**Climate Data Methods**

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This document explains the methods involved with the retrieval, processing, and implementation of climate data in the Bijou Creek study. Files referenced here can be found at – Project/our/GPI/Bijou Creek/Climate.

**Section Name Page number**

Precipitation Introduction 2

Precipitation Weather Stations 3 - 5

Precipitation Methods 6

Precipitation Regression Results 7 – 8

Temperature Introduction 9

Temperature Weather Stations 10 - 11

Temperature Regression Results 12

PDSI Introduction 13

PDSI WWDT 16

Palmer Z-score WWDT 17

PDSI (SC) R Package 19

**Precipitation**

Precipitation data was retrieved on December 6th, 2016 from High Plains Regional Climate Center’s CLIMOD software (climod.unl.edu). Data from the Byers weather station and the 12 most complete surrounding stations was collected in an attempt to gather accurate precipitation data for Bijou Creek. The Byers weather station served as the basis for the Bijou Creek precipitation data, however it is missing 23 monthly values. In order to fill in these missing values, we evaluated the 9 best surrounding weather stations for their correlation to the Byers station. The correlation between the two weather stations monthly precipitation data was important to quantify in order to fill in the data as best we could. Also of importance was figuring out just how many of this missing data points the secondary weather station could fill in.

An analysis and summary of the 12 best weather stations surrounding Byers can be found in the excel document ‘Weather Stations v1’. After evaluating these 12 stations, we concluded that the best stations for precipitation correlation were Parker 6E, and Denver Stapleton. Summary Information for both of these stations can be found below, or in the excel document ‘Weather Stations v3’.

***Weather Stations –***

**Byers 5 ENE**

**Station ID:** 051179 (coop) USC00051179 (GHCN) BYRC2 (NWS LI)

**Location:** Adams County, Platte drainage basin (COO4)

**Lat / long:**  39.7403, -104.1275

**Elevation:** 5100 ft

**Data range:**  1930-02-22 - 2016-11-30

**NOAA Station Metadata**:

https://www.ncdc.noaa.gov/homr/#ncdcstnid=20003761&tab=MSHR

**Coop Form:**

https://www.ncdc.noaa.gov/IPS/coop/coop.html?\_page=2&state=CO&foreign=false&stationID=051179&\_target3=Next+%3E

**Colorado Climate Trends Summary:** This is a good quality station on the high plains east of Denver. Issues affecting long term data continuity include several local station moves within the town of Byers during the 1960's. Undocumented changes in observation time occurred around 1962 and again in 1995. The station was moved to a farm NE of town in 1970 where it remains today. An electronic temperature system was installed September 23, 1998.

**Colorado Climate Trends Information**: Continuous climate observing began in Byers in 1939 and has been maintained ever since. The original observer kept careful records until stepping down May 18, 1961. Between 1961 and 1970 the station was moved short distances within the town of Byers on three occasions. The station relocated to a farm 4.6 miles northeast of town in 1970 where it remains today. Station records indicate that temperatures were measured and reset at 6 PM throughout the history of the station. However, closer examination of the actual data suggest that observations prior to 1962 were likely taken around 8 AM. Since 1995, temperature readings are likely taken around 7 AM each day. These changes do have an affect on monthly mean temperatures and could affect time series results. On October 23, 1998 the traditional weather shelter with liquid-in-glass thermometers was replaced by a new electronic temperature measurement and recording device.

**Parker 6 E**

**Station ID**: 056326 (coop) USC00056326 (GHCN) PKRC2 (NWS LI)

**Location:** Elbert County, Platte Drainage Basin (COO4)

**Lat / Long:** 39.5289, -104.6567

**Elevation:** 6310 ft

**Data Range:** 1930-07-01 – 1997-12-31

**NOAA Station Metadata:**

https://www.ncdc.noaa.gov/homr/#ncdcstnid=20003711&tab=MSHR

**COOP Form:** https://www.ncdc.noaa.gov/IPS/coop/coop.html?\_page=2&state=CO&foreign=false&stationID=056326&\_target3=Next+%3E

**Denver Stapleton**

**Station ID:** 052220 (coop), 23062 (WBAN), USW00023062 (GHCN) DUAC2 (NWS LI)

Location: Denver County, Platte drainage basin (COO4)

Lat / Long: 39.7633, -104.8695

Elevation: 5284 ft

Data Range: 1948-01-01 - 2017-01-10

NOAA Station Metadata:

https://www.ncdc.noaa.gov/homr/#ncdcstnid=20003762&tab=MSHR

COOP Form: https://www.ncdc.noaa.gov/IPS/coop/coop.html?\_page=2&state=CO&foreign=false&stationID=052220&\_target3=Next+%3E

Colorado Climate Trends Summary: Denver-Stapleton station began in November of 1934. The station was located at Stapleton airport at the Weather Bureau Office. The station continued collecting data even after the surface observations were moved to the new Denver International Airport. Observations continue today.

Colorado Climate Trends Information: In May of 1969 the station was moved 1.2 miles to the SE into Aurora on the edge of the airport property. In January 1982 the Weather Service Office was relocated 1 mile to the North onto the Smith Road location where it remains today. In July, 1995 the max/min thermometers were replaces with the automated MMTS system.

**METHODS:**

After downloading the precipitation data from the previously described weather stations, we proceeded to create a series of linear regressions to evaluate the effectiveness of the data. The R program ‘Single Regression Script’ creates 12 linear regressions between two weather stations, one regression for each month. The script then returns the R-squared value of each of these regressions, as well as the regression itself. By evaluating the R-squared value along with the number of missing months the secondary station could fill in, we concluded that Parker 6E and Denver Stapleton were the best stations to use. The full script is titled “Single Regression Script” and can be found in the Climate folder.

These two weather stations are used to fill in the 22 missing months of precipitation data in the Byers weather station’s incomplete record from 1930 to 2015. Parker 6E can be used to find the missing data for all but 4 of these missing months. Denver Stapleton can be used to find the missing data for all but 10 of these missing months. Together, Parker and Denver Stapleton provide full coverage for the missing precipitation data. When possible, we use a multiple regression, based on both the Parker and Denver Stapleton stations to better estimate the missing monthly precipitation values at Byers.

The following 10 months precipitation values were estimated by only using the Parker weather station single regression: 1932-10, 1933-5, 1936-1, 1939-6, 1941-7, 1961-9, 1942-6, 1945-6, 1947-2, and 1936-4.

The following 8 months precipitation values were estimated by using both the Parker and Denver Stapleton, with a multiple regression formula: 1948-2, 1950-3, 1950-4, 1950-5, 1950-7, 1951-6, 1961-3, and 1964-1.

The following 4 months precipitation values were estimated by using the Denver Stapleton weather station single regression: 2006-6, 2014-1, 2014-2, and 2014-3.

***R-squared values and formulas for the precipitation regressions -***

**Parker 6E R-squared:**

Mean: 0.5657, Min: 0.1903, Max: 0.7758, Jan: 0.4199, Feb: 0.6444, Mar: 0.6111, Apr: 0.7003,

May: 0.6480, Jun: 0.5742, Jul: 0.1903 Aug: 0.4689, Sep: 0.5445 Oct: 0.7758 Nov: 0.6983 Dec: 0.5127

**Denver Stapleton R-squared:**

Mean: 0.5493, Min: 0.3022, Max: 0.8087, Jan: 0.6528, Feb: 0.4707, Mar: 0.6448, Apr: 0.5597,

May: 0.6011, Jun: 0.3844, Jul: 0.3022, Aug: 0.3543, Sep: 0.4409, Oct: 0.7493, Nov: 0.6262, Dec: 0.8089

**Both Stations (Multiple Regression) R-squared:**

Mean: 0.6584, Min: 0.3516, Max: 0.8471, Jan: 0.6599, Feb: 0.7478, Mar: 0.7211, Apr: 0.6451

May: 0.6995, Jun: 0.6117, Jul: 0.3516, Aug: 0.5479, Sep: 0.5506, Oct: 0.8142, Nov: 0.7042, Dec: 0.8471

**Parker 6E Regression Formula\*: Denver Stap. Formula\*\*: Multiple Reg. Formula\*\*\*:**

Jan) y = .7975x + .2013 y = .6206x + .1119 y = .1943x1 + .4241x2 + .1078

Feb) y = .8067x + .1194 y = .5308x + .1188 y = .4241x1 + .4265x2 + .0195

Mar) y = .8475x + .3013 y = .6915x + .1581 y = .4402x1 + .4265x2 + .1027

Apr) y = .9707x + .0903 y = .7316x + .2764 y = .4099x1 + .4220x2 + .0706

May) y = .7982x + 6425 y = .9021x + .5062 y = .3487x1 + .5029x2 + .5466

Jun) y = .8778x + .2937 y = .6225x + .9451 y = .6556x1 + .3522x2 + .1650

Jul) y = .4437x + 1.235 y = .4430x + 1.342 y = .1552x1 + .4884x2 + .9911

Aug) y = .6309x + .4904 y = .5799x + .8925 y = .4024x1 + .4016x2 + .4599

Sep) y = .8614x + .3209 y = .4192x + .6604 y = .5456x1 + .3630x2 + .2754

Oct) y = .9605x + .0180 y = .8769x – .0130 y = 4603x1 + .4800x2 – .0208

Nov) y = .7574x + .1242 y = .7650x + .0524 y = .4164x1 + .4607x2 – .0242

Dec) y = .6868x + .1846 y = .5979x + 0.787 y = .0492x1 + .5479x2 + .0559

\* Where y = Byers estimated precipitation, x = parker actual precipitation

\*\* Where y = Byers estimate precipitation, x = Denver Stapleton actual precipitation

\*\*\*Where y = Byers estimated precip, x1 = Parker precip, x2 = Denver Stapleton precip

Difference between missing value section –

With the 8 middle sections, we tried all three precipitation regressions and found these differences in values –

1948-2 1950-3 1950-4 1950-5 1950-7 1951-6 1961-3 1964-1

Both: .27 in .31 in .2.27 in 2.36 in 1.64 in 1.82 in 1.95 in .29 in

Park: .33 in .44 in 2.32 in 1.56 in 2.31 in 1.44 in 2.05 in .36 in

Diff: .06 in .13 in .05 in .8 in .67 in .38 in .1 in . 07 in

Stap: .35 in .37 in 2.46 in 3.03 in 1.59 in 2.36 in 1.89 in .27 in

Diff: .08 in .06 in .19 in .67 in .05 in .54 in .06 in .02 in

Average difference: 0.28 inches (parker), 0.21 inches (stapleton)

**Monthly Mean Maximum Temperature**

Mean monthly maximum temperature was retrieved on January 16th, 2017 from High Plains Regional Climate Center’s CLIMOD software (climod.unl.edu). Data from the 10 most complete weather stations surrounding byers Colorado was collected in an attempt to gather accurate temperature data for Bijou Creek. The Byers weather station served as the basis for the mean max temperature data, however it is missing 17 monthly temperature values. In order to evaluate the temperature data in the seascorr program, the dataset must be complete for the record. 9 surrounding stations were evaluated for their correlation to the byers station, and how many data holes they filled in. the best station is Akron Washington County Airport, which fills in every missing value, and it’s correlation has a mean R-squared value of 0.85.

**Weather Stations –**

**Byers 5 ENE**

**Station ID:** 051179 (coop) USC00051179 (GHCN) BYRC2 (NWS LI)

**Location:** Adams County, Platte drainage basin (COO4)

**Lat / long:**  39.7403, -104.1275

**Elevation:** 5100 ft

**Data range:**  1930-02-22 - 2016-11-30

**NOAA Station Metadata**:

https://www.ncdc.noaa.gov/homr/#ncdcstnid=20003761&tab=MSHR

**Coop Form:**

https://www.ncdc.noaa.gov/IPS/coop/coop.html?\_page=2&state=CO&foreign=false&stationID=051179&\_target3=Next+%3E

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**Akron Washington CO AP**

**Retrieval source**: High Plains Regional Climate Center (climod.unl.edu)

**Station ID:** 050114 (coop), 24015 (WBAN), USW0024015 (GHCN)

**Location:** Washington County, Kansas Drainage Basin (COO3)

**Lat / Long:** 40.1667, -103.2167

**Elevation:** 4663 ft

**Data range:** 1937-03-01 - 2017-01-09

**NOAA Station Metadata**:

https://www.ncdc.noaa.gov/homr/#ncdcstnid=20003826&tab=MSHR

**Station Summary (NOAA):**

https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00024015/detail

Methods for filling in these missing values are the same as the precipitation section, however because the Akron station fills in all of the missing values with such a high correlation R-squared, we used only that data. There is no multiple regression analysis done on the temperature data.

**R-squared –**

**Akron Washington CO AP R-squared:**

Mean: .8500, Min: .7570, Max: .9234, Jan: .9224, Feb: .8689, Mar: .8856, Apr: .8655, May: .8826,

Jun: .7962, Jul: .8807, Aug: .7808, Sep: .7570, Oct: .8497, Nov: .8846, Dec: .9234.

**Akron Washington CO AP Regression Formula:**

Jan) y = .8963x + 7.0542

Feb) y = .8907x + 7.3758

Mar) y = .8304x + 10.8998

Apr) y = .9039x + 7.5482

May) y = .8564x + 11.6365

Jun) y = .9084x + 9.1152

Jul) y = .7760x + 21.44

Aug) y = .7244x + 25.1571

Sep) y = .7941x + 17.8549

Oct) y = .8428x + 12.4606

Nov) y = .9225x + 6.4809

Dec) y = .9142x + 6.5807

\* Where y = Byers estimated temperature, x = Akron WA CO AP actual temperature

**Palmer Drought Severity Index (PDSI)**

Five sources of PDSI information are tested in the initial climate correlation study. Each of the five sources are elaborated on here.

**PDSI SOURCE 1 – West Wide Drought Tracker PDSI – WWDT\_PDSI**

**PDSI SOURCE 2 – West Wide Drought Tracker Palmer Z-score – WWDT\_Z\_SCORE**

**PDSI SOURCE 3 – R PDSI Package (Self Calibrated) – scPDSI**

**PDSI from West Wide Drought Tracker**

Pdsi from west wide drought tracker is from wrcc.dri.edu/wwdt/time/

Retrieved 1/20/2017

http://www.wrcc.dri.edu/wwdt/time/

Latitude 38.91018, longitude -104.30860 PDSI

Plamer z-index

Same as above

**Palmer Z-score from West Wide Drought Tracker**

Pdsi from west wide drought tracker is from wrcc.dri.edu/wwdt/time/

Retrieved 1/20/2017

http://www.wrcc.dri.edu/wwdt/time/

Latitude 38.91018, longitude -104.30860 PDSI

Plamer z-index

Same as above

3. Palmer "Z" Index (ZNDX)

This is the generated monthly Z values, and they can be expressed as the "Moisture Anomaly Index." Each monthly Z value is a measure of the departure from normal of the moisture climate for that month. This index can respond to a month of above-normal precipitation, even during periods of drought. Table 1 contains expected values of the Z index and other drought parameters. See Historical Climatology Series 3-6 through 3-9 for a detailed description of the drought indices.

**scPDSI from R Package**

Self calibrated PDSI from Christian Zang’s R package (GitHub.com/cszang/pdsi)

Calculations are based off available water capacity, latitude, precipitation, and temperature data

byers scPDSI input > scPDSI calculation script.R > byers scPDSI source

Information on the program -

Calculation of (sc)PDSI from monthly temperature and precipition data in R. This is basically a wrapper around a modified version of the University of Nebraska's C++ based PDSI implementation from http://greenleaf.unl.edu/downloads/. This code has an unknown license, I treat it as MIT.

The function calls for an available water capacity measurement in centimeters without defining what the AWC measurement is.

Here are some relevant papers and definitions -

In Palmers paper, Available Water Content is defined as the following

https://www.ncdc.noaa.gov/temp-and-precip/drought/docs/palmer.pdf

PR = AWC - S prime

Where pr = potential recharge - amount of moisture required to bring the soil to field capacity

AWC = available water content

S prime = amount of avaliable moister in both layers at the start of a month

A later paper that is used as an authority on PDSI cites AWC as

http://journals.ametsoc.org/doi/pdf/10.1175/1520-0450%281984%29023%3C1100%3ATPDSIL%3E2.0.CO%3B2

PR = AWC - (Si + Su)

Potential Recharge = Available Water Content - (available moisture in the surface + available moisture in the underlying layers)

http://drought.unl.edu/archive/Documents/NDMC/Presentations/03222012\_Kingston\_Jamaica/references/PDSI\_article.pdf

AWC = FC - WP

Avaliable Water Content = Field Capacity - Wilting Point

http://dbwww.essc.psu.edu/cgi-bin/geotree/list\_datafiles.pl?1996-0035

So in the Manuel for the actual program, they reference two links for more information to how the calculation works…

http://greenleaf.unl.edu/downloads/scPDSI\_Manual.pdf

Thats the user Manuel for the program I used.. in the user Manuel they reference these sites -

http://nadss.unl.edu.

That site no longer exists..

But the author of the Manuel has a few papers out that related to awn and the PDSI calculations..

His name is Nathan wells, he’s from the computer science department of UNL, here’s a paper where he describes using this program

http://journals.ametsoc.org/doi/pdf/10.1175/1520-0442(2004)017%3C2335%3AASPDSI%3E2.0.CO%3B2

Says he gets the AWC data from STATSGO soils data, possibly found in the following links -

http://dbwww.essc.psu.edu/cgi-bin/geotree/list\_datafiles.pl?1996-0035

https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=CO

From preliminary searches, it looks like the value will be around 11 cm? Possibly inches

https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Suggests 11 inches or 28 cm of water storage in the profile ..I think