**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.

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**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

**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.

**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 – National Climate Data Center PDSI - NCDC\_PDSI**

**PDSI SOURCE 2 – West Wide Drought Tracker PDSI – WWDT\_PDSI**

**PDSI SOURCE 3 – West Wide Drought Tracker Palmer Z-score – WWDT\_Z\_SCORE**

**PDSI SOURCE 4 – R PDSI Package – R\_PDSI**

**PDSI SOURCE 5 – R PDSI Package (Self Calibrated) – R\_PDSI\_SC**

**PDSI from the National Climate Data Center**

PDSI data was retrieved on January 16th, 2017 from NOAA under the National Centers for Environmental Information (NCEI), formerly the National Climatic Data Center (NCDC) at www.ncdc.noaa.gov. The data is specifically retrieved from ‘ClimDiv’ at -

https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

Select the appropriate nation, region, state, and division; for the Bijou Creek study, I used the selection U.S > Colorado > 04 – Platte Drainage Basin, start period = 1930, end period = 2015, text output = space delimited. A map of each climate division can be found under the link titled ‘Divisional Map View”, found at the ClimDiv search page. Confirm the request for data by hitting submit, or learn more about the indices output by clicking the “Divisional Data Description” below.

Divisional Data Description describes the methodology in creating the PDSI dataset as:

“nClimDiv DIVISIONAL TEMPERATURE-PRECIPITATION-DROUGHT JUNE 2014

The major parameters in this file are sequential climatic division monthly maximum, minimum and average temperature (deg. F. to 10ths, national temperature to 100ths), precipitation (inches to 100ths), Standardized Precipitation Index (SPI), and Palmer Drought Indices (PDSI, PHDI, PMDI, and ZNDX). Period of record is 1895 through latest month available, updated monthly.

Values from the most recent two calendar years will be updated on a monthly basis. Period of record updates will occur when the underlying data set undergoes a version change.

METHODOLOGY:

Divisional values in nClimDiv were derived from area-weighted averages of grid-point estimates interpolated from station data. A nominal grid resolution of 5 km was used to ensure that all divisions had sufficient spatial sampling (only four small divisions had less than 100 points) and because the impact of elevation on precipitation is minimal below 5 km. Station data were gridded via climatologically aided interpolation to minimize biases from topographic and network variability.

The Global Historical Climatology Network (GHCN) Daily dataset is the source of station data for nClimDiv. GHCN-Daily contains several major observing networks in North America, five of which are used here. The primary network is the National Weather Service (NWS) Cooperative Observing (COOP) program, which consists of stations operated by volunteers as well as by agencies such as the Federal Aviation Administration. To improve coverage in western states and along international borders, nClimDiv also includes the National Interagency Fire Center (NIFC) Remote Automatic Weather Station (RAWS) network, the USDA Snow Telemetry (SNOTEL) network, the Environment Canada (EC) network (south of 52°N), and part of Mexicos Servicio Meteorologico Nacional (SMN) network (north of 24°N). Note that nClimDiv does not incorporate precipitation data from RAWS because that networks tipping-bucket gauges are unheated, leading to suspect cold-weather data.

All GHCN-Daily stations are routinely processed through a suite of logical, serial, and spatial quality assurance reviews to identify erroneous observations. For nClimDiv, all such data were set to missing before computing monthly values, which in turn were subjected to additional serial and spatial checks to eliminate residual outliers. Stations having at least 10 years of valid monthly data since 1950 were used in nClimDiv.

For temperature, bias adjustments were computed to account for historical changes in observation time, station location, temperature instrumentation, and siting conditions. Changes in observation time are only problematic for the COOP network whereas changes in station location and instrumentation occur in almost all surface networks. As in the U.S. Historical Climatology Network version 2.5, the method of Karl et al. (1986) was applied to remove the observation time bias from the COOP network, and the pairwise method of Menne and Williams (2009) was used to address changes in station location and instrumentation in all networks. Because the pairwise method also largely accounts for local, unrepresentative trends that arise from changes in siting conditions, nClimDiv contains no separate adjustment in that regard.

For additional information on how nClimDiv is constructed, please see: http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-13-0248.1

Monthly heating and cooling degree day values are available for the period 1895 to present. The divisional degree day values are derived from the adjusted temperatures using a statistical algorithm. The heating and cooling degree day values available at this site are used for perational monitoring purposes and may be different from the heating and cooling degree day values published in official degree day publications. Population weights utilize the 1981-2010 Census data. Historical drought data have been added to this file for the period 1895 to present. The file is updated monthly. All drought data are calibrated using the period 1931-1990 (cf. Karl, 1986; Journal of Climate and Applied Meteorology, Vol. 25, No. 1, January 1986). Drought data include:

1. Palmer Drought Severity Index (PDSI)

This is the monthly value (index) that is generated indicating the severity of a wet or dry spell. This index is based on the principles of a balance between moisture supply and demand. Man-made changes were not considered in this calculation. The index generally ranges from -6 to +6, with negative values denoting dry spells and positive values indicating wet spells. There are a few values in the magnitude of +7 or -7. PDSI values 0 to -.5 = normal; -0.5 to -1.0 = incipient drought; -1.0 to -2.0 = mild drought; -2.0 to -3.0 = moderate drought; -3.0 to -4.0 = severe drought; and greater than - 4.0 = extreme drought. Similar adjectives are attached to positive values of wet spells. This is a meteorological drought index used to assess the severity of dry or wet spells of weather.

**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.

**PDSI from R Package**

R package from Christian zeng

Calculations based off the precipitation and temperature data from this study

bijou\_pdsi<- pdsi(12, 50, pdsi\_source, 1932, 2014, mode="both")

**PDSI (Self Calibrated) from R Package**

R package from Christian zeng

Calculations based off the precipitation and temperature data from this study

bijou\_pdsi<- pdsi(12, 50, pdsi\_source, 1932, 2014, mode="both