CAP)
NOAA Climate Diagnostics Center (CDC)

This project is the first formal activity of the group.

Western Regional Climate Center





Scope of current NOAA NCTP effort

U of Arizona

- Guide development of interface. Goal: Intuitive look and feel.
- Usability and usefulness. Examples and tutorials.
- Surveys, evaluation and feedback processes.

WRCC

- Web page with manipulation tools
- Pre-calculate common areal domains.
- Comparison ability with other “known” data: “track record”
- Data ingest and update info, to/from OSU SCAS.
- Output formats.

OSU

- Provision of update information.
- Assist with uncertainty assessment and depiction.
- Improved data: finer resolution, more refined techniques
- Guidance and advice

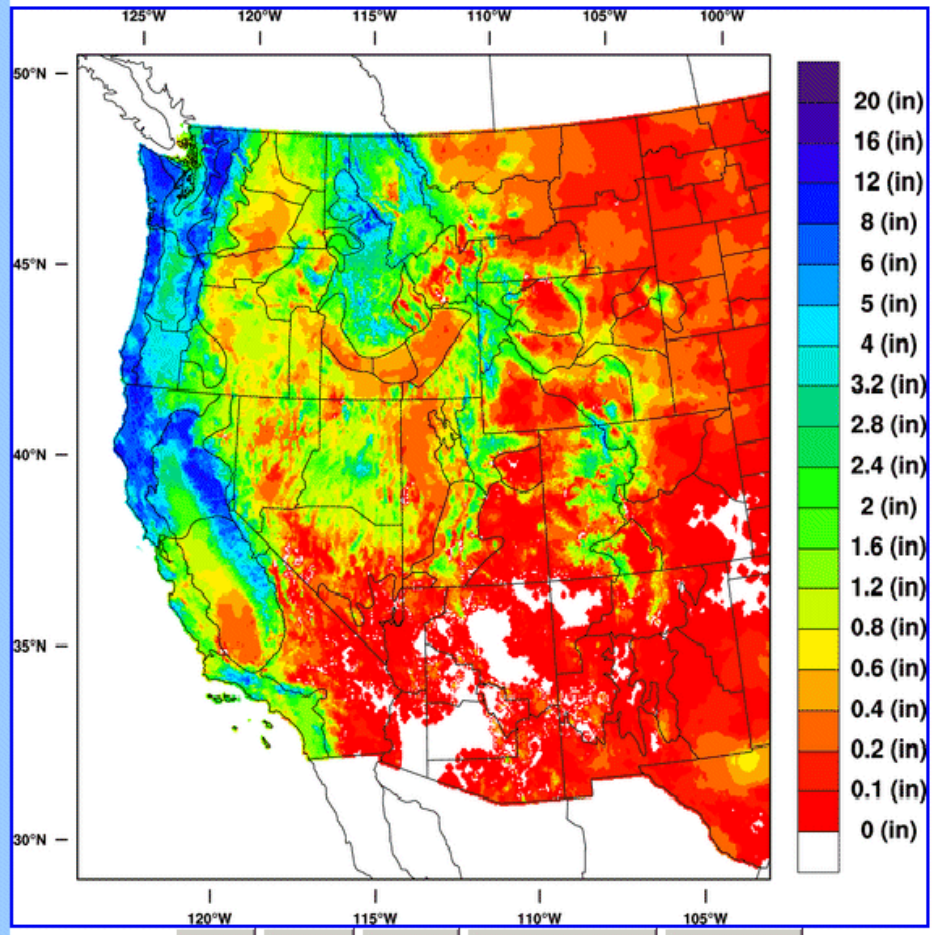
WestMap...

Access, Tools, & Resources for Fine-Scale Regional Climate Data

Western Climate Mapping Project | Tutorial | Interactive Analysis Tools | Useful Links | Contact Us | Help

Work in progress
Appearance will change

Precipitation: February 2006



West | States | County | Climate Divisions | Hydro Units

Click buttons to change map region display. Click map to explore subregions.

Interactive Analysis Tools

Select Climate Map

Precipitation

Monthly Mean

Interactive Analysis Tools

Select Region of Interest

Select Western or National Region

Select County

Select Climate Division

Select Hydrologic Unit

Room for Expansion

Help!

save map

print map

Climate Divisions

Climate Divisions (84 in West, 344 in USA)

WestMap...

Access, Tools, & Resources for Fine-Scale Regional Climate Data

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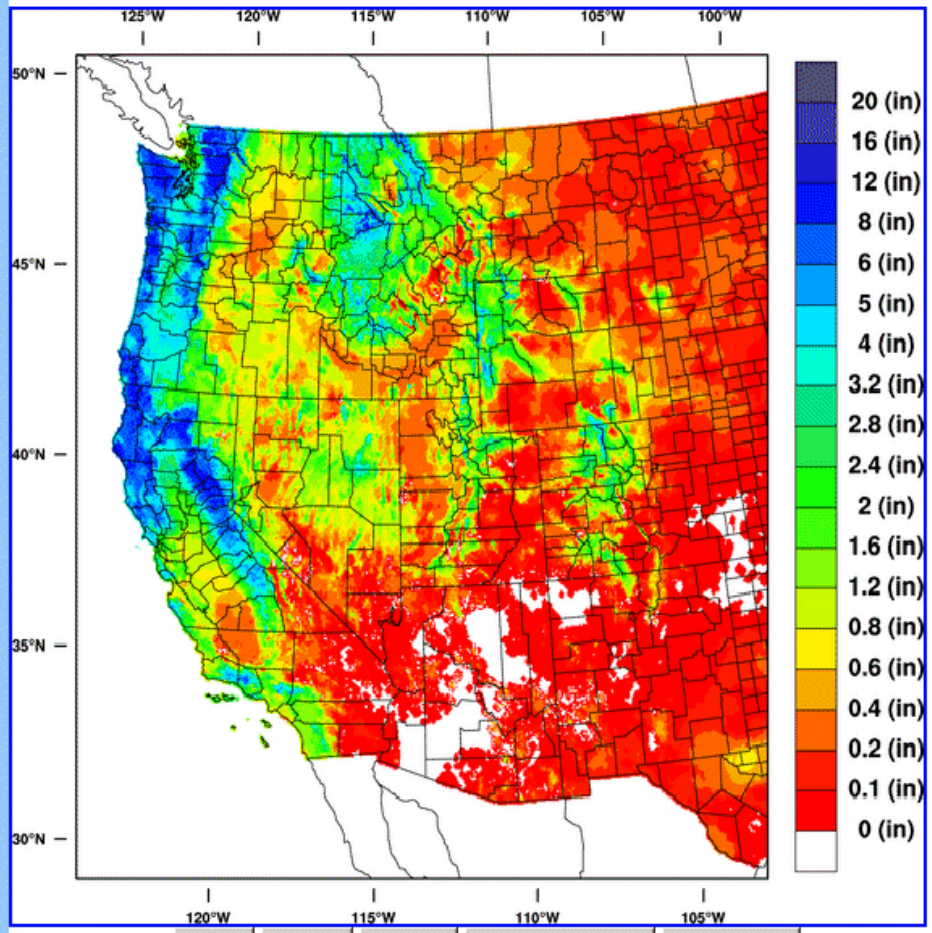
Precipitation: February 2006



West | States | County | Climate Divisions | Hydro Units

Click buttons to change map region display. Click map to explore subregions.

Interactive Analysis Tools

Select Climate Map

Maximum Temperature

Monthly Mean

Interactive Analysis Tools

Select Region of Interest

Select Western or National Region

Select County

Select Climate Division

Select Hydrologic Unit

Room for Expansion

Help!

save map

print map

Counties

WestMap...

Access, Tools, & Resources for Fine-Scale Regional Climate Data

Western Climate Mapping Project | Tutorial | Interactive Analysis Tools | Useful Links | Contact Us | Help

WestMap Overview
- Project Overview
- Data Overview
- Resource Overview

Interactive Data Analysis
- Tutorial User Guide
- Analysis Tools

Climate Data
- Temperature
- Precipitation
- Indicies
- Other Data

Metadata
- Data Description
- Data Quality Issues

Education Resources
- Climate
- Statistical Links

Publications

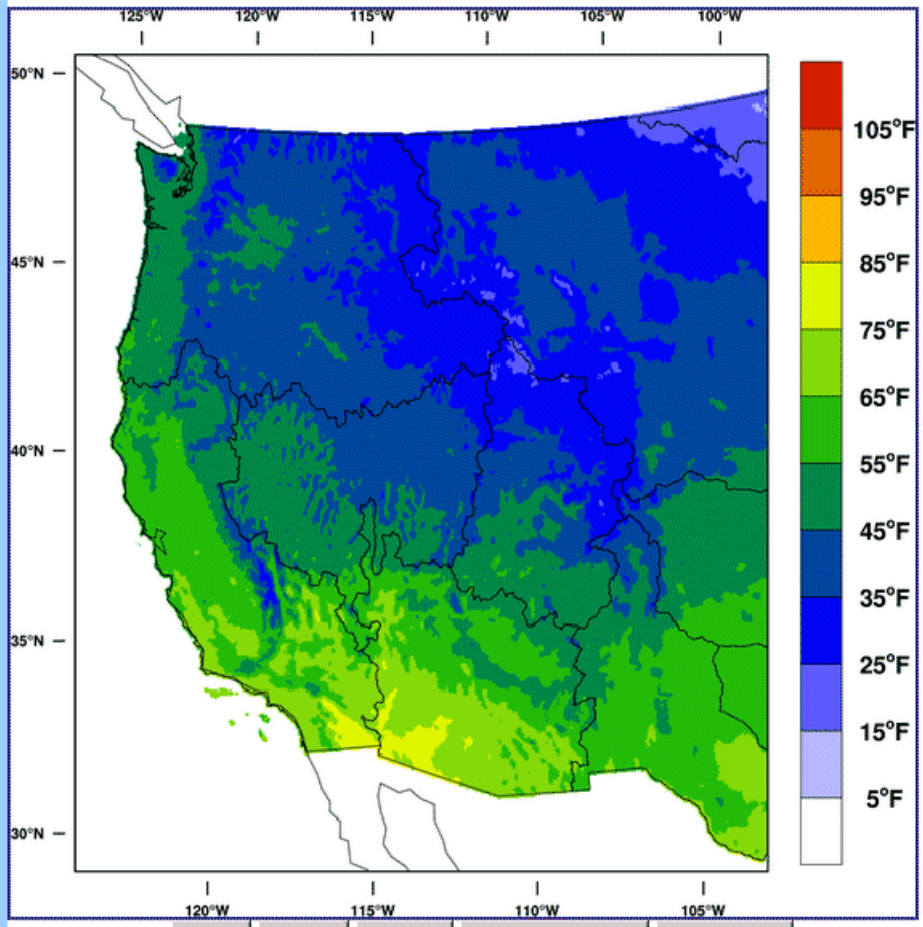
Climate Related Links

Help !!

Contact Us

Revised 3/17/06

Maximum Temperature: February 2006



West | States | County | Climate Divisions | Hydro Units

Click buttons to change map region display. Click map to explore subregions.

Interactive Analysis Tools

Select Climate Map

Maximum Temperature

Monthly Mean

Interactive Analysis Tools

Select Region of Interest

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Select Climate Division

Select Hydrologic Unit

Room for Expansion

Help!

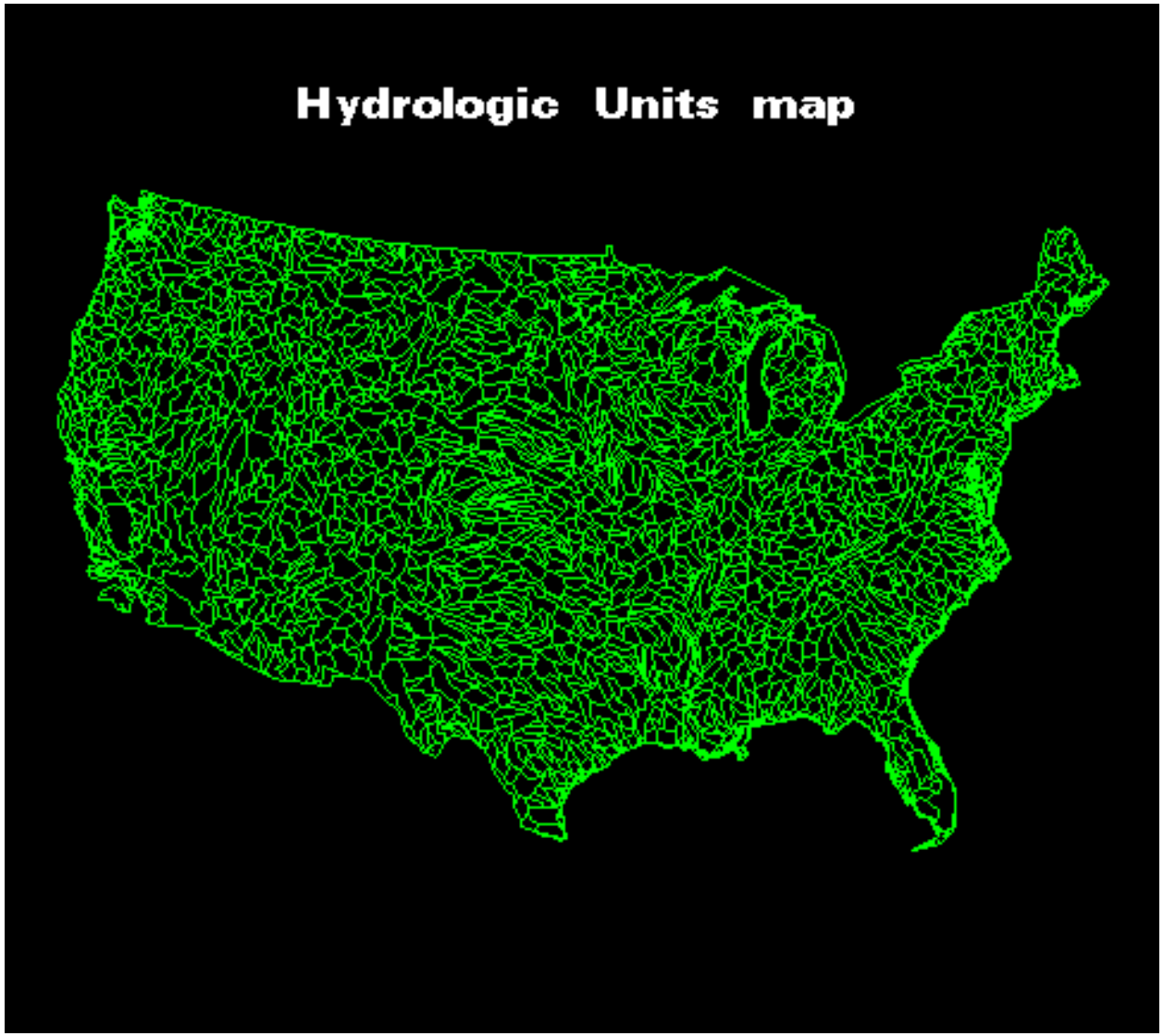
save map

print map

Hydrologic basins Here, large scale

Major hydrologic units

Less major hydrologic units



Credibility:

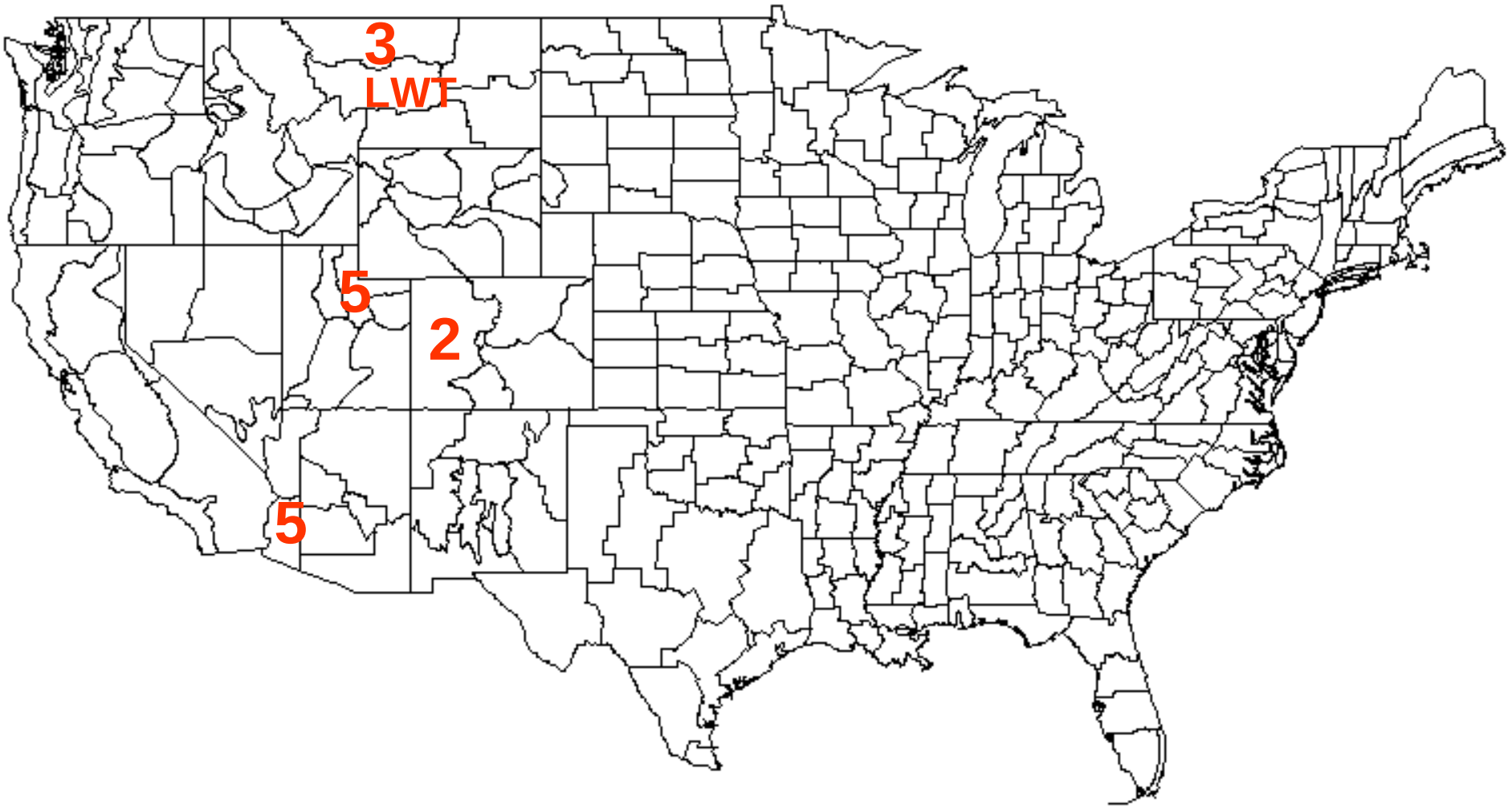
How good are these numbers?

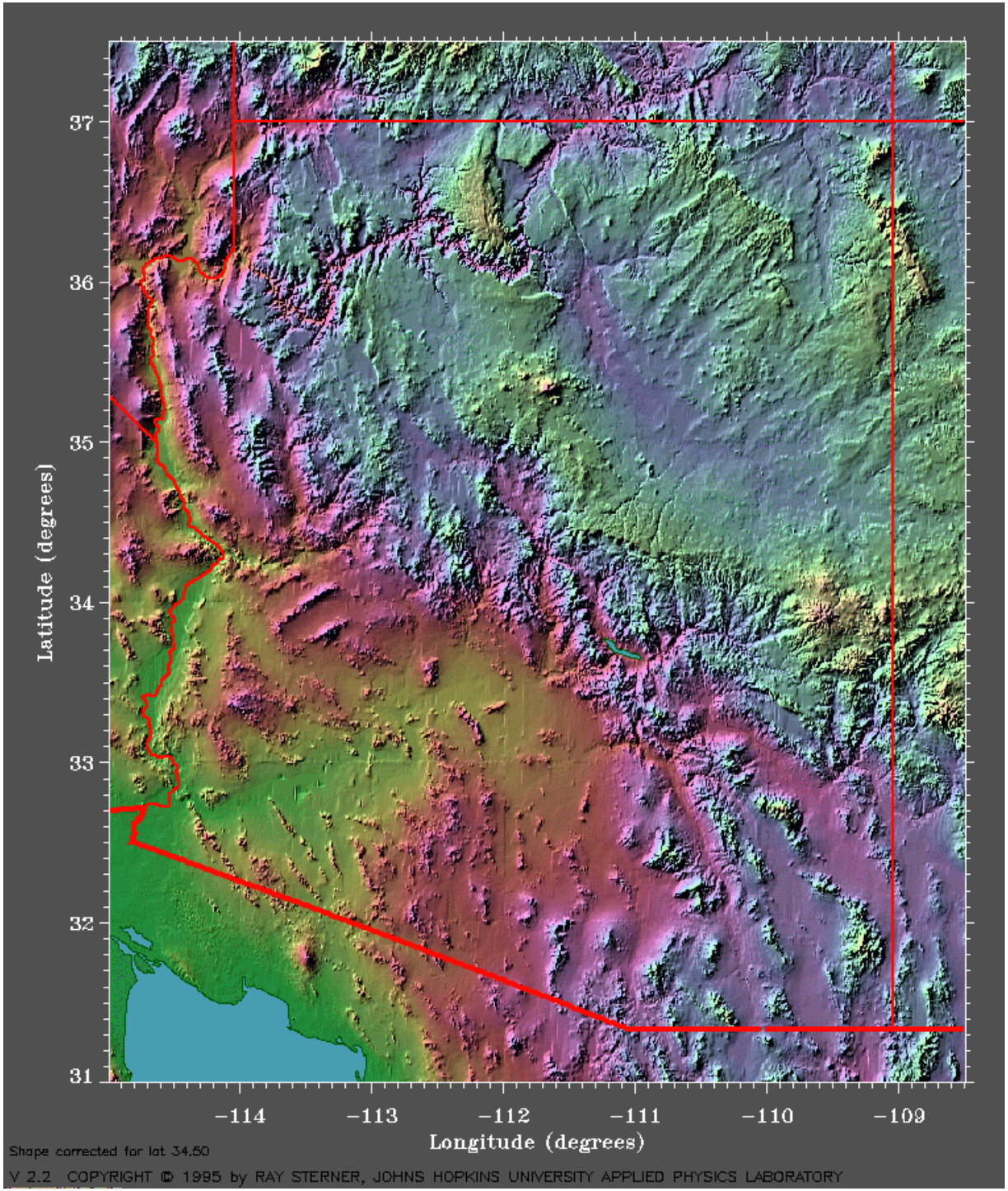
Do they replicate “known” climate histories?

And, how good are the “known” climate histories?

Some preliminary investigations:

Four Basins and a Gage




37
36
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32
31
Latitude (degrees)
−114
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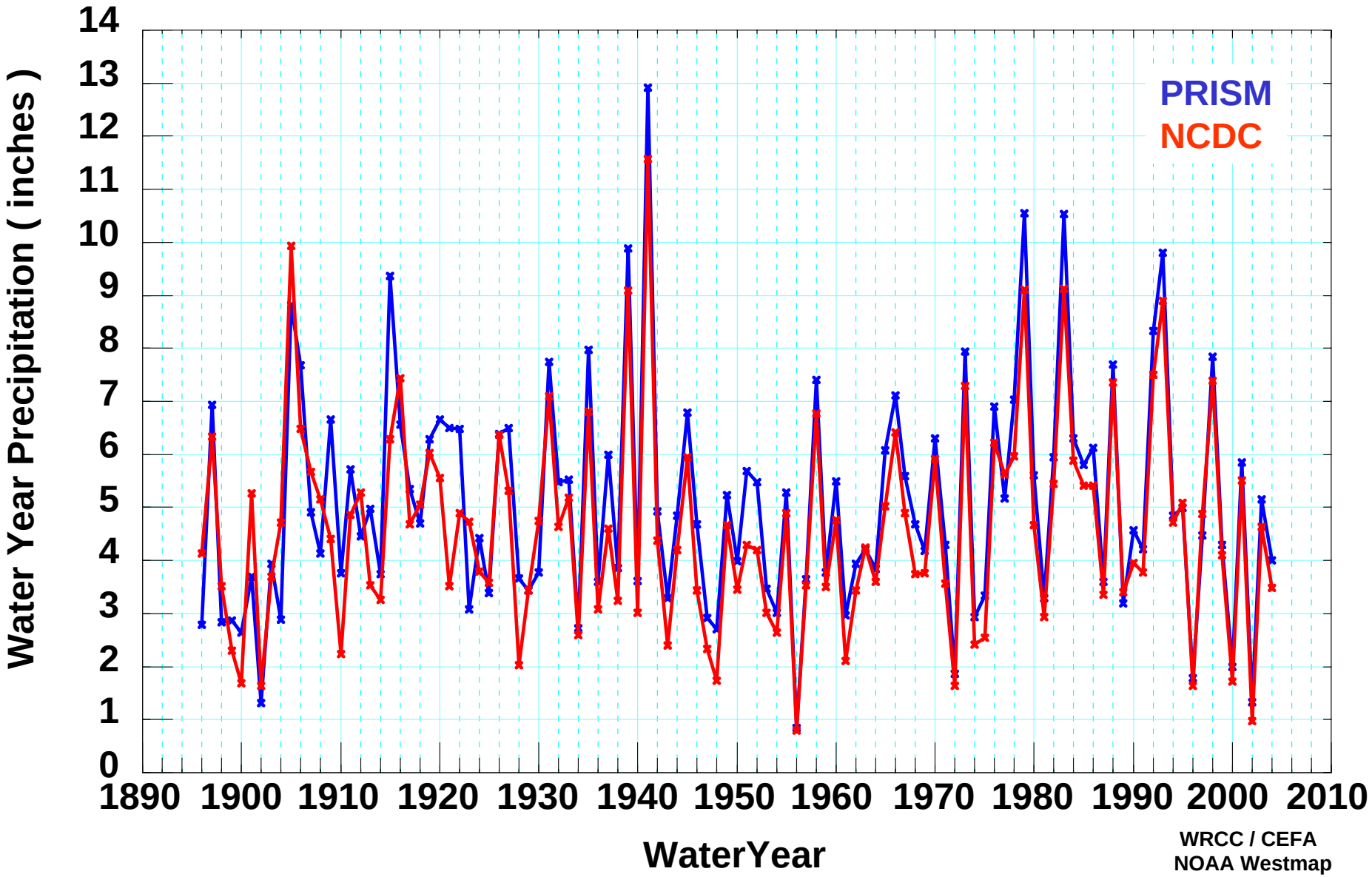
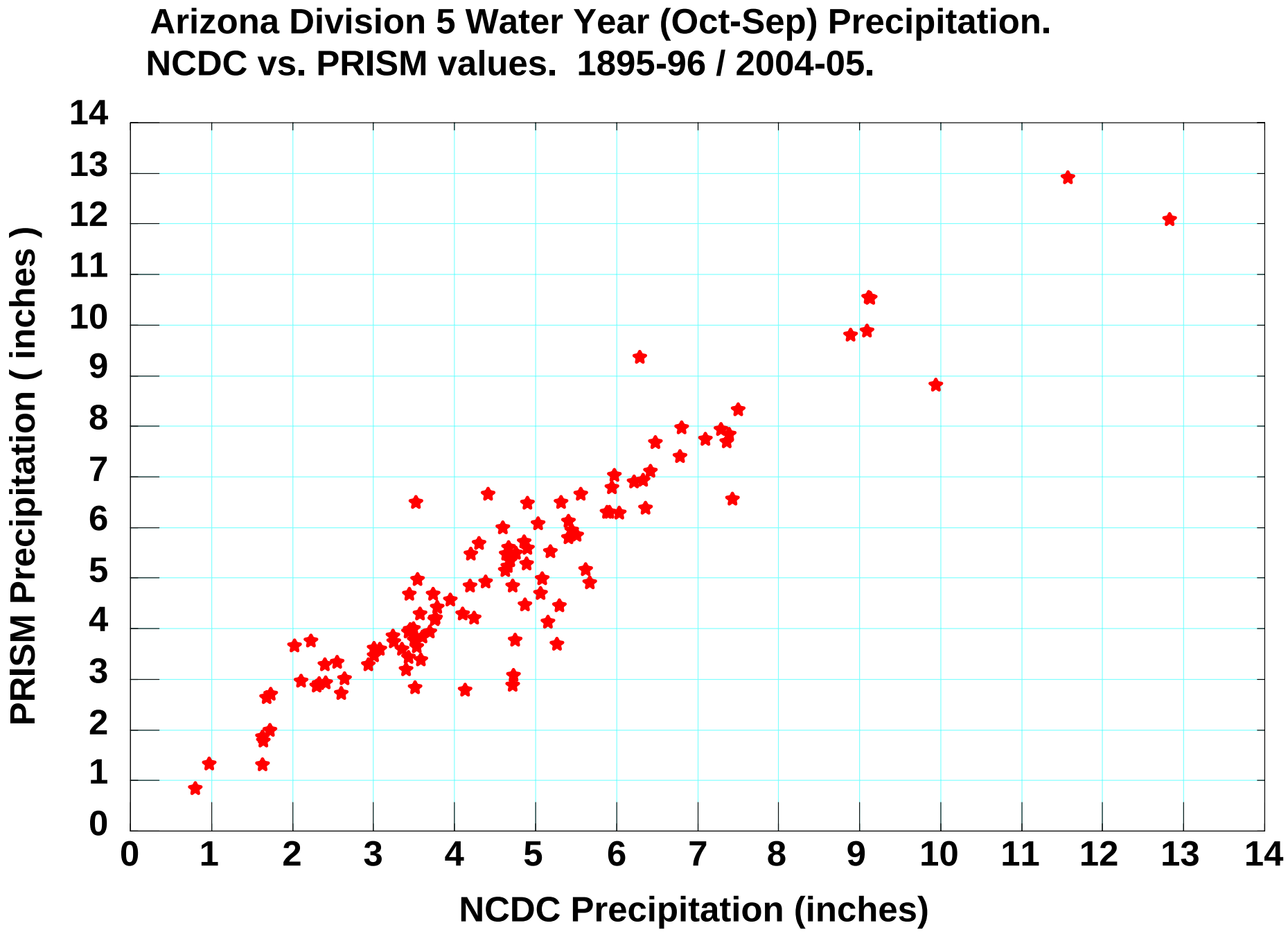
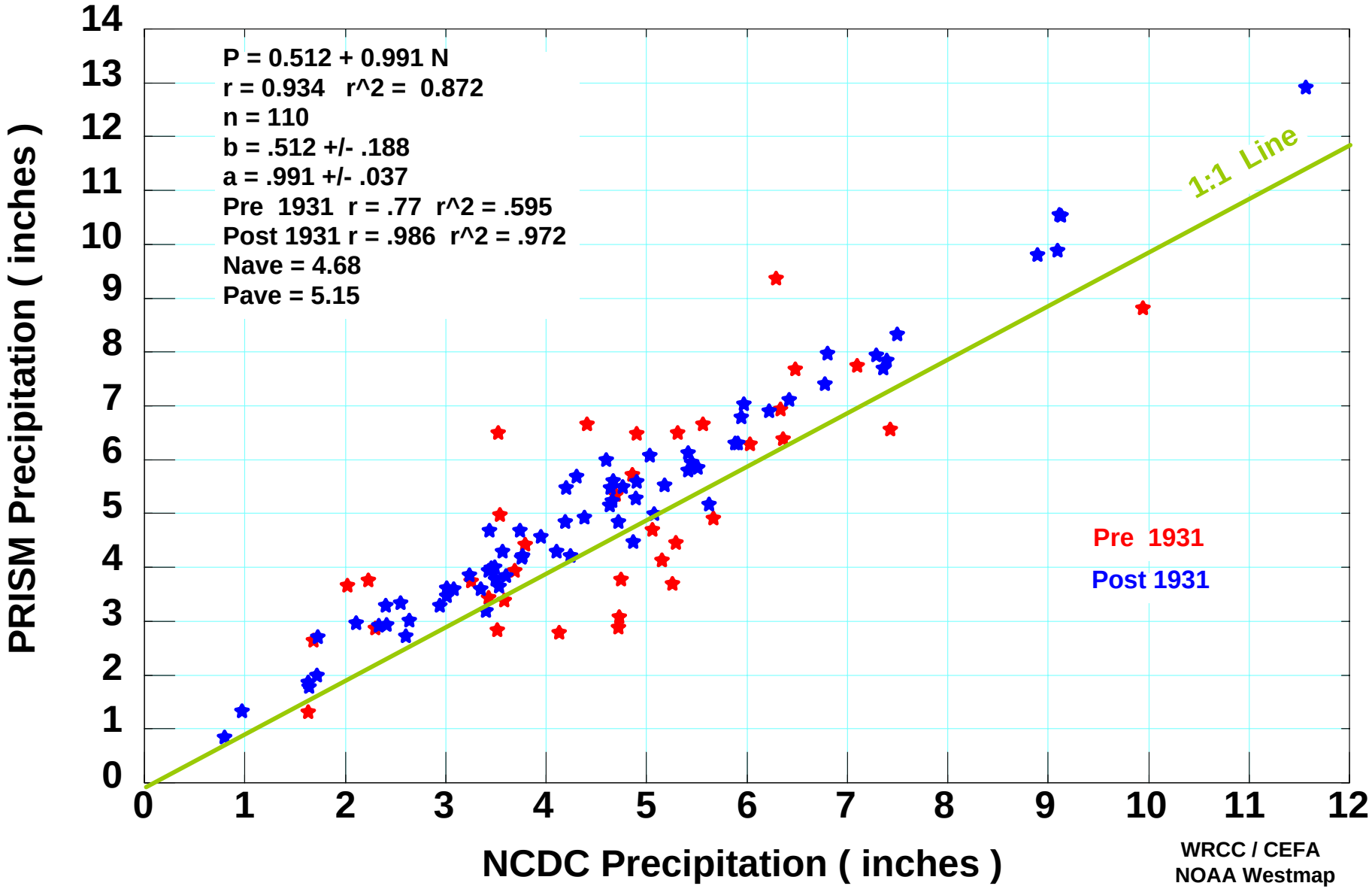
−111
−110
−109
Longitude (degrees)
Shape corrected for lat 34.50
V 2.2 COPYRIGHT © 1995 by RAY STERNER, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY


Arizona Division 5 Water Year Precipitation.
Units: Inches. PRISM - Blue NCDC - Red.
Data from 1895-2005.
Water Year Precipitation (inches)
WaterYear
PRISM
NCDC
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
WRCC / CEFA
NOAA Westmap

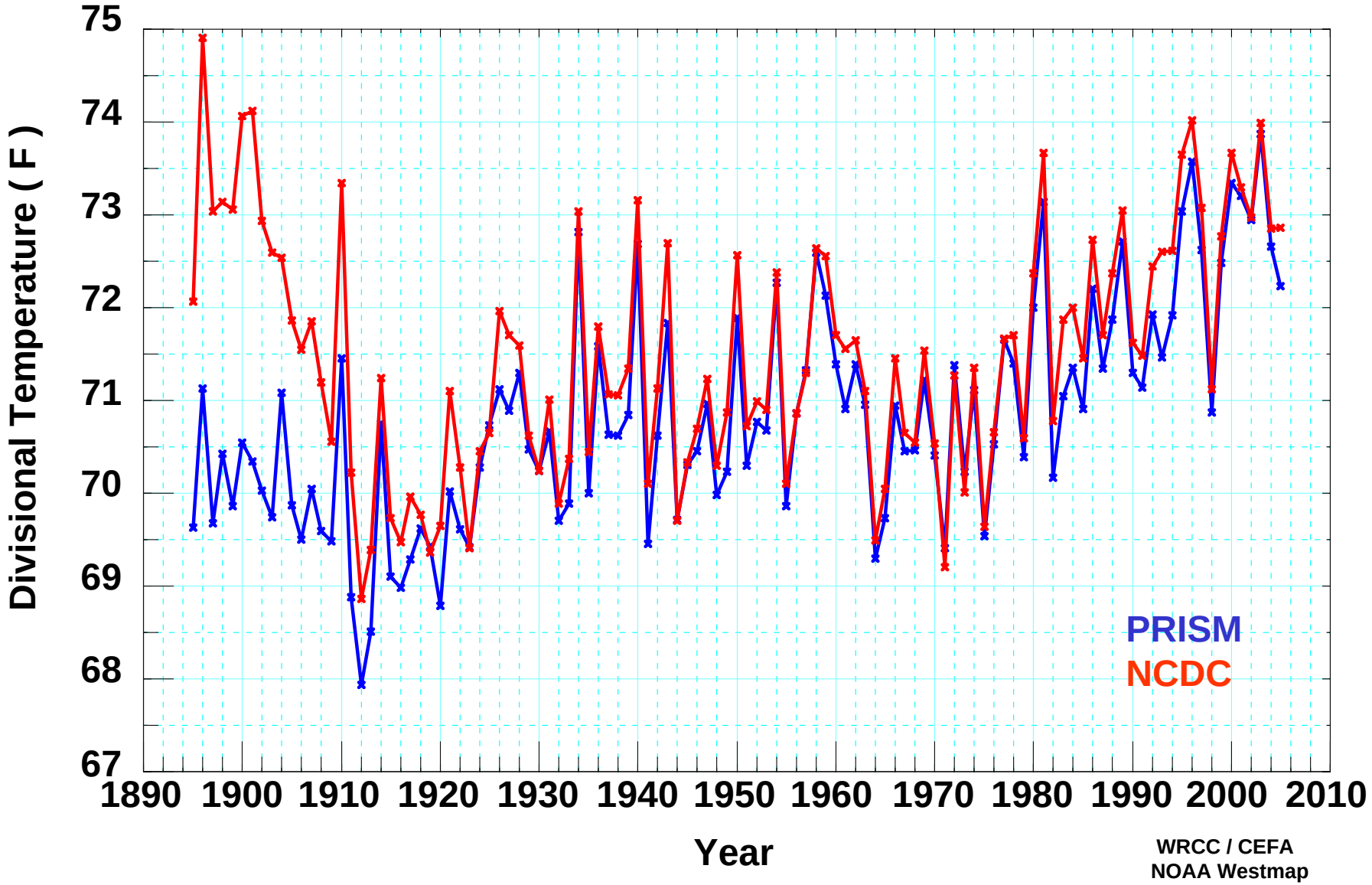

Arizona Division 5 Water Year (Oct-Sep) Precipitation.
NCDC vs. PRISM values. 1895-96 / 2004-05.
PRISM Precipitation (inches)
NCDC Precipitation (inches)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Arizona Division 5 Water Year (Oct-Sep) Precipitation.
NCDC vs. PRISM values.
Red 1895-96 / 1930-31. Blue 1931-32 / 2004-05.

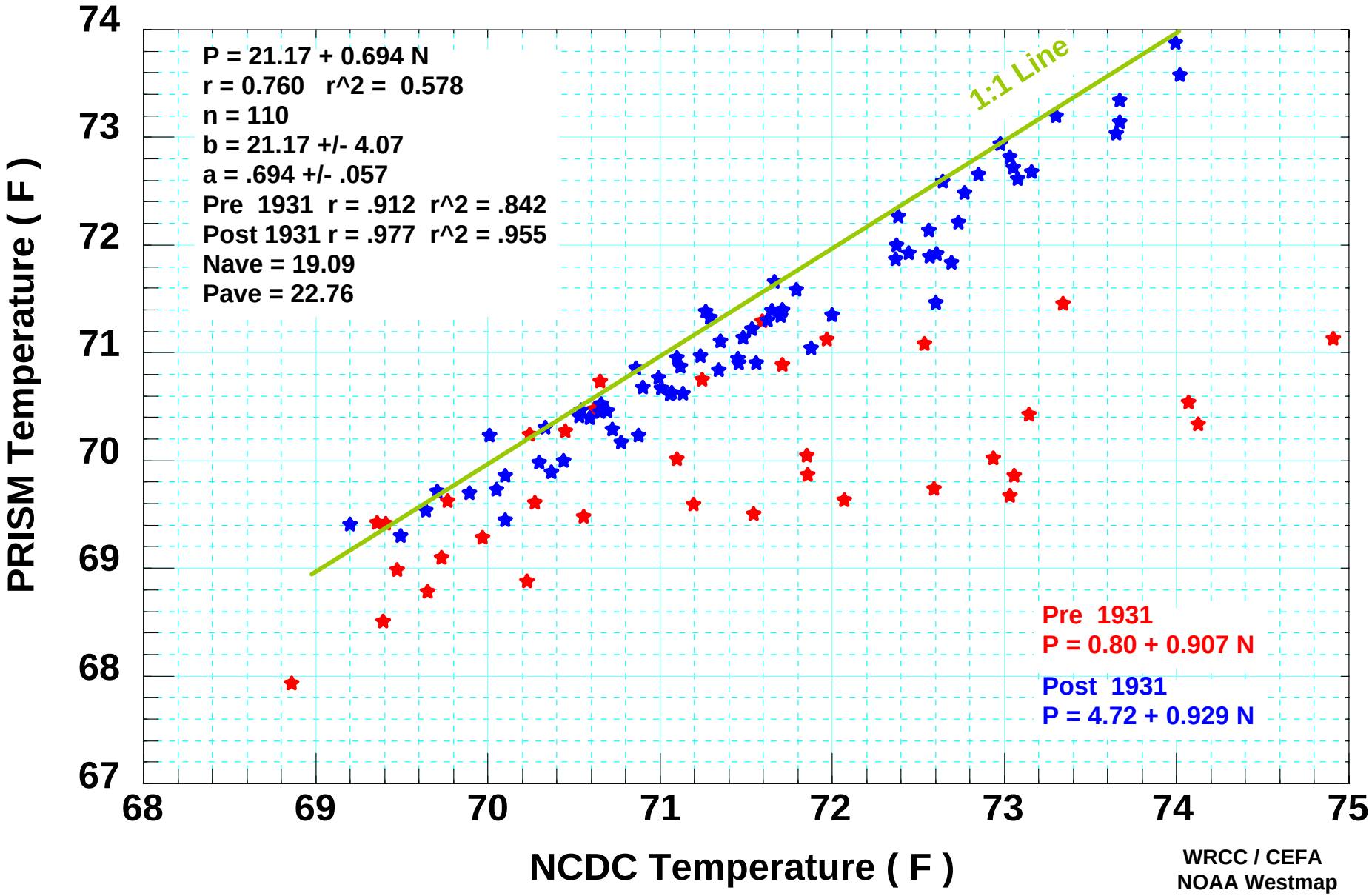


WRCC / CEFA
NOAA Westmap

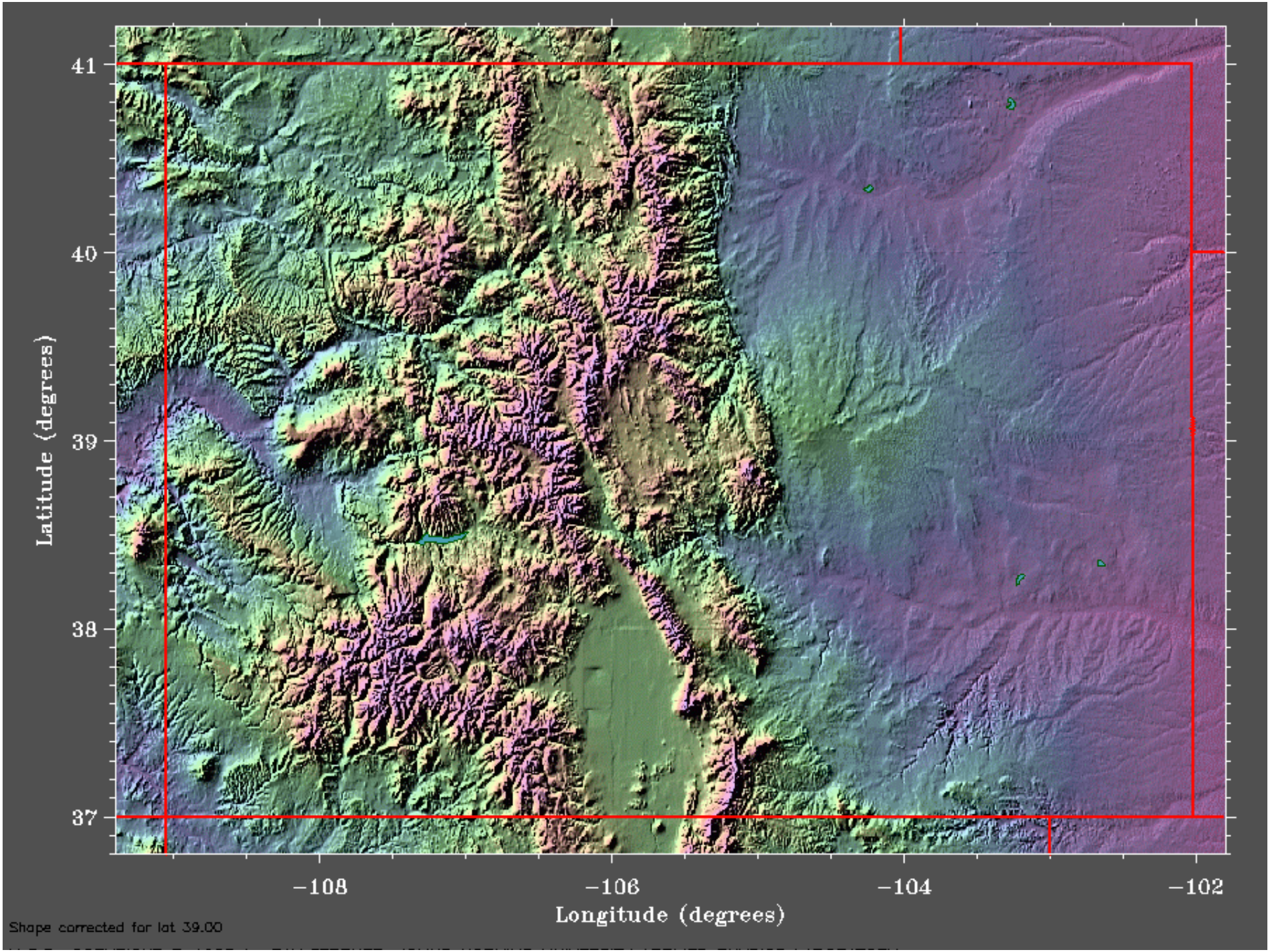
Arizona Division 5 Annual Mean Temperature.
Units: Degrees F. PRISM - Blue NCDC - Red.
Data from 1895-2005.



Arizona Division 5 Annual Mean Temperatures.
NCDC vs. PRISM values.
Red 1895-1930. Blue 1931-2005.



WRCC / CEFA
NOAA Westmap


41
40
39
38
37
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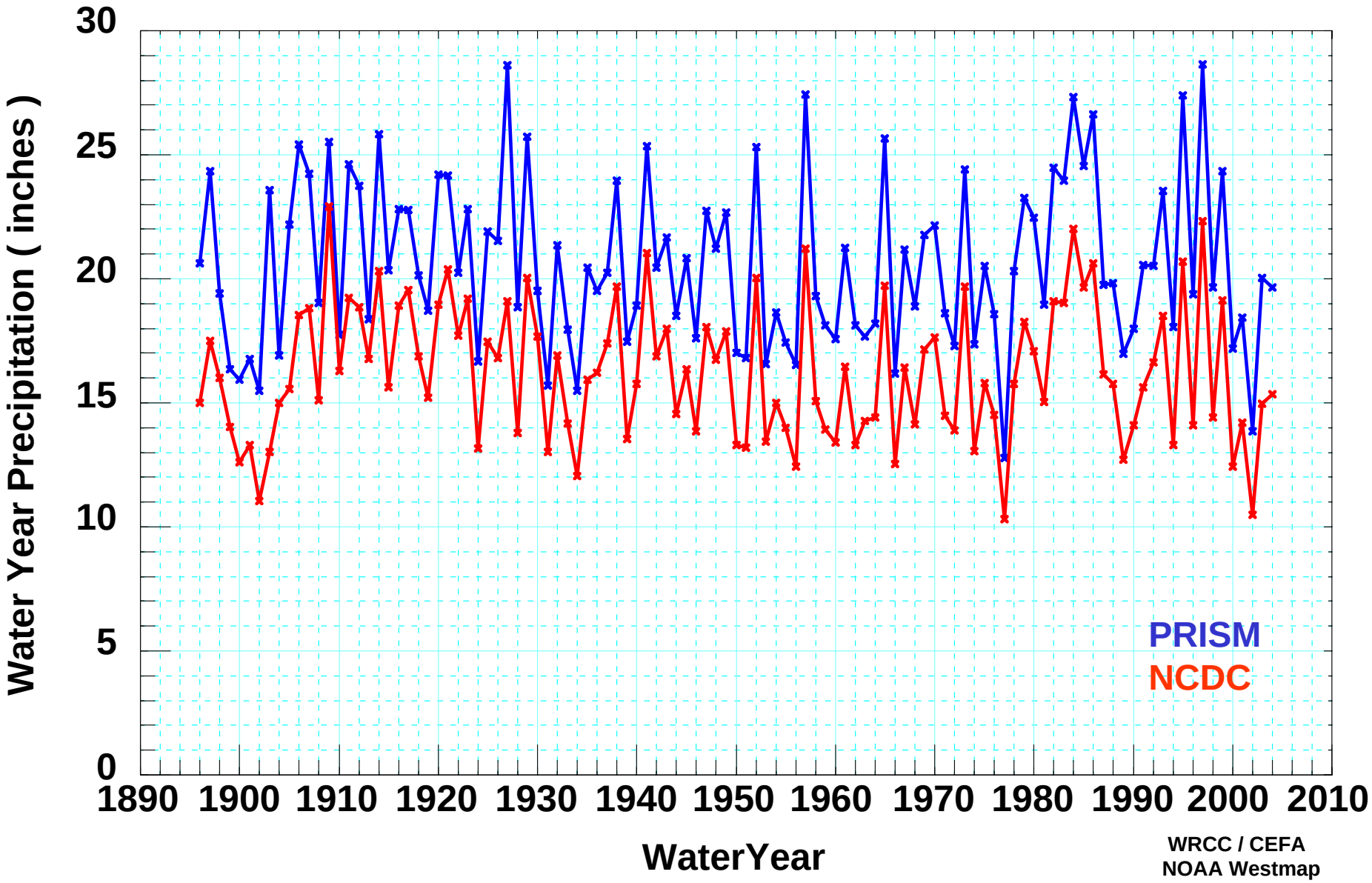
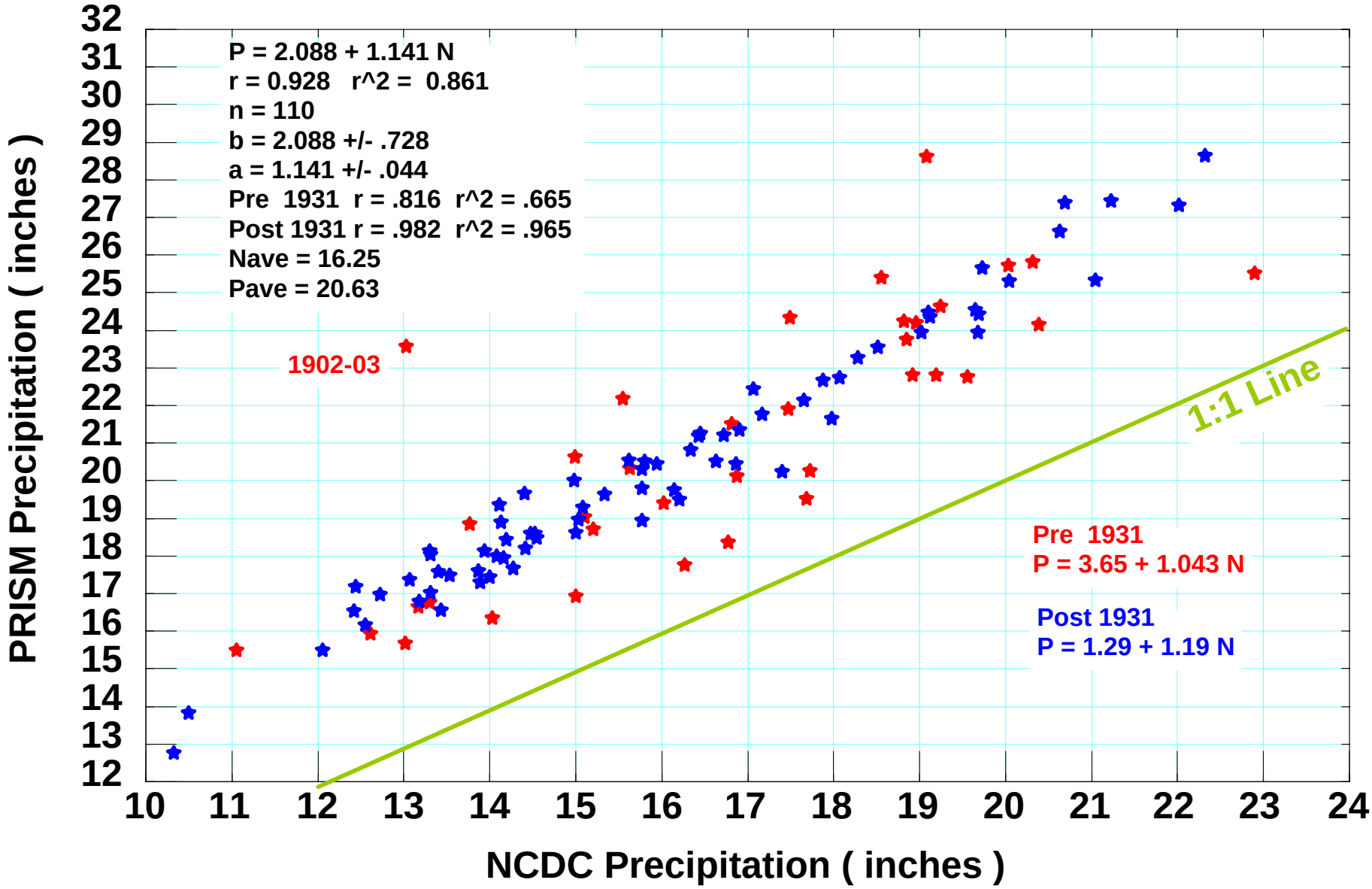
−106
−104
−102
Longitude (degrees)
Shape corrected for lat 39.00


Colorado Division 2 Water Year Precipitation.
Units: Inches. PRISM - Blue NCDC - Red.
Data from 1895-96 / 2004-05.
Water Year Precipitation (inches)
30
25
20
15
10
5
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
WaterYear
PRISM
NCDC
WRCC / CEFA
NOAA Westmap


Colorado Division 2 Water Year (Oct-Sep) Precipitation.
NCDC vs. PRISM values.
Red 1895-96 / 1930-31. Blue 1931-32 / 2004-05.
P = 2.088 + 1.141 N
r = 0.928 r^2 = 0.861
n = 110
b = 2.088 +/- .728
a = 1.141 +/- .044
Pre 1931 r = .816 r^2 = .665
Post 1931 r = .982 r^2 = .965
Nave = 16.25
Pave = 20.63
1902-03
1:1 Line
Pre 1931
P = 3.65 + 1.043 N
Post 1931
P = 1.29 + 1.19 N
PRISM Precipitation (inches)
NCDC Precipitation (inches)
32
31
30
29
28
27
26
25
24
23
22
21
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19
18
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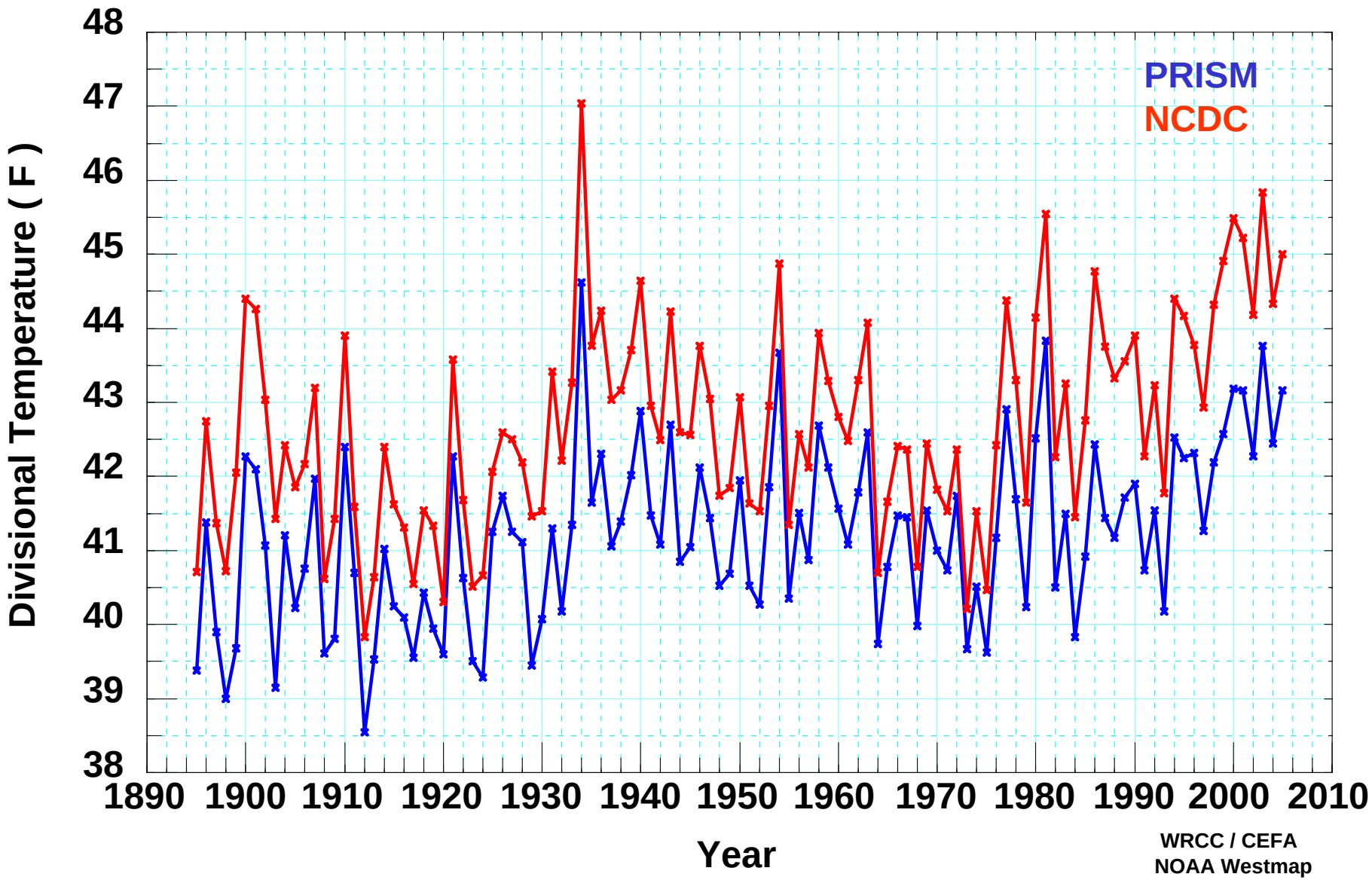
Colorado Division 2 Annual Mean Temperature.
Units: Degrees F. PRISM - Blue NCDC - Red.
Data from 1895-2005.
PRISM
NCDC
Divisional Temperature (F)
48
47
46
45
44
43
42
41
40
39
38
1890
1900
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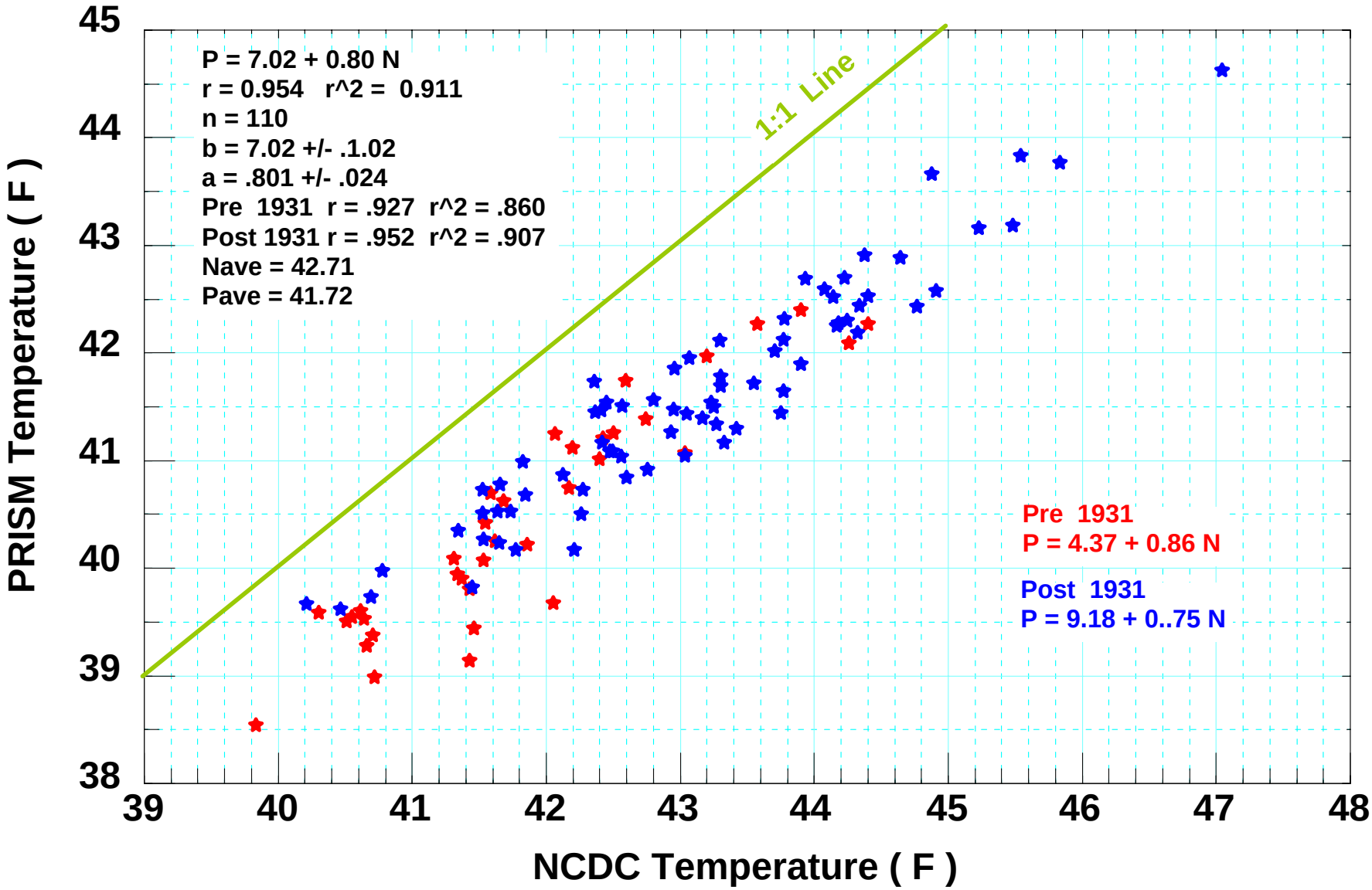
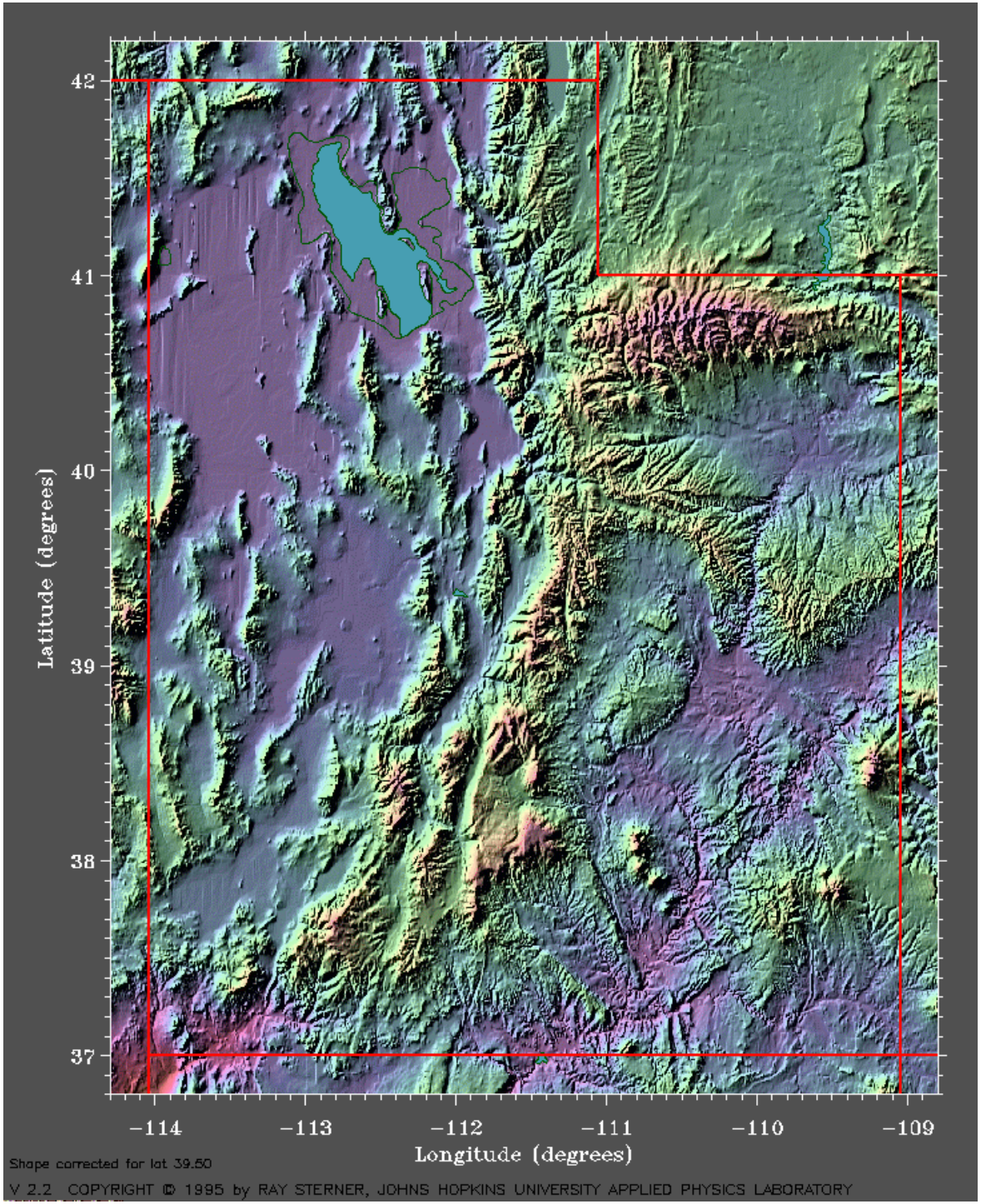
2010
Year
WRCC / CEFA
NOAA Westmap


Colorado Division 2 Mean Annual Temperature.
NCDC vs. PRISM values.
Red 1895-1930. Blue 1931-2005.
P = 7.02 + 0.80 N
r = 0.954 r^2 = 0.911
n = 110
b = 7.02 +/- .1.02
a = .801 +/- .024
Pre 1931 r = .927 r^2 = .860
Post 1931 r = .952 r^2 = .907
Nave = 42.71
Pave = 41.72
1:1 Line
Pre 1931
P = 4.37 + 0.86 N
Post 1931
P = 9.18 + 0..75 N
PRISM Temperature (F)
NCDC Temperature (F)
45
44
43
42
41
40
39
38
39
40
41
42
43
44
45
46
47
48


42
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Latitude (degrees)
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−112
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−109
Longitude (degrees)
Shape corrected for lat 39.50
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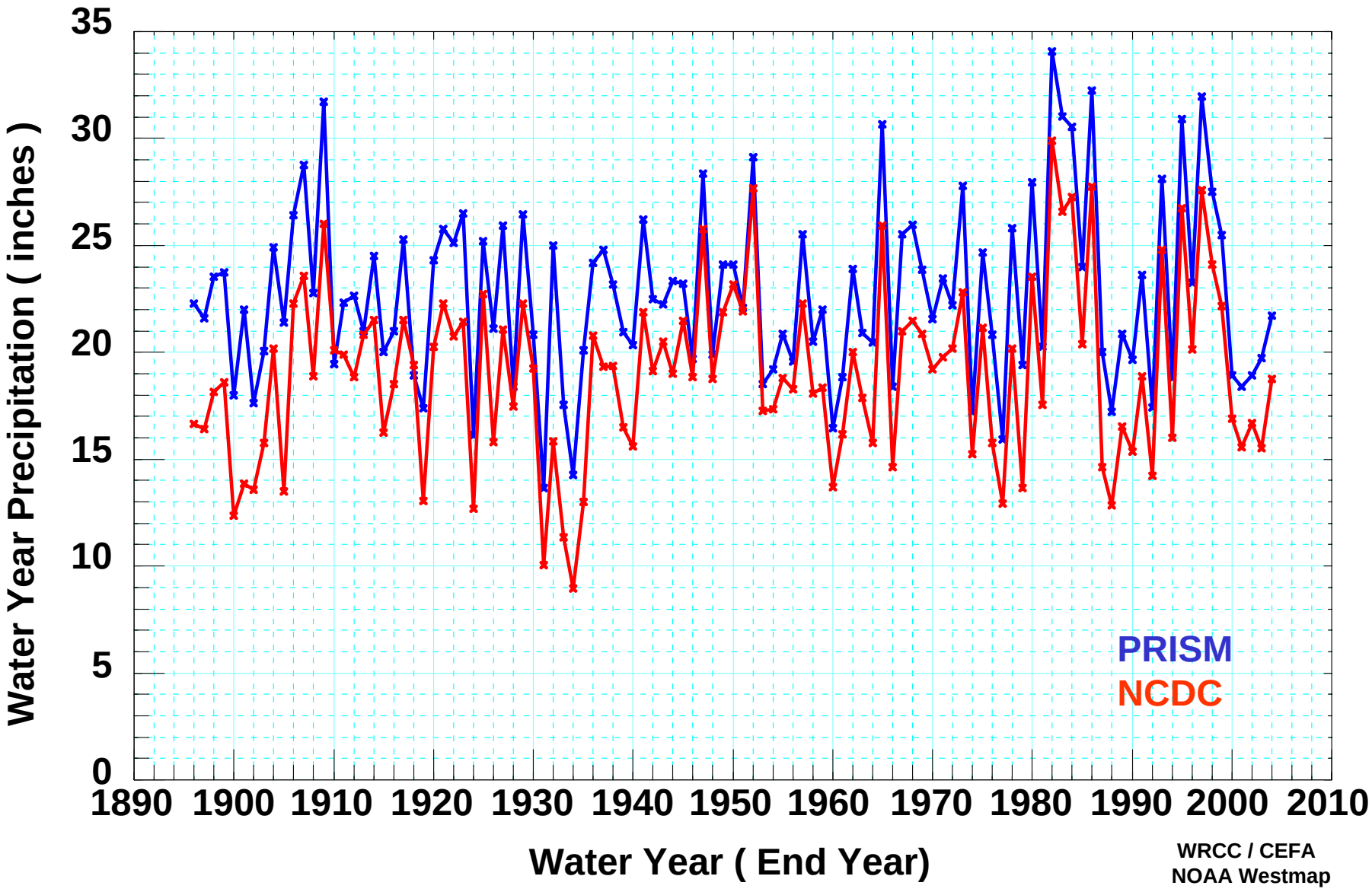
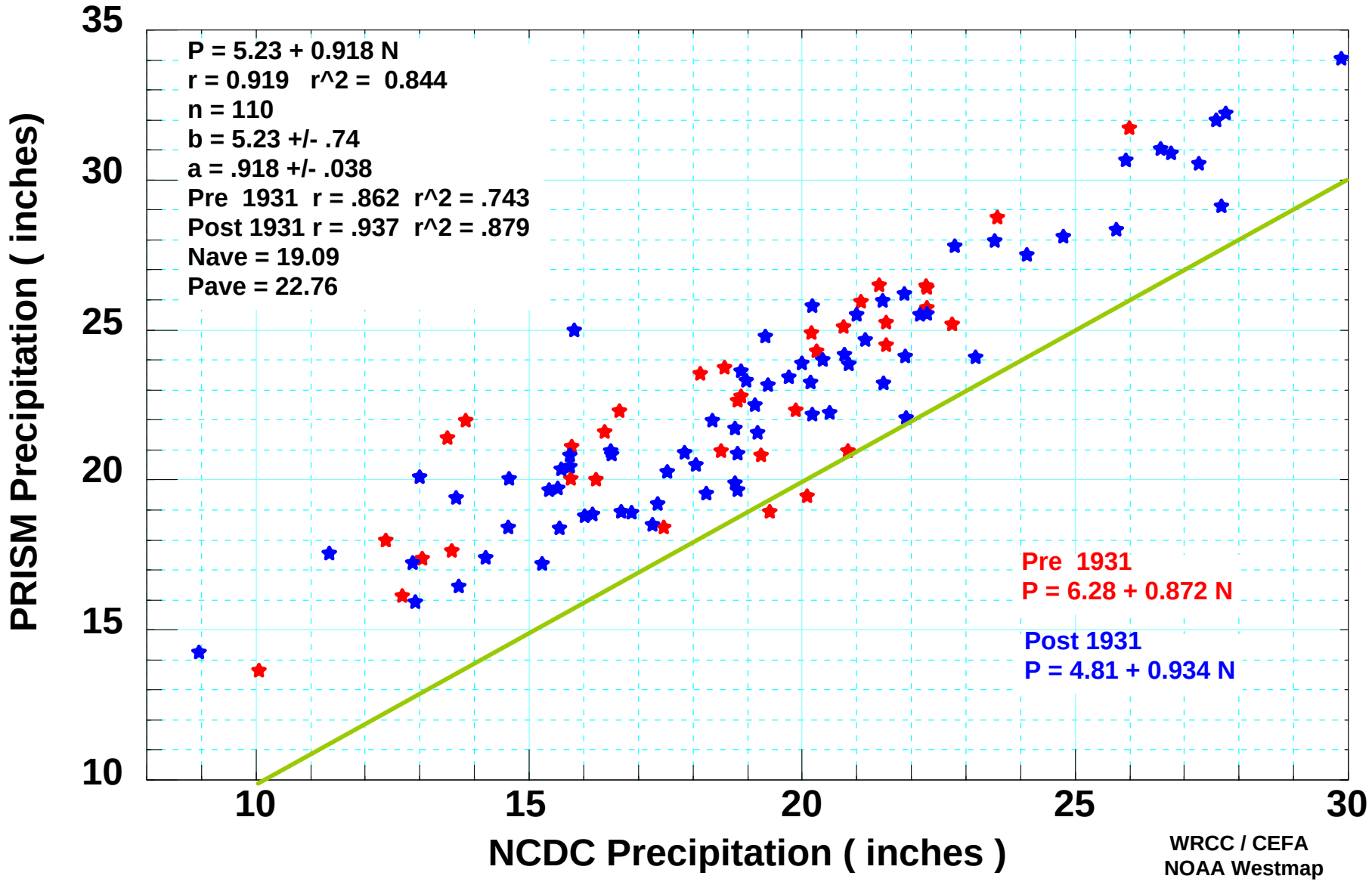
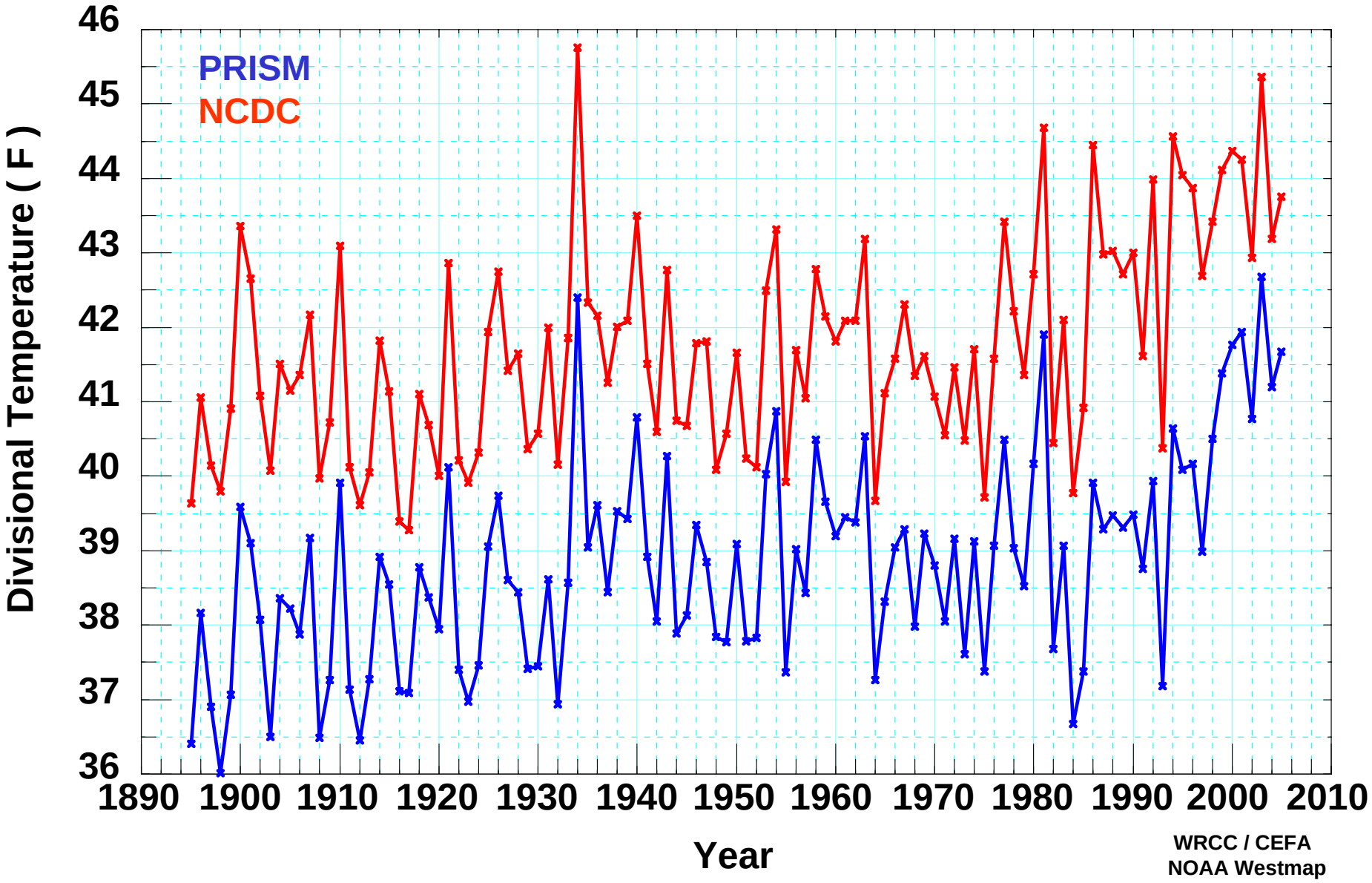

Utah Division 5 Water Year Precipitation.
Units: Inches. PRISM - Blue NCDC - Red.
Data from 1895-2005.
Water Year Precipitation (inches)
0
5
10
15
20
25
30
35
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year (End Year)
PRISM
NCDC
WRCC / CEFA
NOAA Westmap

Utah Division 5 Water Year (Oct-Sep) Precipitation.
NCDC vs. PRISM values.
Red 1895-96 / 1930-31. Blue 1931-32 / 2004-05.

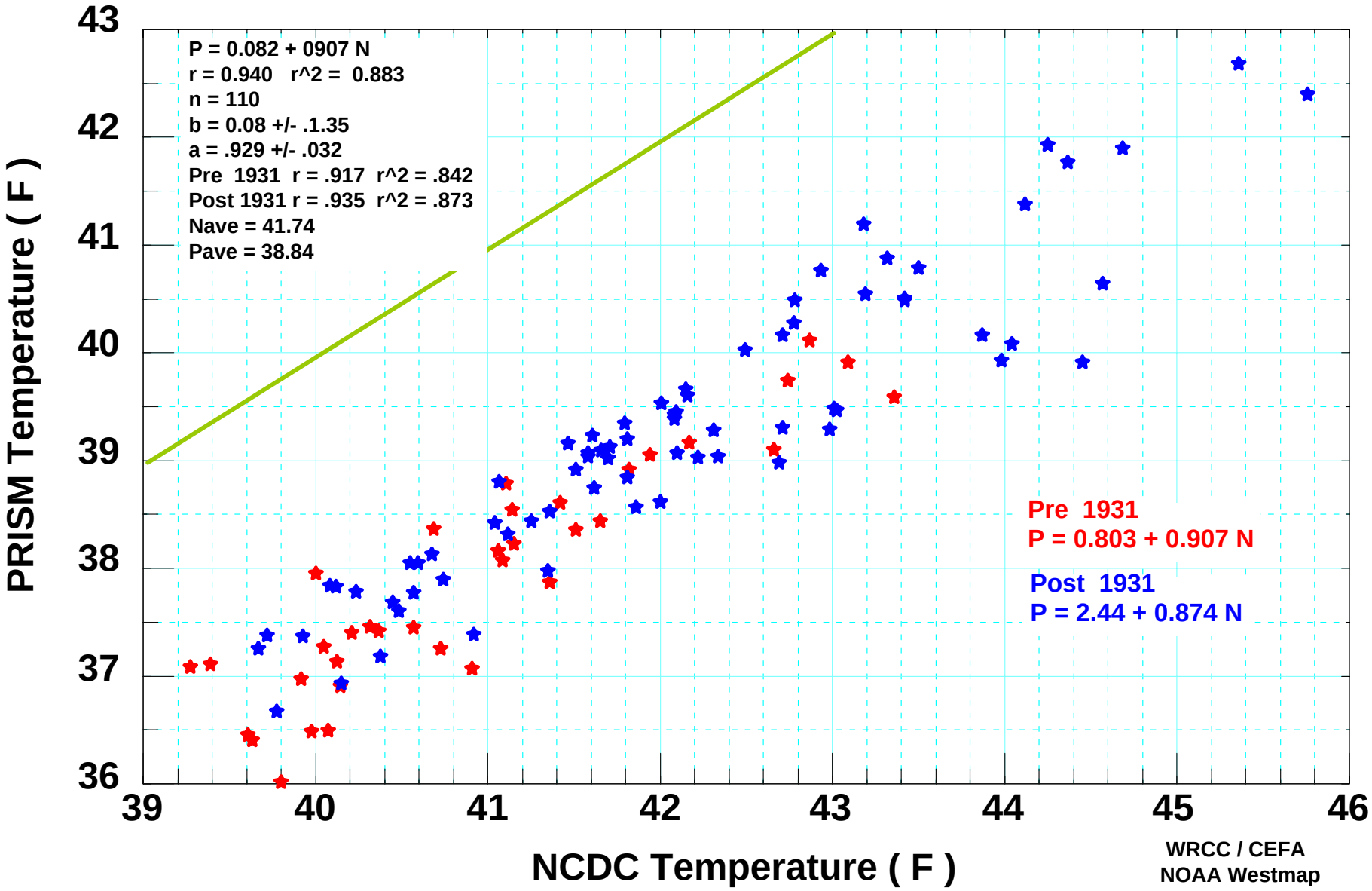


WRCC / CEFA
NOAA Westmap

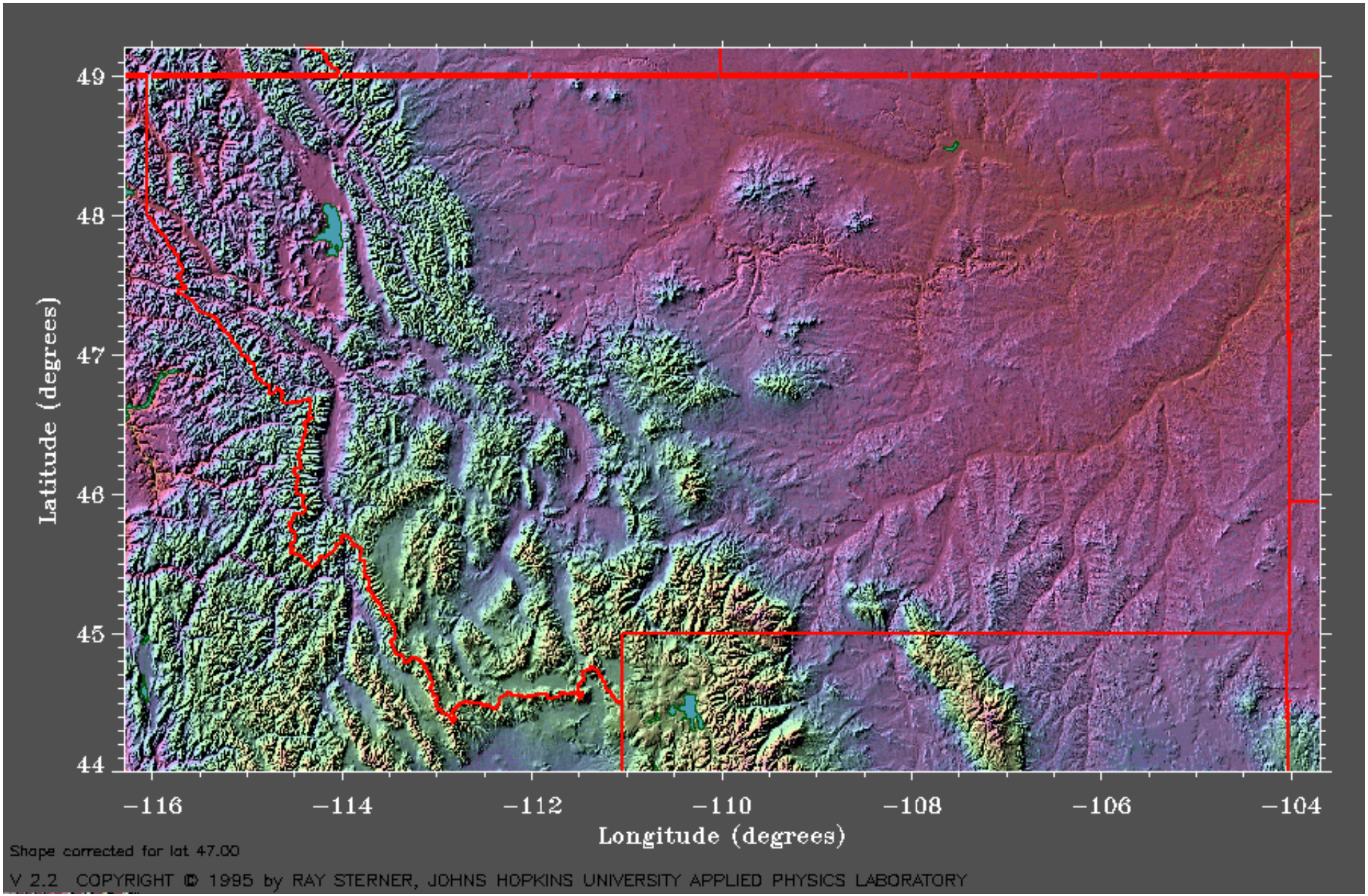
Utah Division 5 Mean Annual Temperature.
Units: Degrees F. PRISM - Blue NCDC - Red.
Data from 1895-2005.



Utah Division 5 Mean Annual Temperature.
NCDC vs. PRISM values.
Red 1895-1930. Blue 1931-2005.



WRCC / CEFA
NOAA Westmap


49
48
47
46
45
44
Latitude (degrees)
−116
−114
−112
−110
−108
−106
−104
Longitude (degrees)
Shape corrected for lat 47.00
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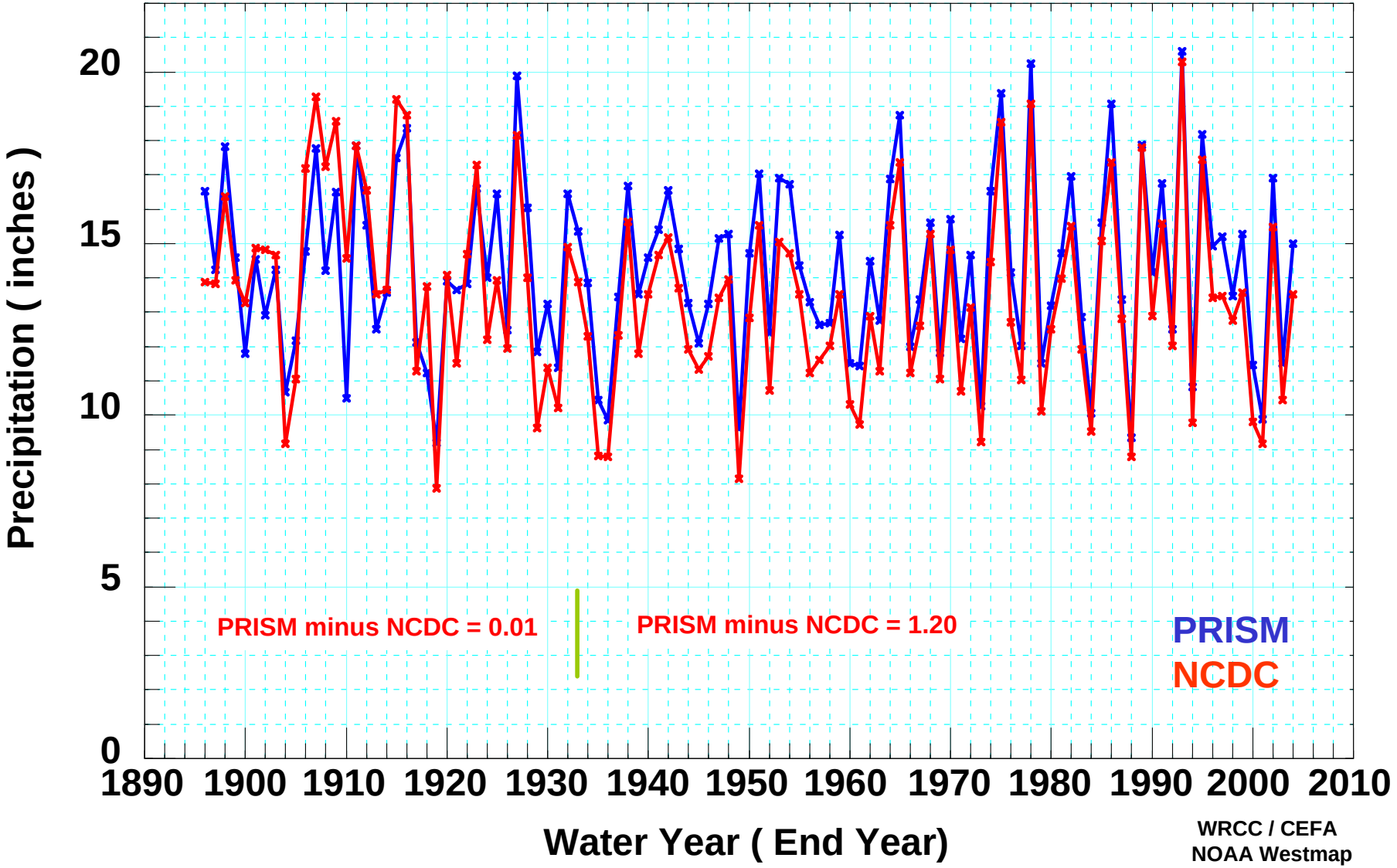
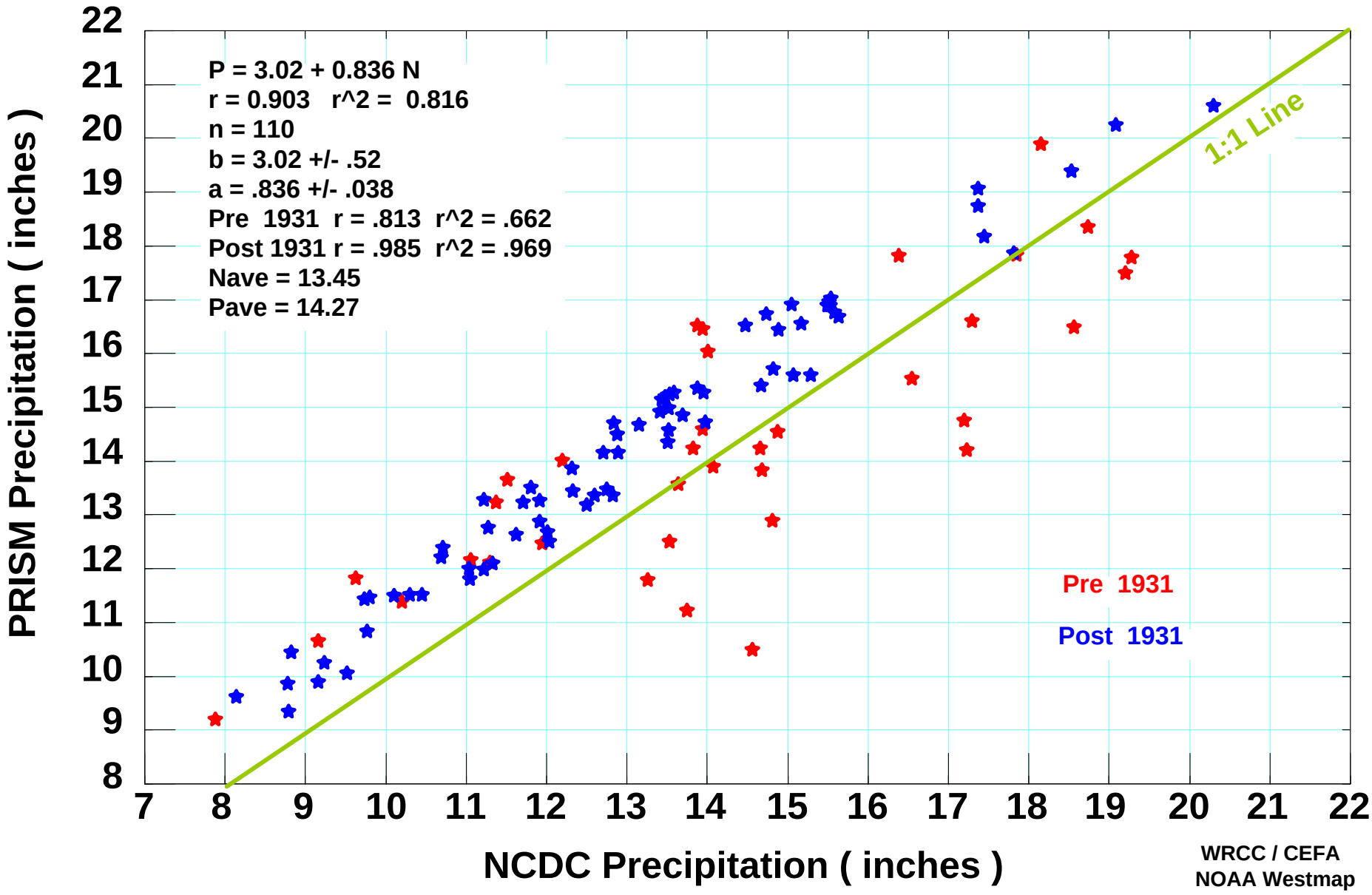
Montana Division 3 Water Year Precipitation.
Units: Inches. PRISM - Blue NCDC - Red.
Data from 1895-2005.




Montana Division 3 Water Year (Oct-Sep) Precipitation.
NCDC vs. PRISM values.
Red 1895-96 / 1930-31. Blue 1931-32 / 2004-05.
P = 3.02 + 0.836 N
r = 0.903 r^2 = 0.816
n = 110
b = 3.02 +/- .52
a = .836 +/- .038
Pre 1931 r = .813 r^2 = .662
Post 1931 r = .985 r^2 = .969
Nave = 13.45
Pave = 14.27
1:1 Line
Pre 1931
Post 1931
PRISM Precipitation (inches)
NCDC Precipitation (inches)
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
8
9
10
11
12
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14
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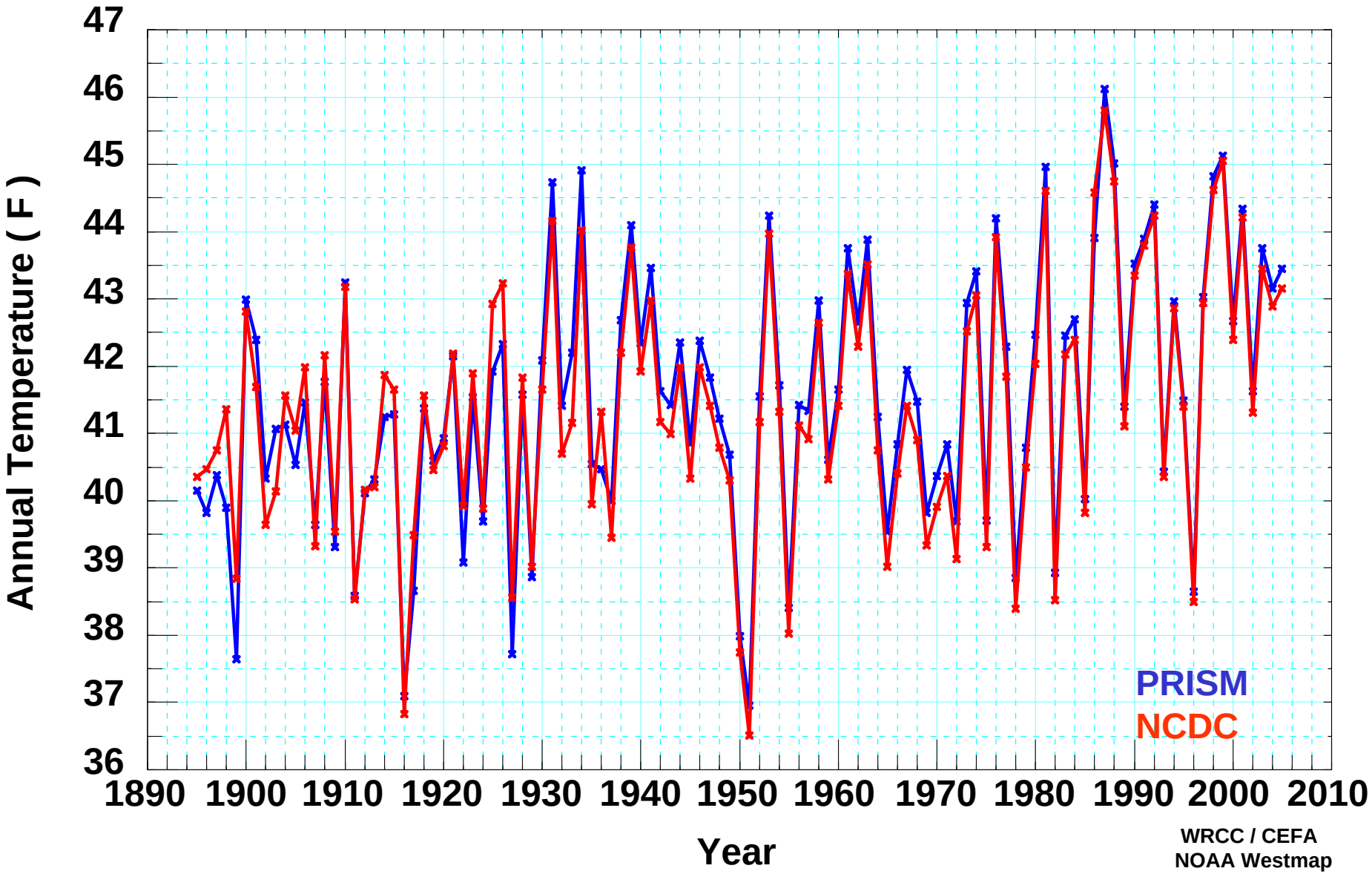
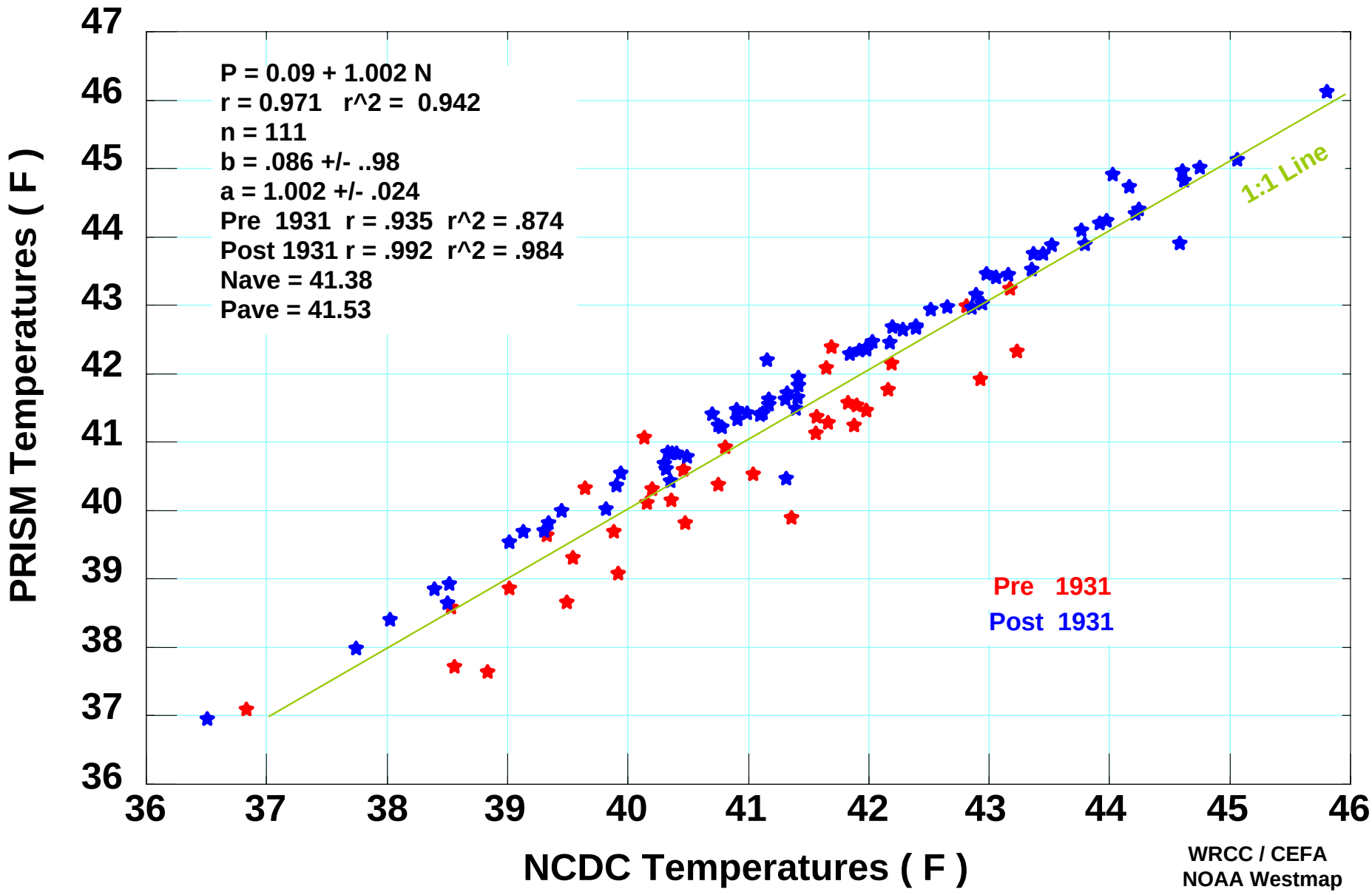
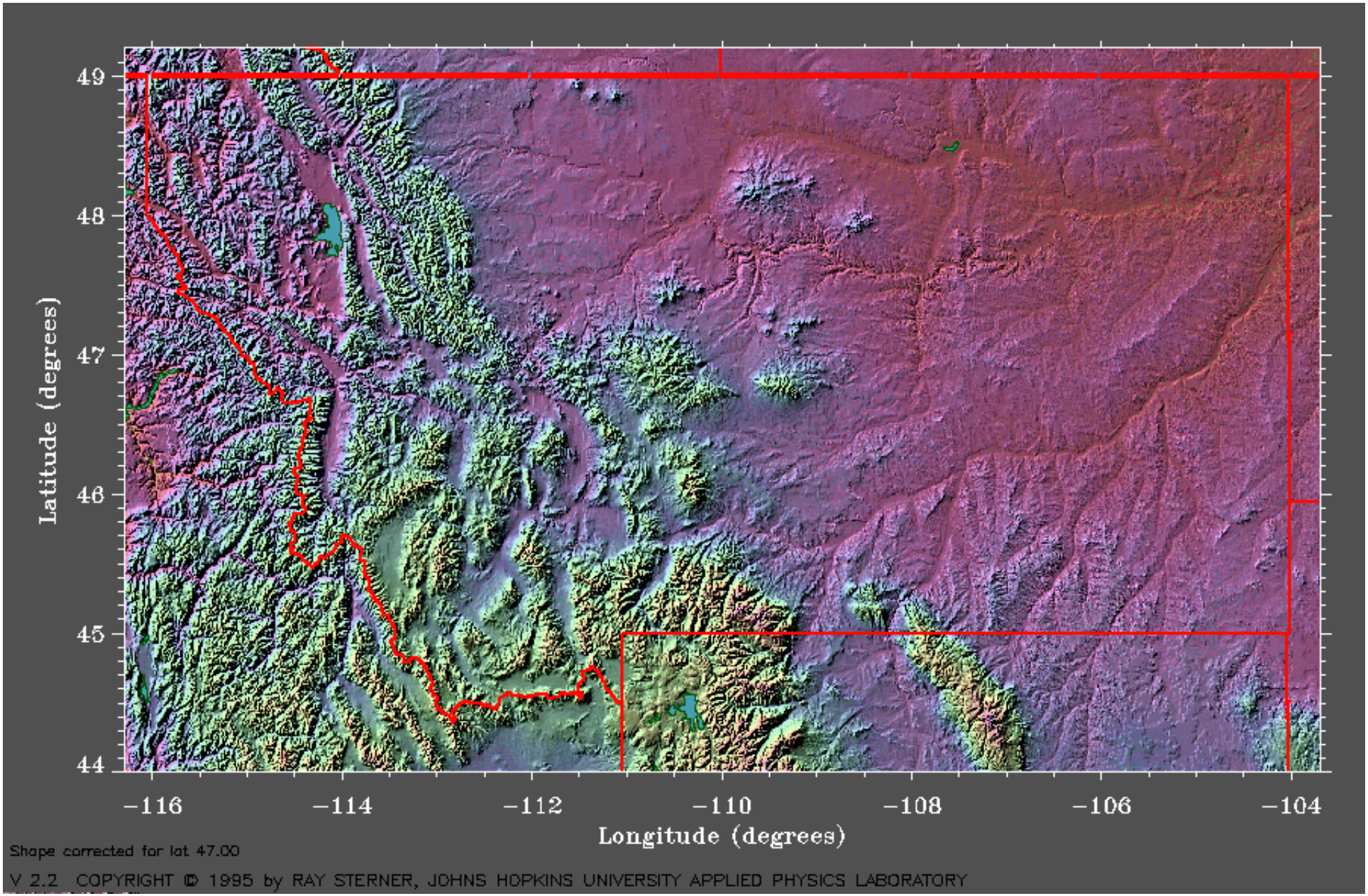
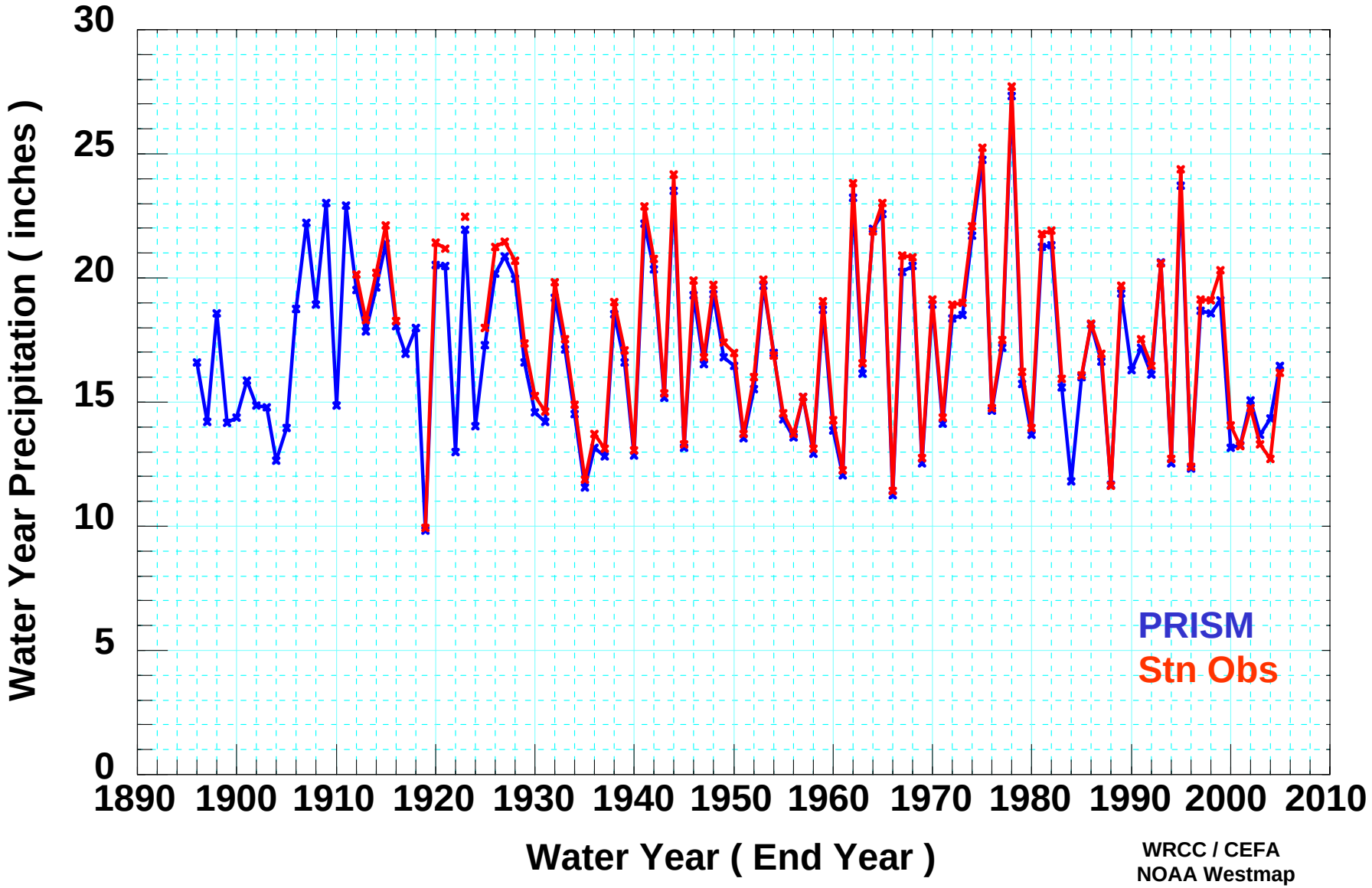
16
17
18
19
20
21
22
WRCC / CEFA
NOAA Westmap


Montana Division 3 Mean Annual Temperature
Units: Inches. PRISM - Blue NCDC - Red.
Data from 1895-2005.
Annual Temperature (F)
47
46
45
44
43
42
41
40
39
38
37
36
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
PRISM
NCDC
WRCC / CEFA
NOAA Westmap

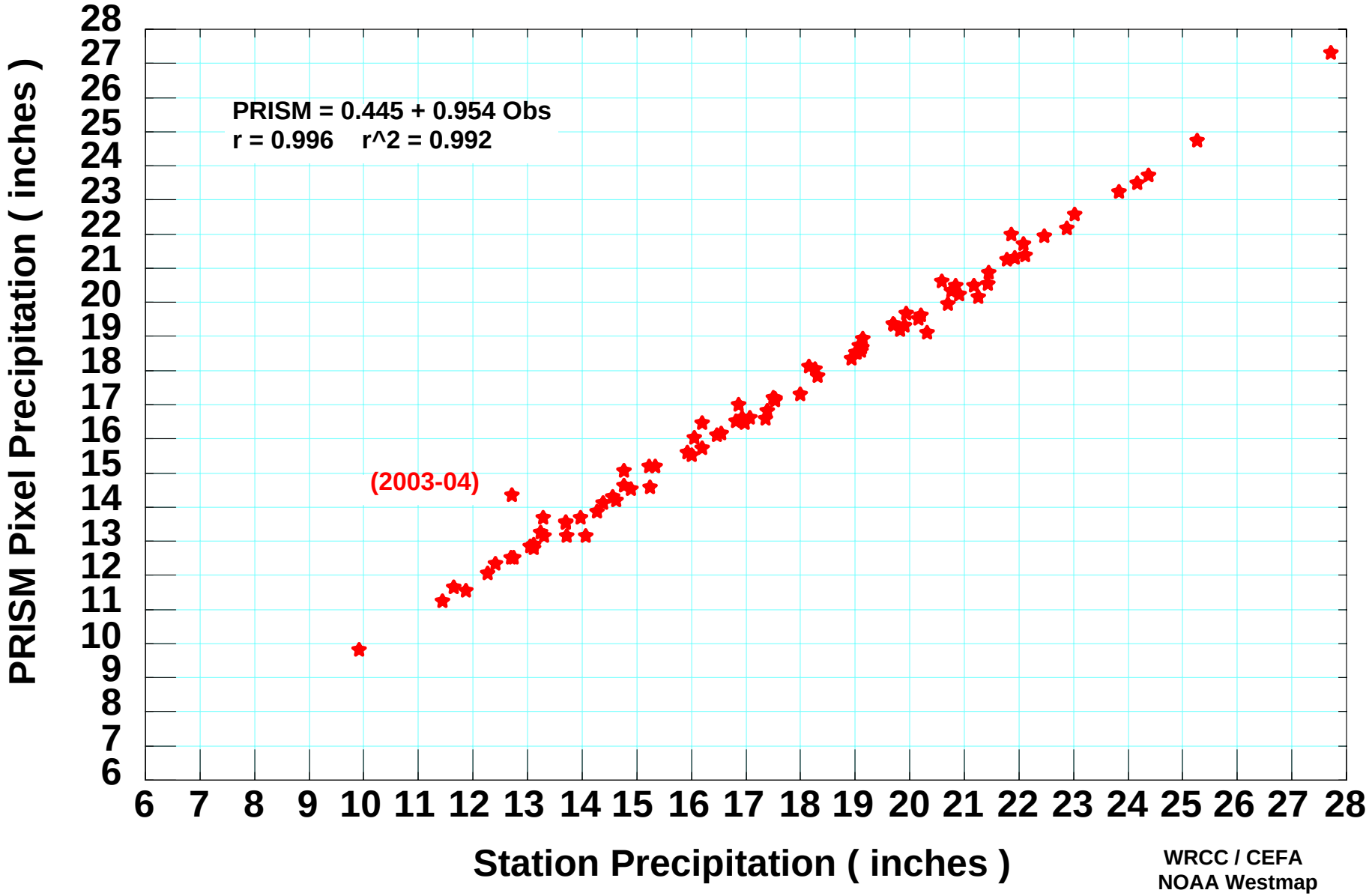

Montana Division 3 Mean Annual Temperature.
NCDC vs. PRISM values.
Red 1895-1930. Blue 1931-2005.
P = 0.09 + 1.002 N
r = 0.971 r^2 = 0.942
n = 111
b = .086 +/- ..98
a = 1.002 +/- .024
Pre 1931 r = .935 r^2 = .874
Post 1931 r = .992 r^2 = .984
Nave = 41.38
Pave = 41.53
1:1 Line
Pre 1931
Post 1931
PRISM Temperatures (F)
NCDC Temperatures (F)
47
46
45
44
43
42
41
40
39
38
37
36
36
37
38
39
40
41
42
43
44
45
46
WRCC / CEFA
NOAA Westmap


49
48
47
46
45
44
Latitude (degrees)
−116
−114
−112
−110
−108
−106
−104
Longitude (degrees)
Shape corrected for lat 47.00
V 2.2 COPYRIGHT © 1995 by RAY STERNER, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

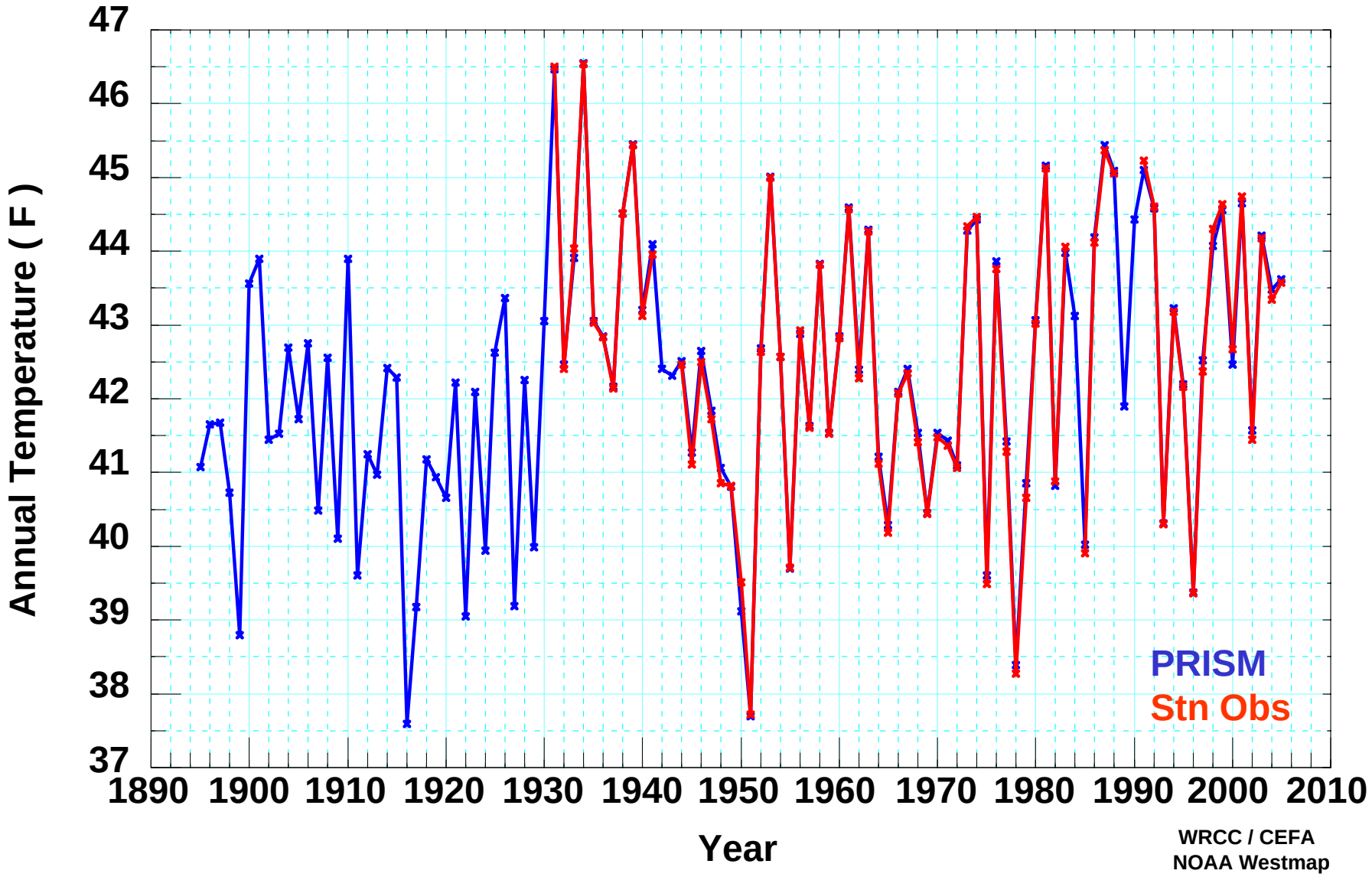
Lewistown Montana Airport. Water Year (Oct-Sep) Precipitation.
Units: Inches. PRISM pixel: Blue Airport: Red
PRISM data from 1895-2005. Lewistown data as available.

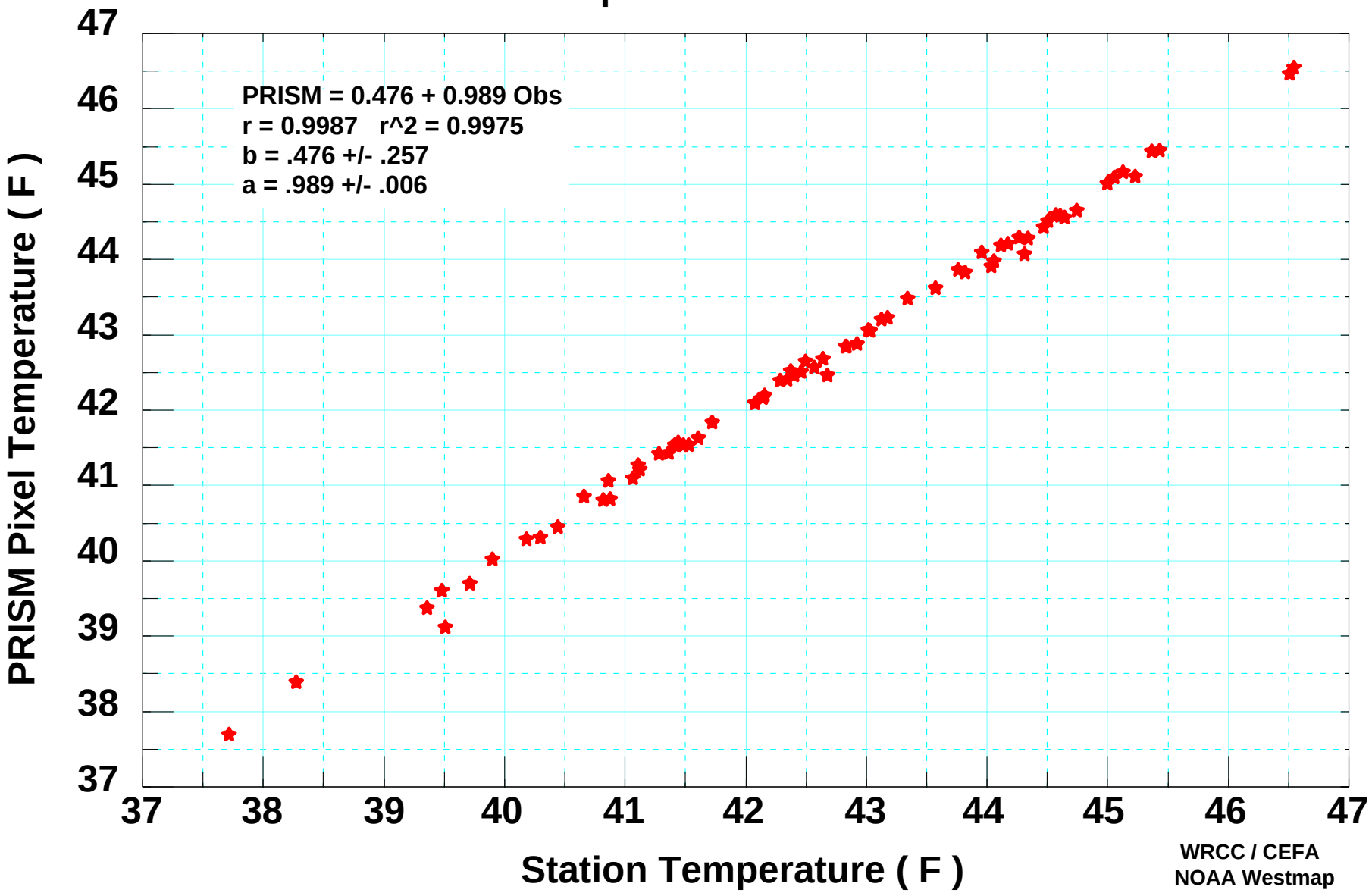


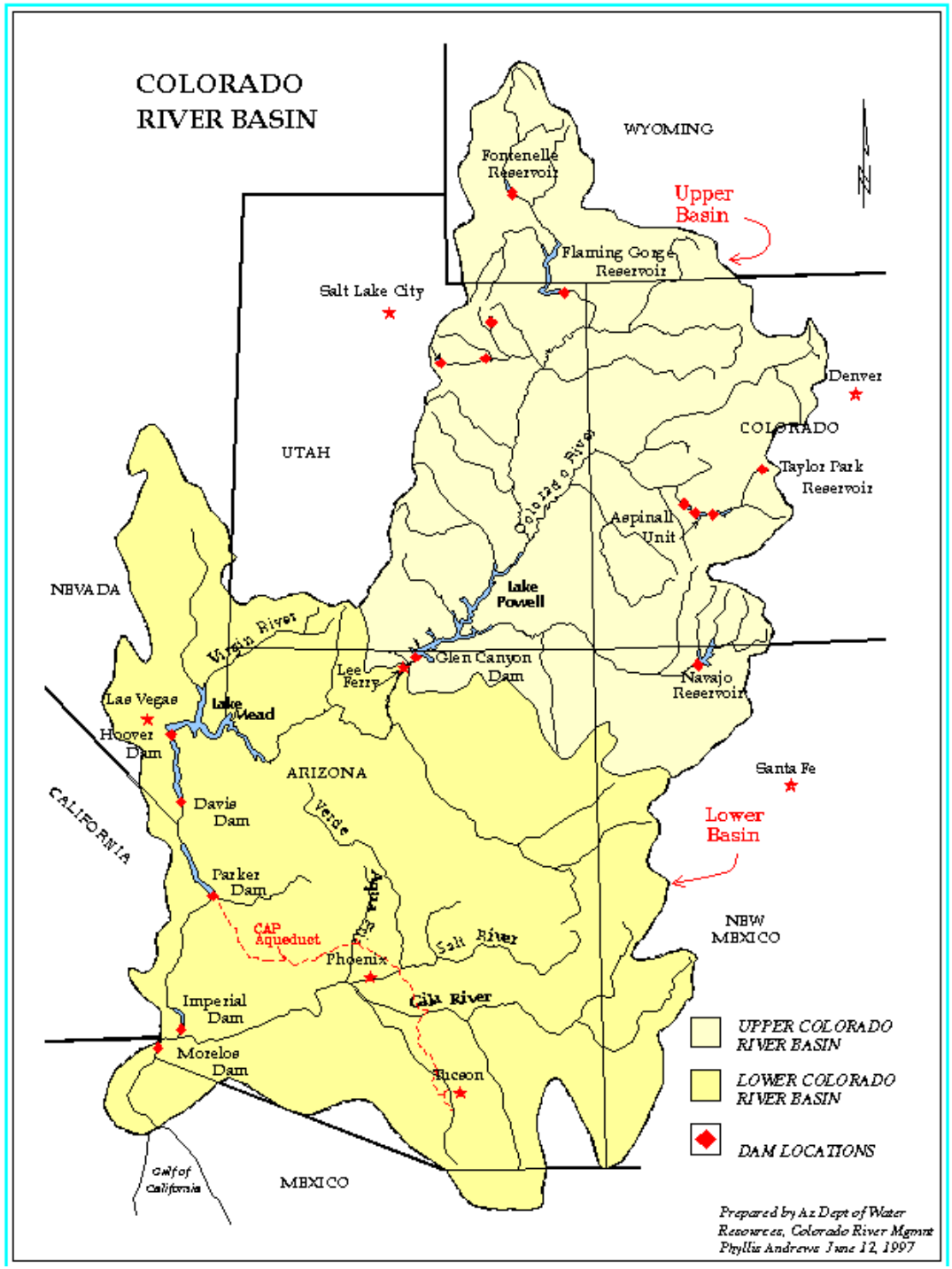
WRCC / CEFA
NOAA Westmap

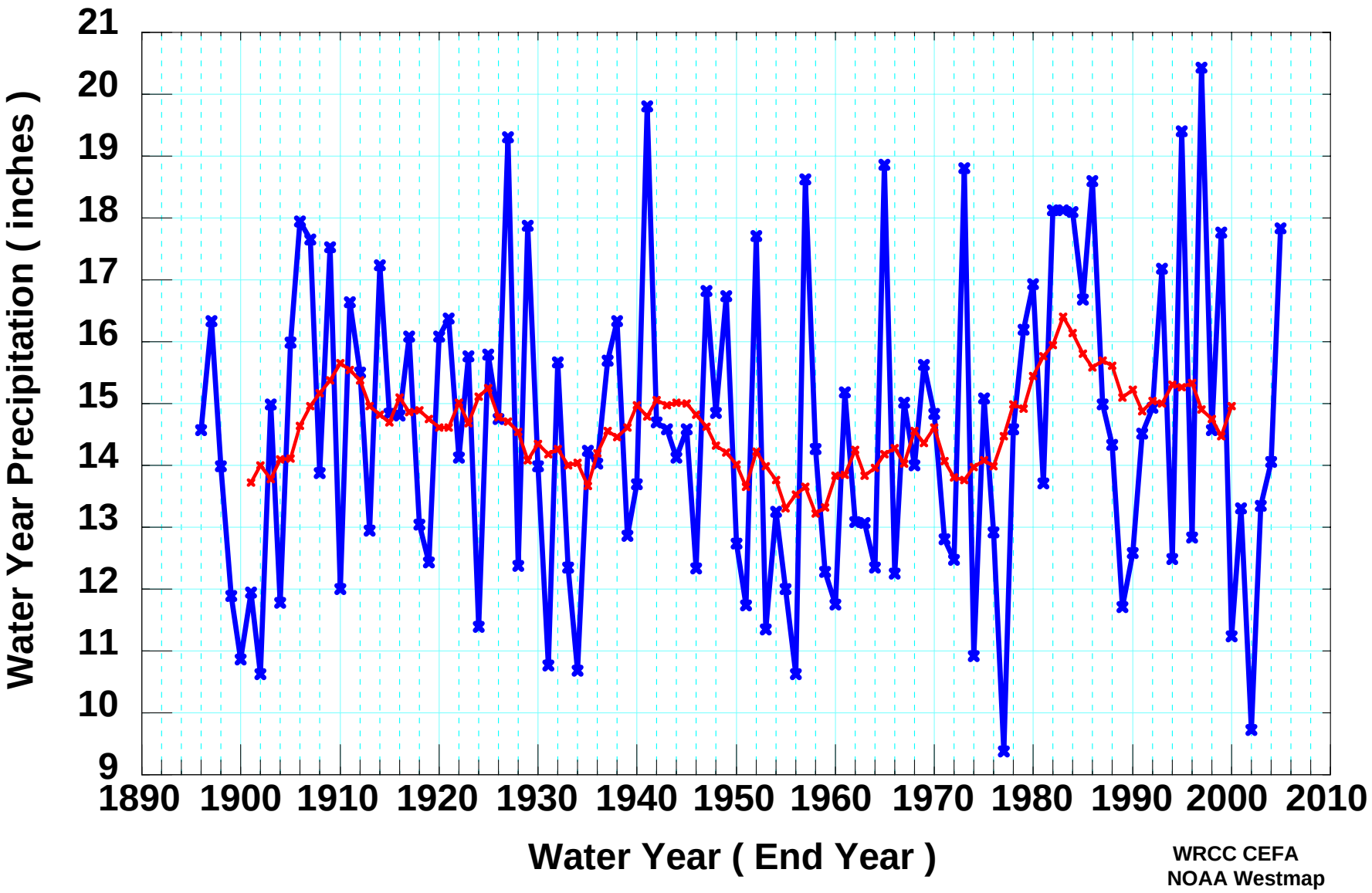

Lewistown Montana Airport. Water Year Precipitation.
Station Data vs. PRISM Pixel.
Station Data from within period 1911-2005.
PRISM = 0.445 + 0.954 Obs
r = 0.996 r^2 = 0.992
(2003-04)
PRISM Pixel Precipitation (inches)
Station Precipitation (inches)
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
WRCC / CEFA
NOAA Westmap

Lewistown Montana Airport. Mean Annual Temperature.
Units: Degrees F. PRISM pixel: Blue Airport: Red
PRISM data from 1895-2005. Lewistown data as available.

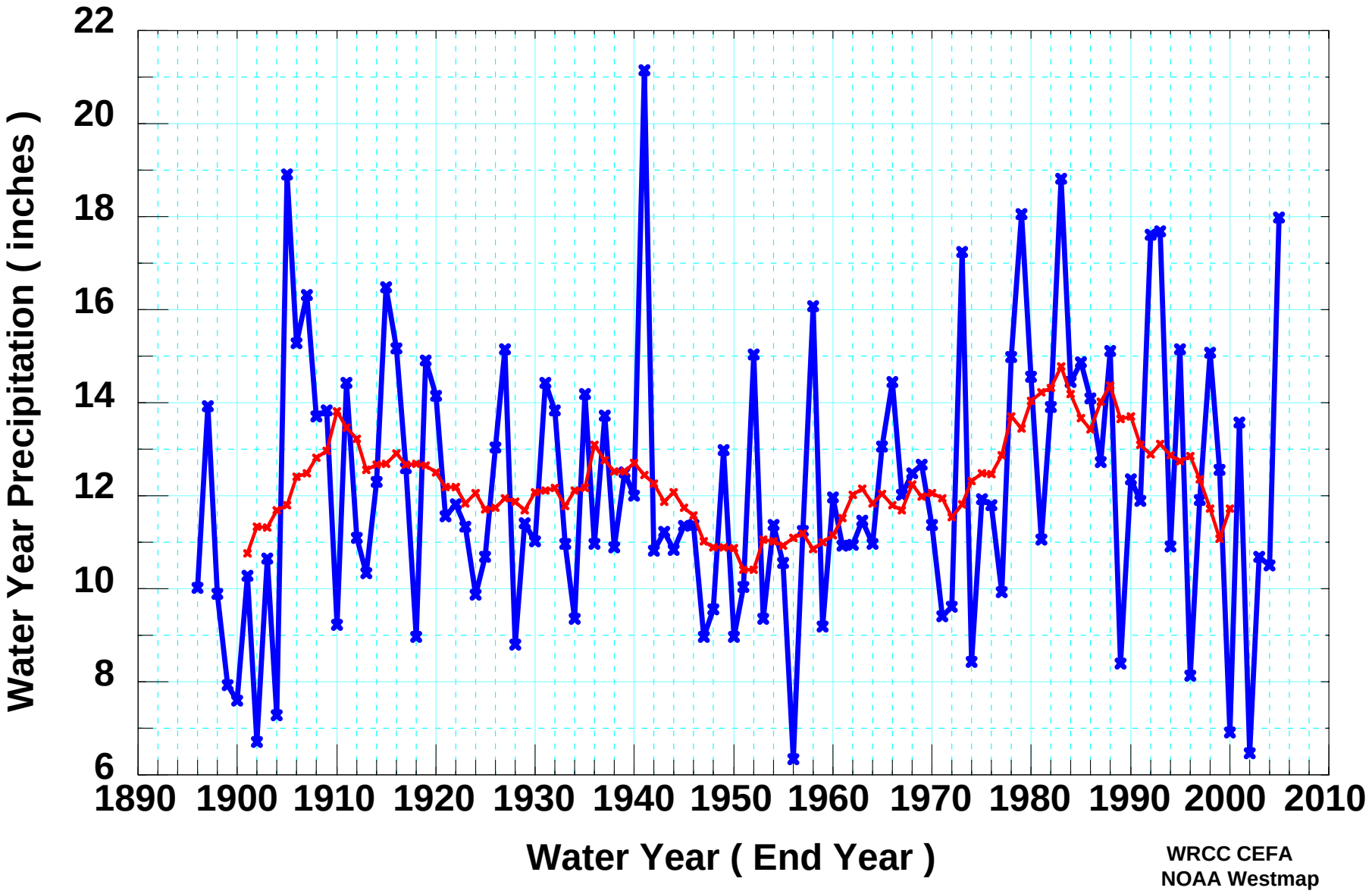


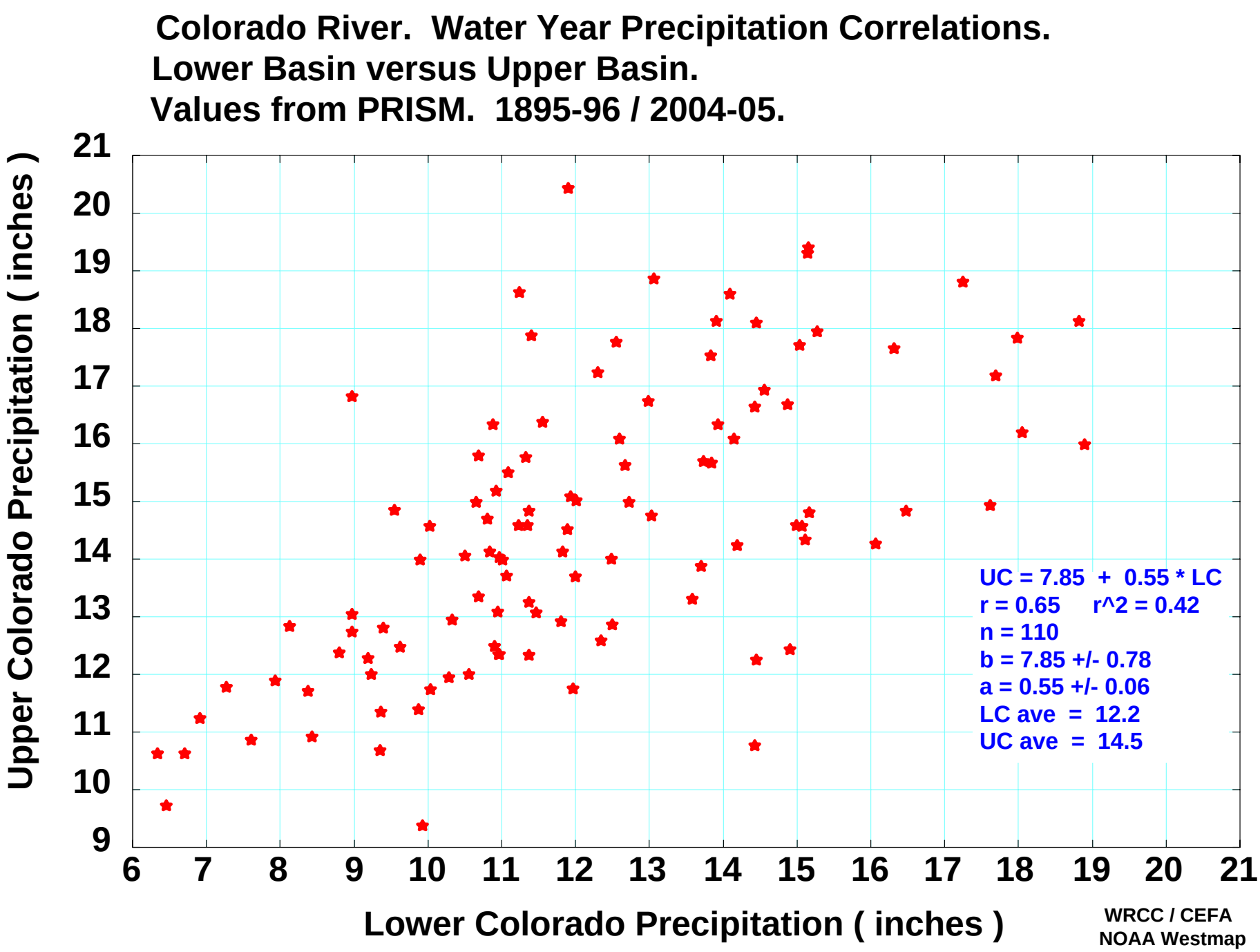

Lewistown Montana Airport. Mean Annual Temperature.
Station Data vs. PRISM Pixel.
Station Data from within period 1911-2005.
PRISM = 0.476 + 0.989 Obs
r = 0.9987 r^2 = 0.9975
b = .476 +/- .257
a = .989 +/- .006
PRISM Pixel Temperature (F)
Station Temperature (F)
37
38
39
40
41
42
43
44
45
46
47
WRCC / CEFA
NOAA Westmap

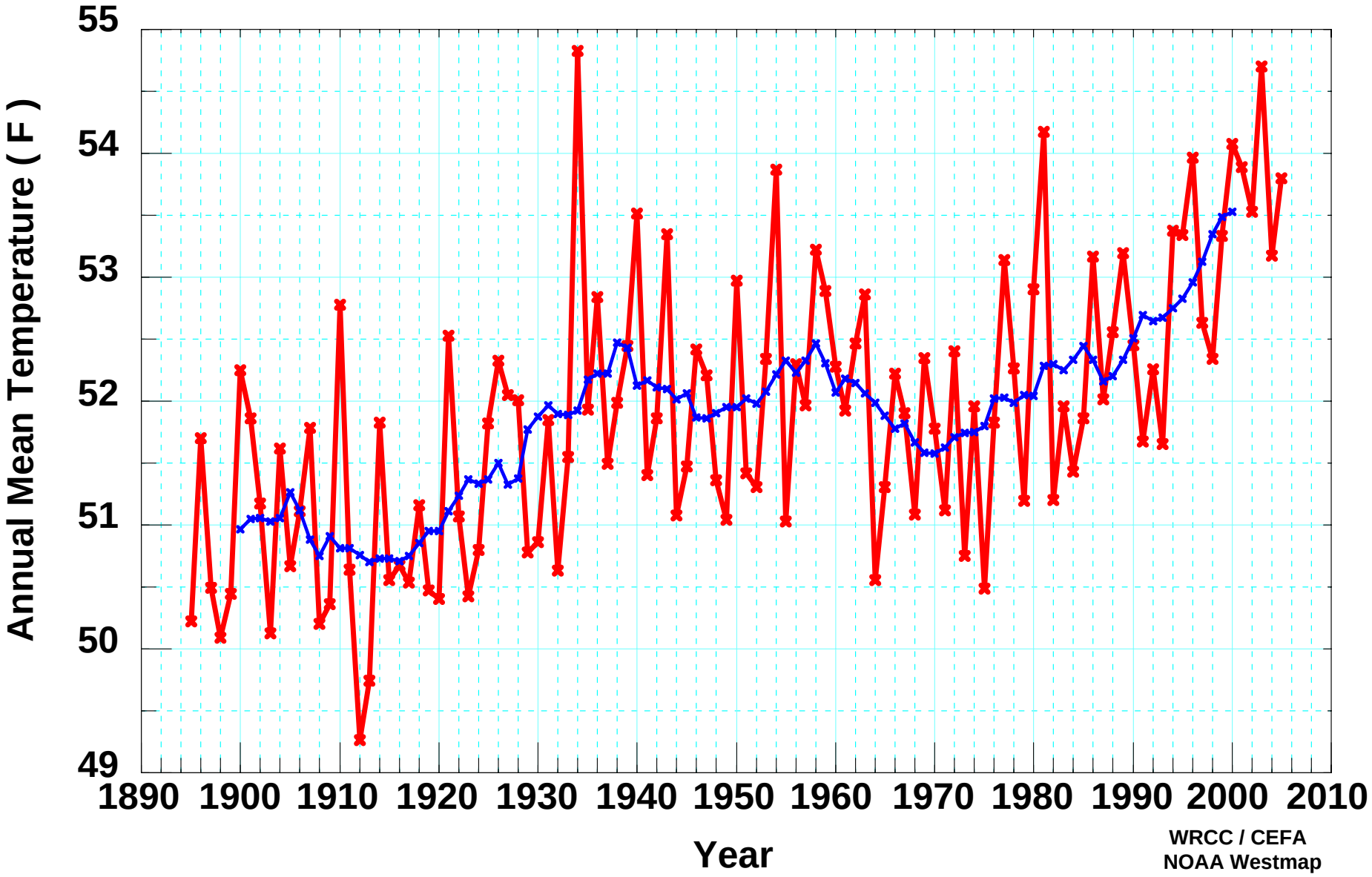

COLORADO
RIVER BASIN
WYOMING
Fontenelle Reservoir
Upper Basin
Flaming Gorge Reservoir
Salt Lake City
Denver
COLORADO
UTAH
Colorado River
Taylor Park Reservoir
Aspinall Unit
NEVADA
Lake Powell
Virgin River
Glen Canyon Dam
Lee Ferry
Navajo Reservoir
Las Vegas
Lake Mead
Hoover Dam
ARIZONA
Santa Fe
Lower Basin
CALIFORNIA
Davis Dam
Verde
Parker Dam
Agua Fria
CAP Aqueduct
Salt River
NEW MEXICO
Phoenix
Gila River
Imperial Dam
Morelos Dam
Tucson
Gulf of California
MEXICO
UPPER COLORADO RIVER BASIN
LOWER COLORADO RIVER BASIN
DAM LOCATIONS
Prepared by Az Dept of Water Resources, Colorado River Mgmnt
Phyllis Andrews June 12, 1997


Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
21
20
19
18
17
16
15
14
13
12
11
10
9
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year (End Year)
WRCC CEFA
NOAA Westmap

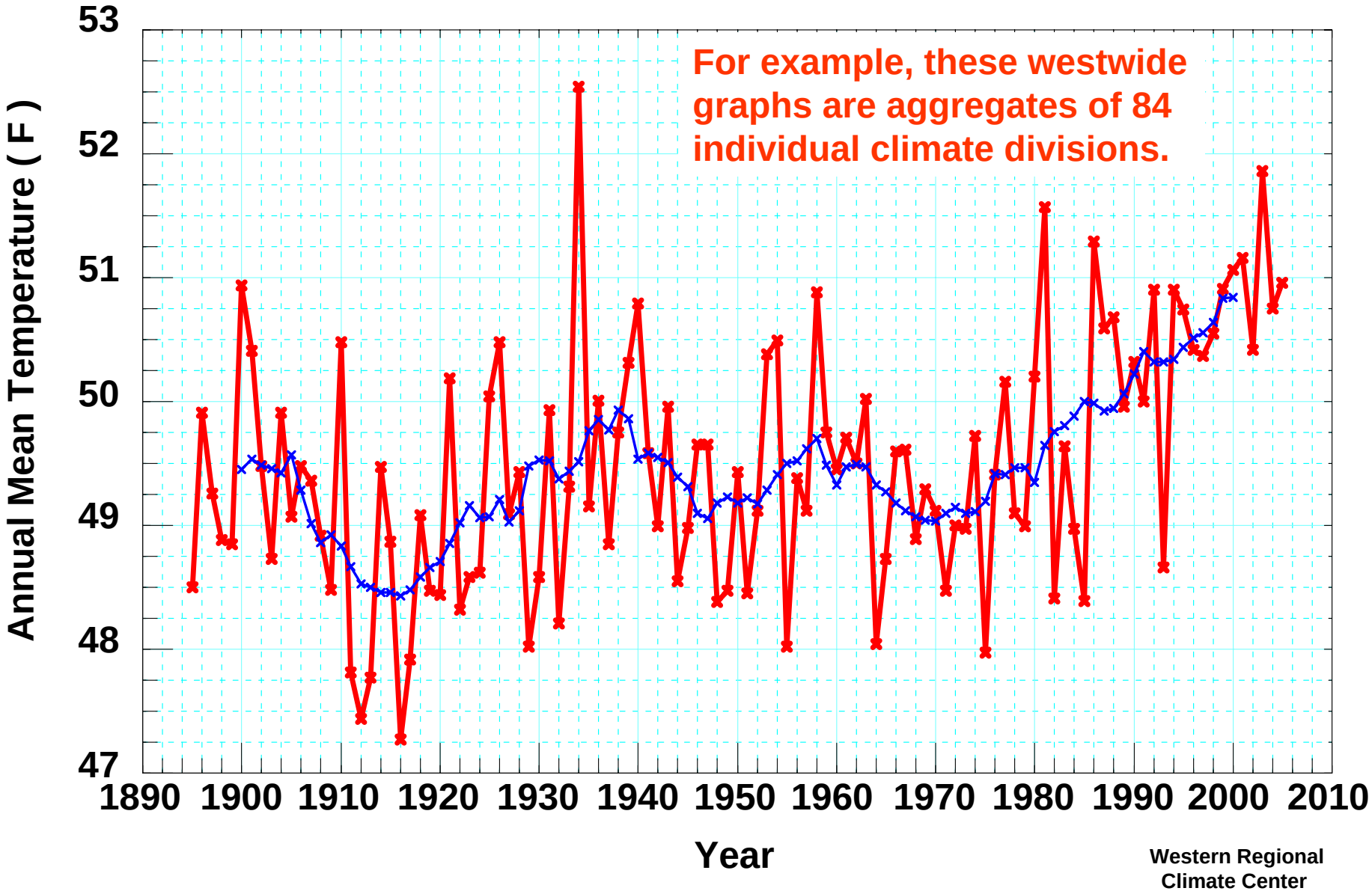
Lower Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.



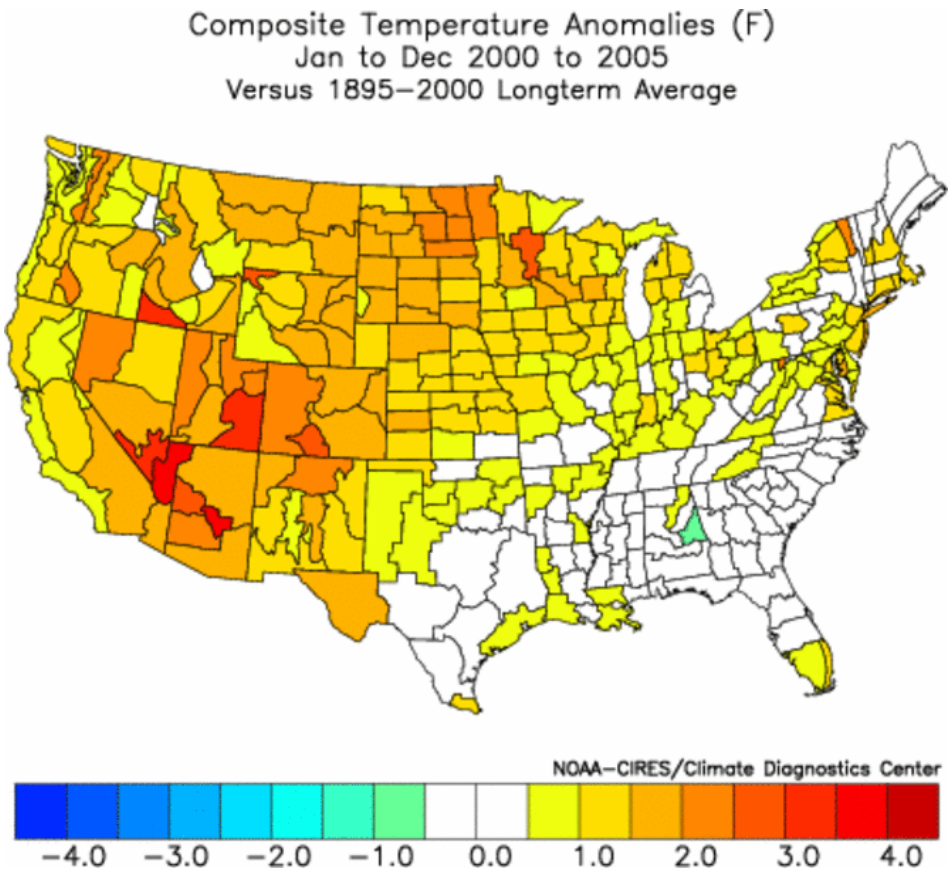

Colorado River. Water Year Precipitation Correlations.
Lower Basin versus Upper Basin.
Values from PRISM. 1895-96 / 2004-05.
Upper Colorado Precipitation (inches)
Lower Colorado Precipitation (inches)
21
20
19
18
17
16
15
14
13
12
11
10
9
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
UC = 7.85 + 0.55 * LC
r = 0.65 r^2 = 0.42
n = 110
b = 7.85 +/- 0.78
a = 0.55 +/- 0.06
LC ave = 12.2
UC ave = 14.5
WRCC / CEFA
NOAA Westmap

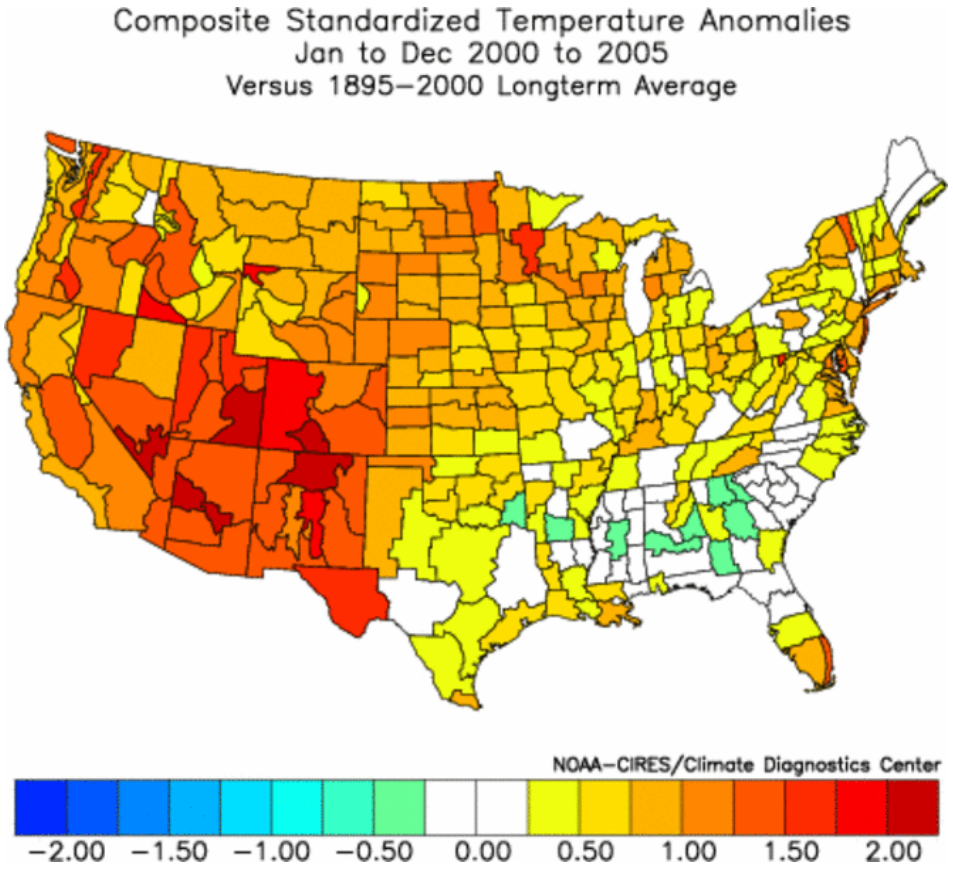

Colorado River Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.
Annual Mean Temperature (F)
55
54
53
52
51
50
49
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
WRCC / CEFA
NOAA Westmap

Western United States (11 states) Annual Jan-Dec Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Jan 2006.



Annual Mean Temperatures, 2000-2005.
Departures from 1895-2000 Mean.





Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West dominates recent U.S. warming.

One way this might work … like the existing divisional form at WRCC

Plot time history of single/multi-month precipitation/temperature.

More details about this program

To access state-wide averages, use division pull-down.

Arizona | 07 - Southeast | Create Plot

Select the quantity you wish to plot

(•) Precipitation ( ) Temperature

Enter the Beginning year: 1890 Enter the Ending year: 2010

Enter the period of months each data point will represent (1-72): 4

Select the last month of the period. February

Would you like a running mean? (blue) (•) Yes ( ) No

Enter the number of years in the running mean (2-30) 10

Show the average? (green) (•) Yes ( ) No

Select the image size of the plot.

( ) Small (510x290) (•) Medium (650x370) ( ) Large (850x480)

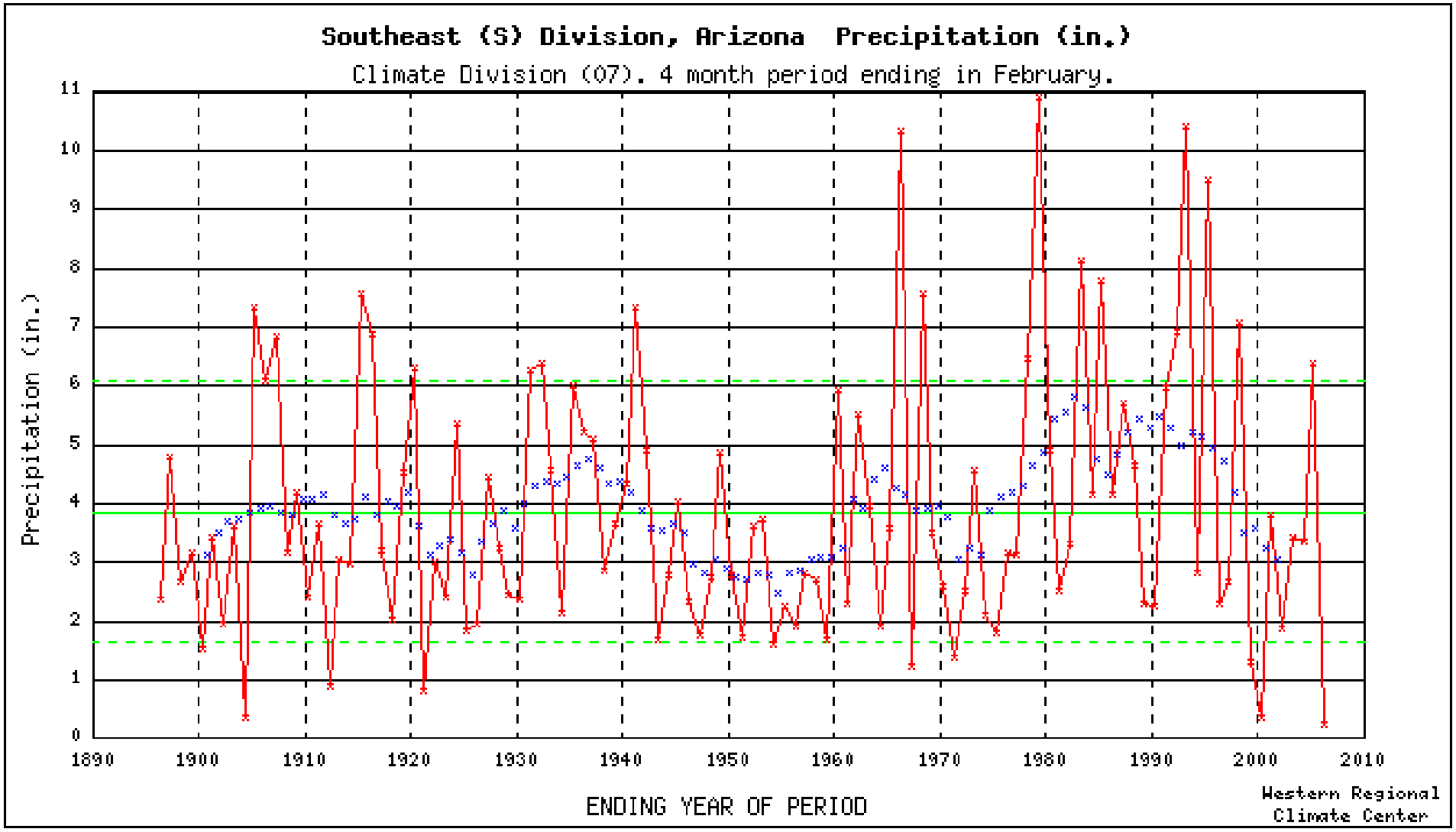
List the data for the points plotted? (•) Yes ( ) No

To select divisions

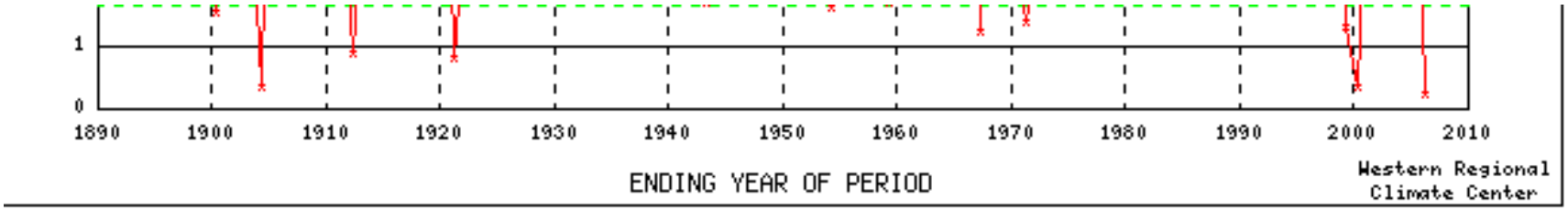
- **Use pulldowns**
- **Or click on division(s)**

Western Regional Climate Center, wrcc@dri.edu

… which produces this graphical output, and …



… summary information and a data listing if desired.



red - 4 month period
blue - 10 year running mean
green - average (solid), ± sigma (dashed)

```
Total Precipitation          4-Month Period Ending in Month  2
   YEARS : 1890 - 2010
  AVERAGE              3.853
  SIGMA (RMS)          2.220
  COEFF OF VAR         0.576
  SKEWNESS             1.001
  MEDIAN               3.240
  MAXIMUM VALUE       10.890
  MINIMUM VALUE        0.210
  NUMBER OBS            111.
YEAR 1896. VALUE =     2.350
YEAR 1897. VALUE =     4.780
YEAR 1898. VALUE =     2.670
YEAR 1899. VALUE =     3.140
YEAR 1900. VALUE =     1.510
YEAR 1901. VALUE =     3.430
YEAR 1902. VALUE =     1.940
YEAR 1903. VALUE =     3.600
YEAR 1904. VALUE =     0.360
YEAR 1905. VALUE =     7.330
YEAR 1906. VALUE =     6.060
YEAR 1907. VALUE =     6.810
YEAR 1908. VALUE =     3.150
YEAR 1909. VALUE =     4.190
YEAR 1910. VALUE =     2.380
YEAR 1911. VALUE =     3.660
```

Several different output formats

- **Descriptive (wordy)**
- **Text columns**
- **Delimiter separated**
- **Etc**

Remaining stray thoughts:

Could also combine divisions (or counties or hydro units or grids) to get desired larger areas. It's inefficient to start from pixels if pre-calculated domains can be aggregated to create a larger domain.

Currently in discussions with Climate Diagnostics Center about developing and utilizing complementary (and also excellent) analysis capabilities there, such as compositing, correlation fields, etc.

For the present, most domains will be pre-calculated. Individual pixels will also be accessible.

We are still testing to determine how quickly a time series from a large or complex arbitrary-shaped area can be generated (web patience).

To display station data simultaneously will require building links into the monthly database.

The methodology permits usage of higher-resolution grids as they become available in the future.

The focus of the web page is western, but we will have an internal ability to deal with the whole country. Alaska and the islands not yet addressed.

** Comments and advice appreciated **

Contacts:

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kelly.redmond@dri.edu

WRCC: Hauss Reinbold

hauss.reinbold@dri.edu

OSU: Chris Daly

daly@coas.oregonstate.edu

Thank You

Discards

Credibility:

How good are these numbers?

Do they replicate “known” climate histories?

And, how good are the “known” climate histories?

Some preliminary investigations:

Westmap Long-Term Goals

50-100 years, 1 km gridded monthly climate observations, continuously updated.

Provide to data users & stakeholders:

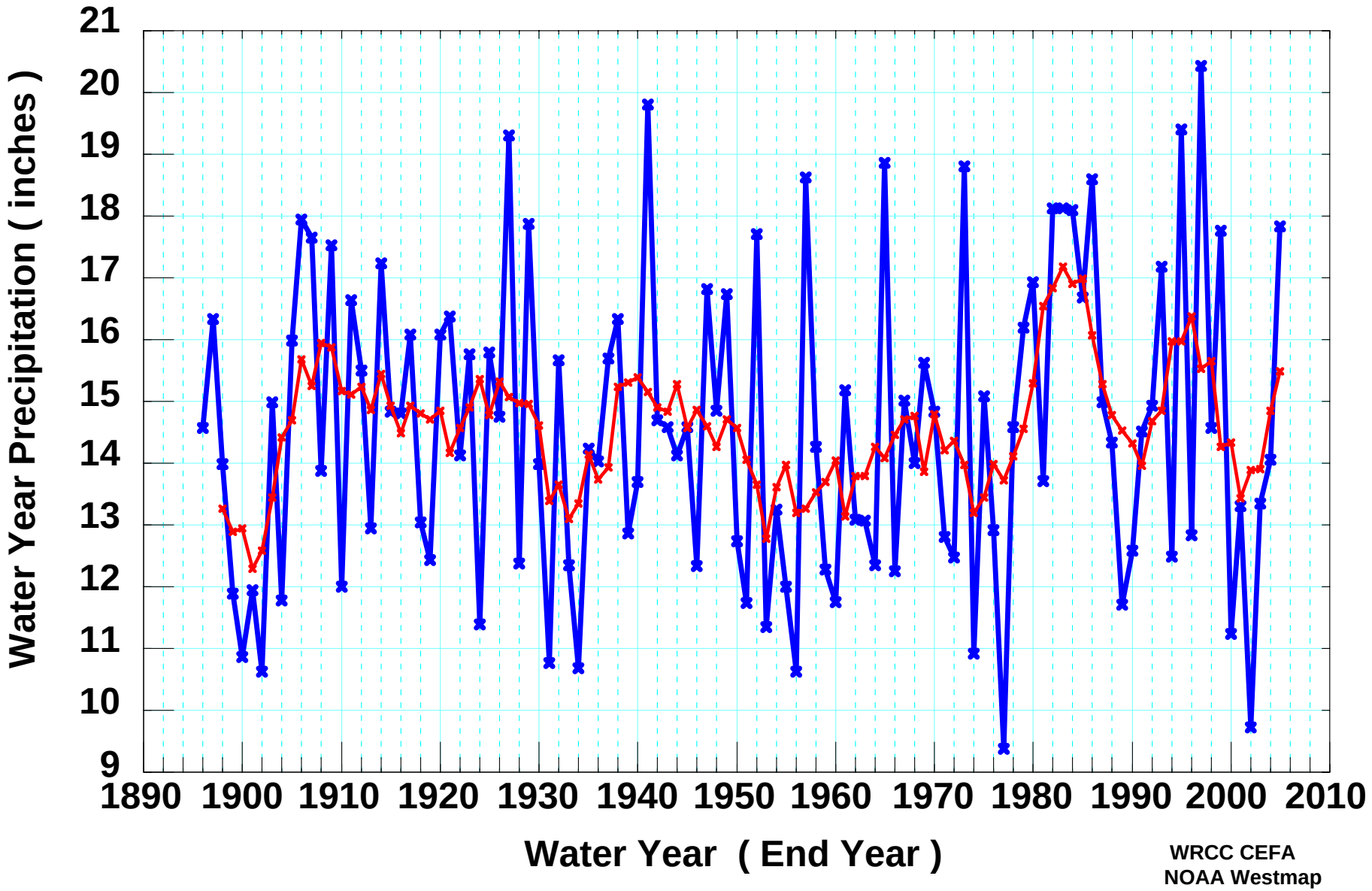
- **online analysis tools**
- **associated error/accuracy estimates**
- **educational resources**

- **Main Westmap focus on a western US domain**
  - **Large demand and complex climate mapping challenges in the West**
    - **fine scale topographic variations**
    - **extensive high elevation mountain ranges**
    - **deserts**
    - **coastal boundary regions**
    - **interior valleys**
    - **rain shadows**
    - **data availability**
    - **poor station distribution**

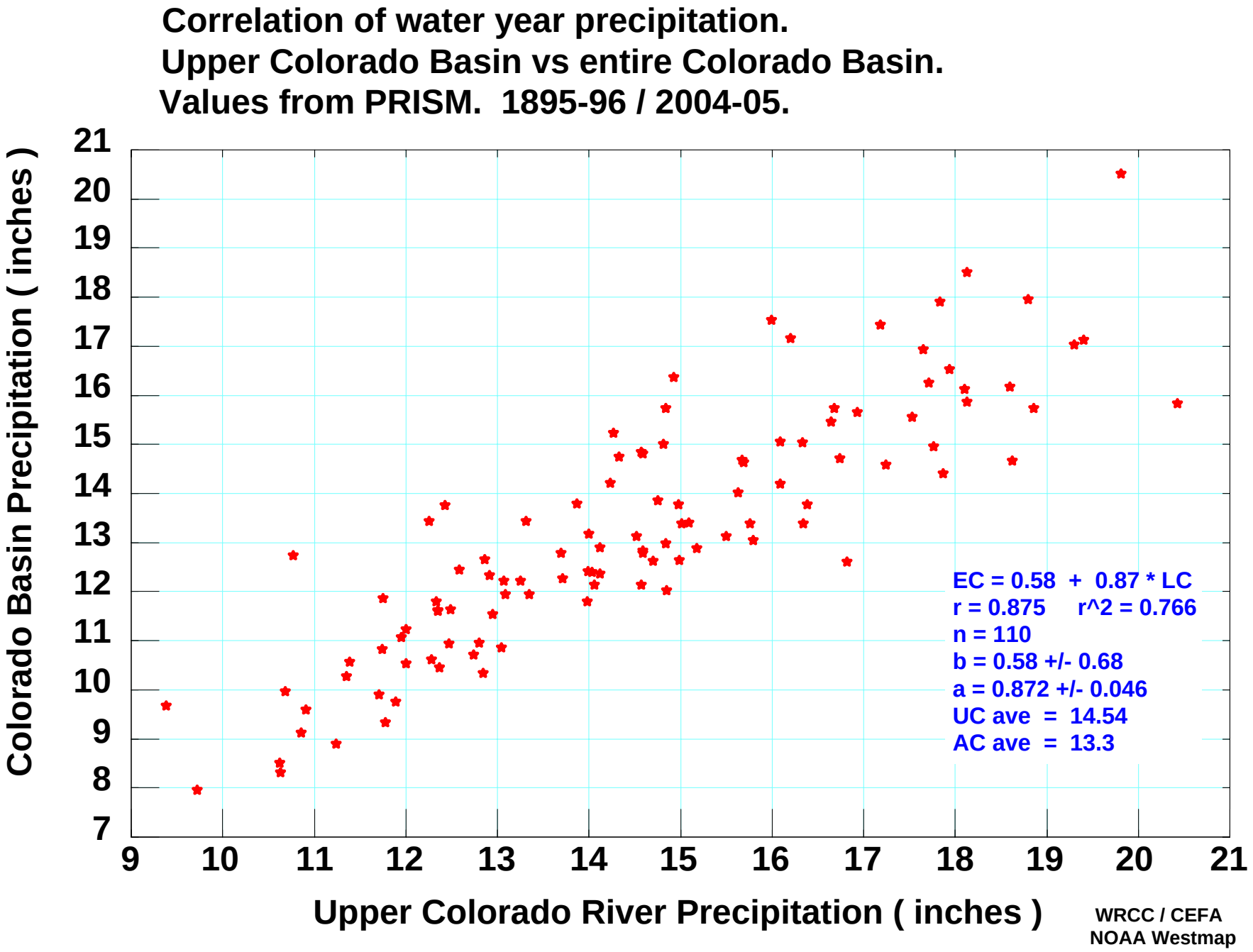
Product Applications

- Six key areas
  - Drought mitigation/monitoring, e.g.:
    - Complement and enhance developing drought management initiatives and monitoring programs
    - In turn, these activities will help future mapping through identifying gaps/problems in the present data sets
  - Climate variability
  - Water management
  - Resource management of public and private lands in the West
  - Global change modeling and assessment
  - Forecasts (initial conditions) and downscaling of forecasts (limits of predictability, model verification)

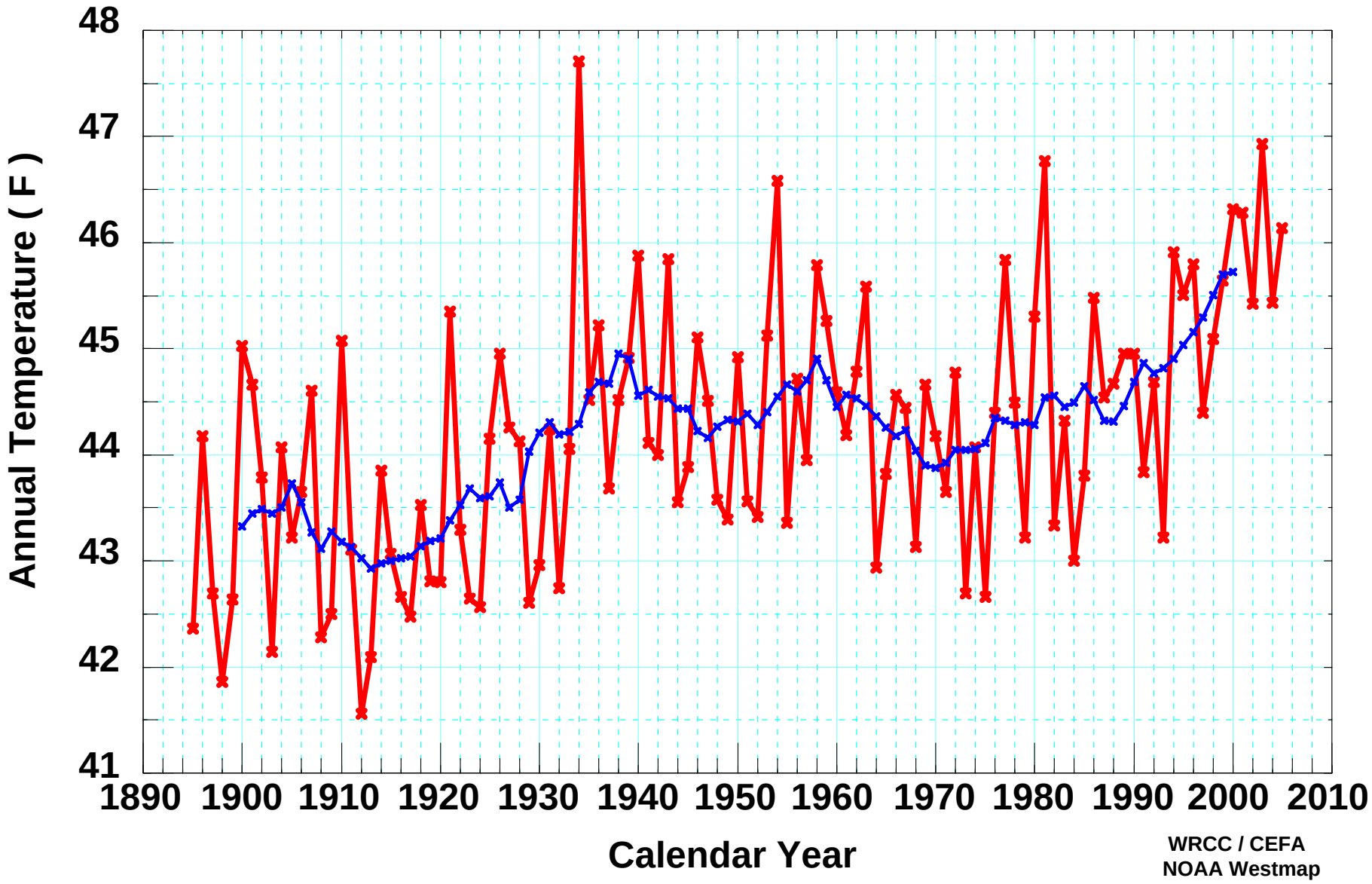
Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 7-yr mean.



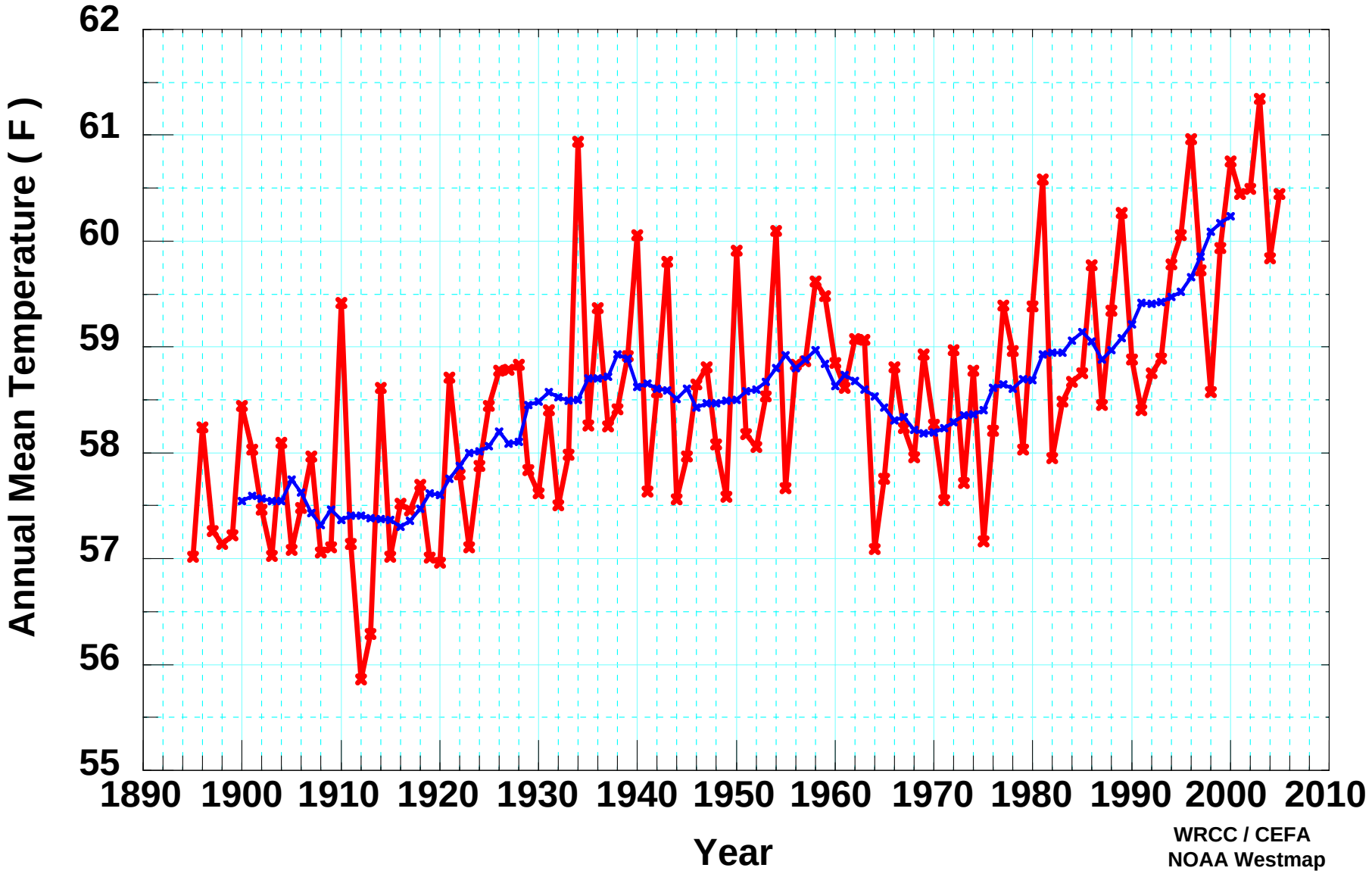
WRCC CEFA
NOAA Westmap

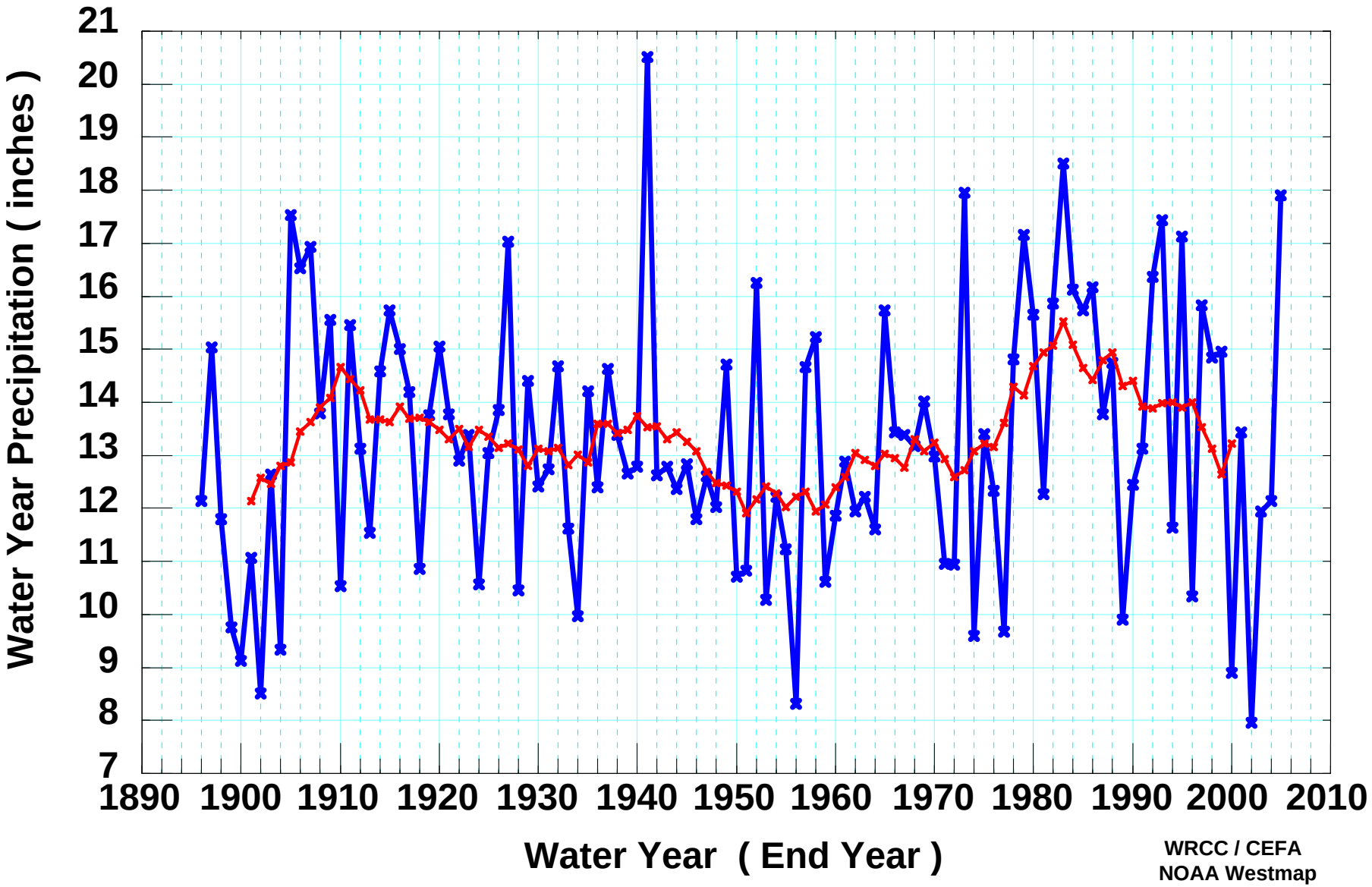

Correlation of water year precipitation.
Upper Colorado Basin vs entire Colorado Basin.
Values from PRISM. 1895-96 / 2004-05.
Colorado Basin Precipitation (inches)
Upper Colorado River Precipitation (inches)
EC = 0.58 + 0.87 * LC
r = 0.875 r^2 = 0.766
n = 110
b = 0.58 +/- 0.68
a = 0.872 +/- 0.046
UC ave = 14.54
AC ave = 13.3
WRCC / CEFA
NOAA Westmap

Upper Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.



Lower Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.




Colorado River Basin Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
21
20
19
18
17
16
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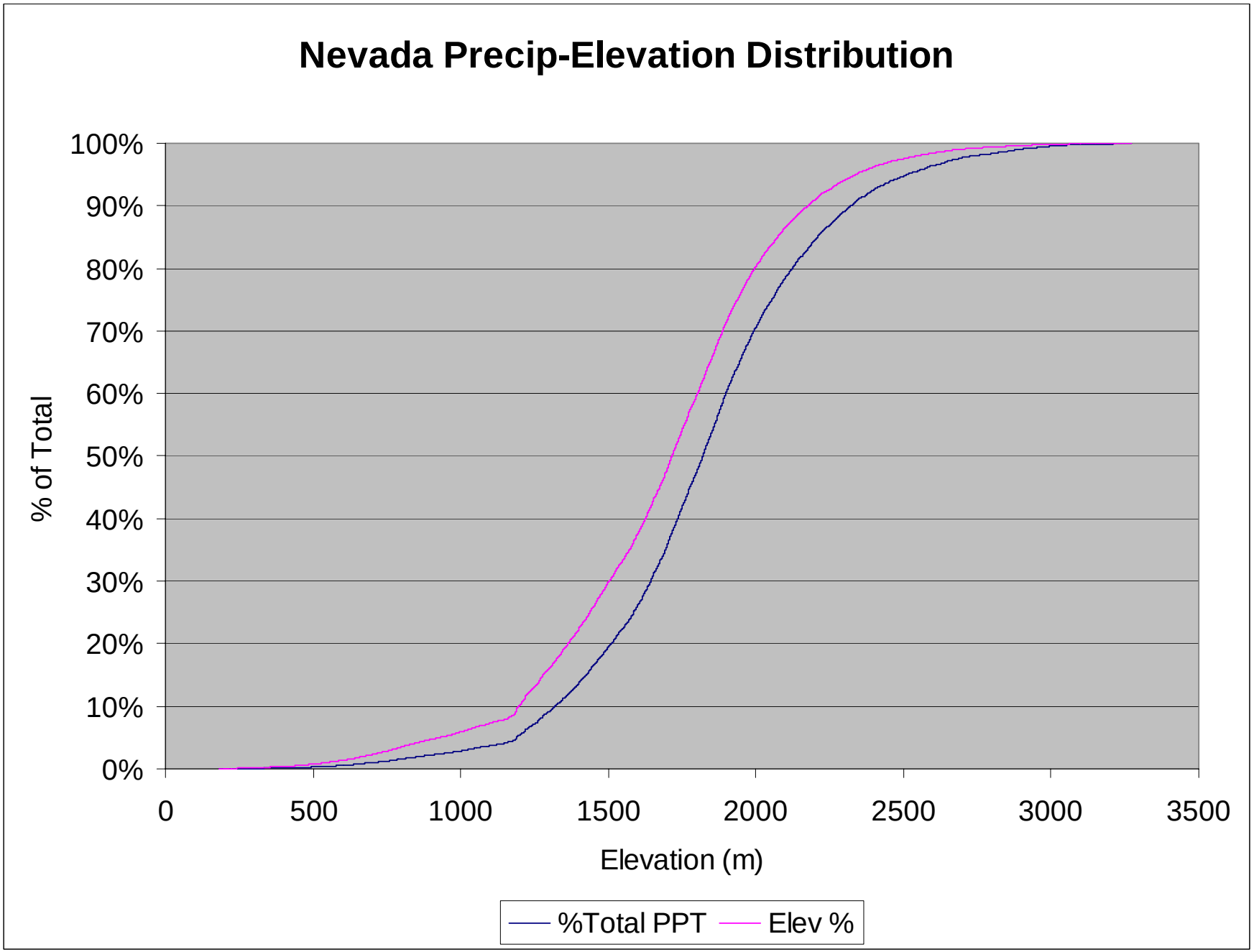
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year (End Year)
WRCC / CEFA
NOAA Westmap



Courtesy of Chris Daly, OSU, Based on PRISM.