chapter_2_2019

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Chapter_2_1
ATMOS 6040: Environmental Statistics
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Download this notebook and all images and data by downloading the ZIP file from GitHub, or use the git command:

```
git clone https://github.com/weech/ATMOS_5040_2019.git
```

> Note: Windows users will have to install git for Windows and execute the git command from the PowerShell.

1 Using Python modules

`numpy` provides routines to handle arrays and many calculations efficiently and imported by convention as `np`. Numpy functions are very good at handling homogeneous data arrays (and similar in that respect to matlab functions).

`pandas` is really good at handling tabular/array data that may have heterogeneous types (floating and text, for example). It is imported by convention as `pd`.

There are a couple sets of panda library routines (`Series`, and `DataFrame`) used so frequently that we'll import those directly too.

`scipy` has a bunch of statistical functions and we'll import `stats` from `scipy`

`pyplot` is a *submodule* of matplotlib. It is typically imported as the alias `plt` to handle basic plotting

```
In [1]: import numpy as np
        import pandas as pd
        from pandas import Series, DataFrame
        from scipy import stats
        import matplotlib.pyplot as plt
```

---

2 Chapter 2a

3 Level of the Great Salt Lake

On GitHub, look in the `data` folder for a file called `gsl_yr.csv` and download it.

Open the `gsl_yr.csv` file in the Jupyter Lab environment to see the column contents and the units.

- The 0th column is the Year
- The 1st column is the Number of observations
- The 2nd column is the Lake level (in feet)

read 3 column vectors of years, number of observations, and yearly lake level for 1895-2018 period lake level (in ft)

```
In [2]: #read the lake level data
        year = np.genfromtxt('../data/gsl_yr.csv', delimiter=',', usecols=0)
        #convert lake level to meters
        lev = .3048 * np.genfromtxt('../data/gsl_yr.csv', delimiter=',', usecols=2)
```

```
In [3]: print(year)
        print(lev)
```

```
[1895. 1896. 1897. 1898. 1899. 1900. 1901. 1902. 1903. 1904. 1905. 1906.
 1907. 1908. 1909. 1910. 1911. 1912. 1913. 1914. 1915. 1916. 1917. 1918.
 1919. 1920. 1921. 1922. 1923. 1924. 1925. 1926. 1927. 1928. 1929. 1930.
 1931. 1932. 1933. 1934. 1935. 1936. 1937. 1938. 1939. 1940. 1941. 1942.
 1943. 1944. 1945. 1946. 1947. 1948. 1949. 1950. 1951. 1952. 1953. 1954.
 1955. 1956. 1957. 1958. 1959. 1960. 1961. 1962. 1963. 1964. 1965. 1966.
 1967. 1968. 1969. 1970. 1971. 1972. 1973. 1974. 1975. 1976. 1977. 1978.
 1979. 1980. 1981. 1982. 1983. 1984. 1985. 1986. 1987. 1988. 1989. 1990.
 1991. 1992. 1993. 1994. 1995. 1996. 1997. 1998. 1999. 2000. 2001. 2002.
 2003. 2004. 2005. 2006. 2007. 2008. 2009. 2010. 2011. 2012. 2013. 2014.
 2015. 2016. 2017. 2018.]
[1280.58672 1280.49528 1280.55624 1280.4648  1280.3124  1280.25144
 1279.91616 1279.30656 1279.21512 1279.33704 1279.18464 1279.30656
 1279.97712 1280.28192 1280.70864 1281.04392 1280.89152 1280.80008
 1280.86104 1281.01344 1280.89152 1280.7696  1280.922   1281.01344
 1280.70864 1280.55624 1280.83056 1281.16584 1281.40968 1281.40968
 1281.28776 1281.19632 1280.98296 1280.70864 1280.49528 1280.3124
 1279.97712 1279.7028  1279.51992 1279.00176 1278.66648 1278.60552
 1278.7884  1278.81888 1278.7884  1278.54456 1278.57504 1278.7884
 1278.75792 1278.81888 1278.81888 1279.03224 1279.15416 1279.21512
 1279.33704 1279.5504  1279.82472 1280.12952 1280.09904 1279.7028
 1279.33704 1279.2456  1279.12368 1279.06272 1278.75792 1278.36168
 1277.96544 1277.93496 1277.75208 1277.96544 1278.27024 1278.4836
 1278.36168 1278.57504 1278.9408  1278.87984 1279.27608 1279.73328
 1280.03808 1280.19048 1280.3124  1280.49528 1280.12952 1279.91616
 1279.76376 1279.91616 1279.94664 1280.16    1281.31824 1282.53744
 1282.87272 1283.32992 1283.29944 1282.53744 1281.3792  1281.04392
 1280.58672 1280.16    1280.12952 1279.8552  1279.8552  1279.94664
 1280.28192 1280.80008 1281.0744  1280.83056 1280.25144 1279.73328
 1279.12368 1278.69696 1278.9408  1279.21512 1279.06272 1278.66648
 1278.636   1278.54456 1279.2456  1279.398   1278.81888 1278.39216
```

```
 1278.14832 1278.08736 1278.3312  1278.1788 ]
```

4 Read Utah annual precip and temperature

convert inches to cm convert F to C

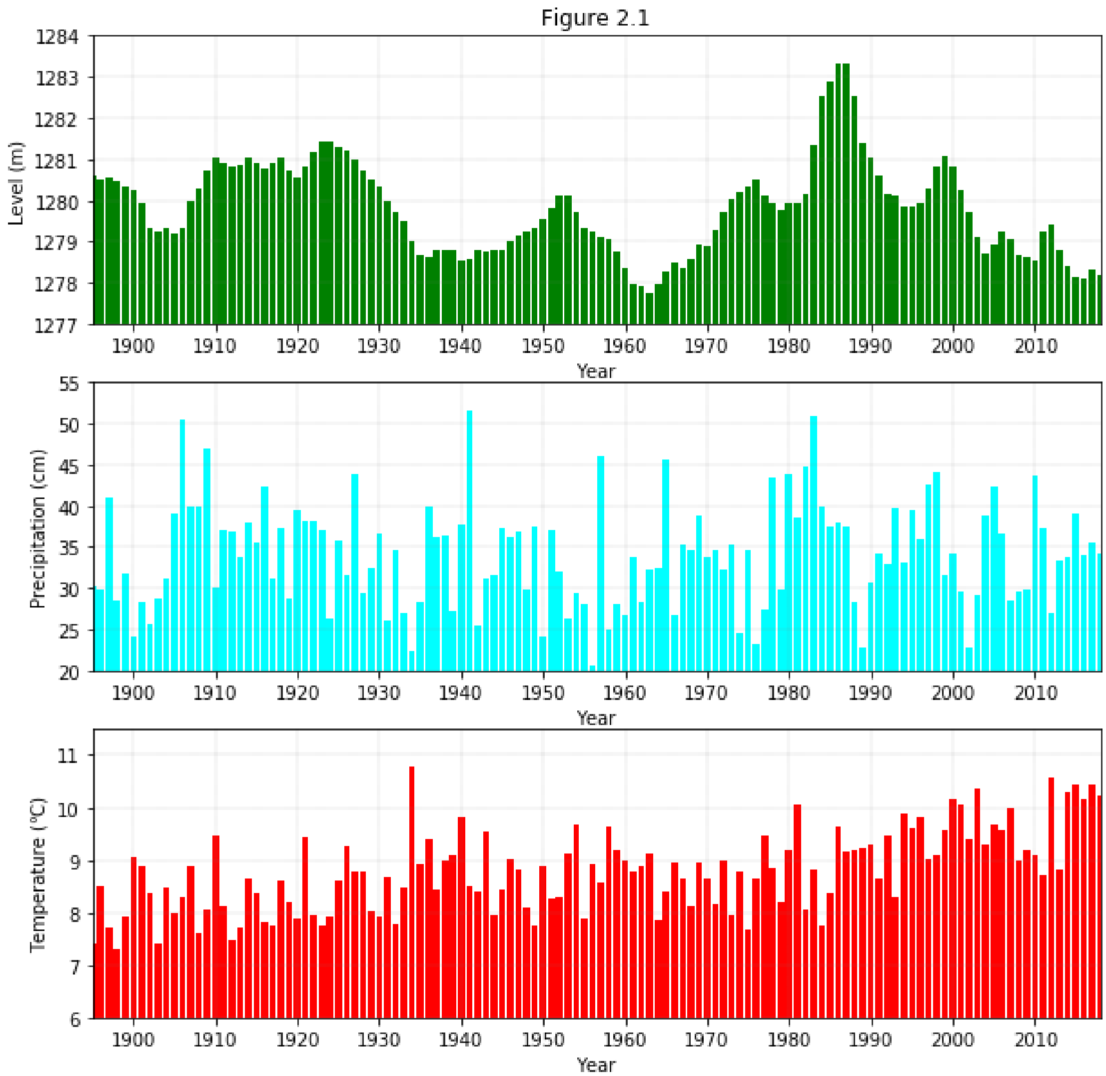
```
In [4]: yearp = np.genfromtxt('../data/utah_precip.csv', delimiter=',', usecols=0)
        ppt = 2.54 * np.genfromtxt('../data/utah_precip.csv', delimiter=',', usecols=1)
        yeart = np.genfromtxt('../data/utah_temp.csv', delimiter=',', usecols=0)
        temp = np.genfromtxt('../data/utah_temp.csv', delimiter=',', usecols=1)
        temp = 5. * (temp - 32.)/9.
```

```
In [5]: #print(yearp)
        #print(ppt)
        #print(yeart)
        #print(temp)
```

5 Figure 2.1

Create bar plot time series of lake level, Utah ppt, and Utah temp

```
In [6]: decade_ticks = np.arange(1900,2020,10)
        #print("tick marks",decade_ticks)

        fig,(ax1,ax2,ax3) = plt.subplots(3,1,figsize=(10,10))
        ax1.bar(year,lev,color='green')
        ax1.set(xlim=(1895,2018),ylim=(1277,1284))
        ax1.set(xlabel="Year",ylabel='Level (m)')
        ax1.set(xticks=decade_ticks)
        ax1.set(title="Figure 2.1")
        ax2.bar(year,ppt,color='cyan')
        ax2.set(xlim=(1895,2018),ylim=(20,55))
        ax2.set(xlabel="Year",ylabel='Precipitation (cm)')
        ax2.set(xticks=decade_ticks)
        ax3.bar(year,temp,color='red')
        ax3.set(xlim=(1895,2018),ylim=(6,11.5))
        ax3.set(xlabel="Year",ylabel='Temperature ()')
        ax3.set(xticks=decade_ticks)

        ax1.grid(linestyle='--', color='grey', linewidth=.2)
        ax2.grid(linestyle='--', color='grey', linewidth=.2)
        ax3.grid(linestyle='--', color='grey', linewidth=.2)

        plt.savefig('figure_2.1_2019_python.png')
```



6 Figure 2.2

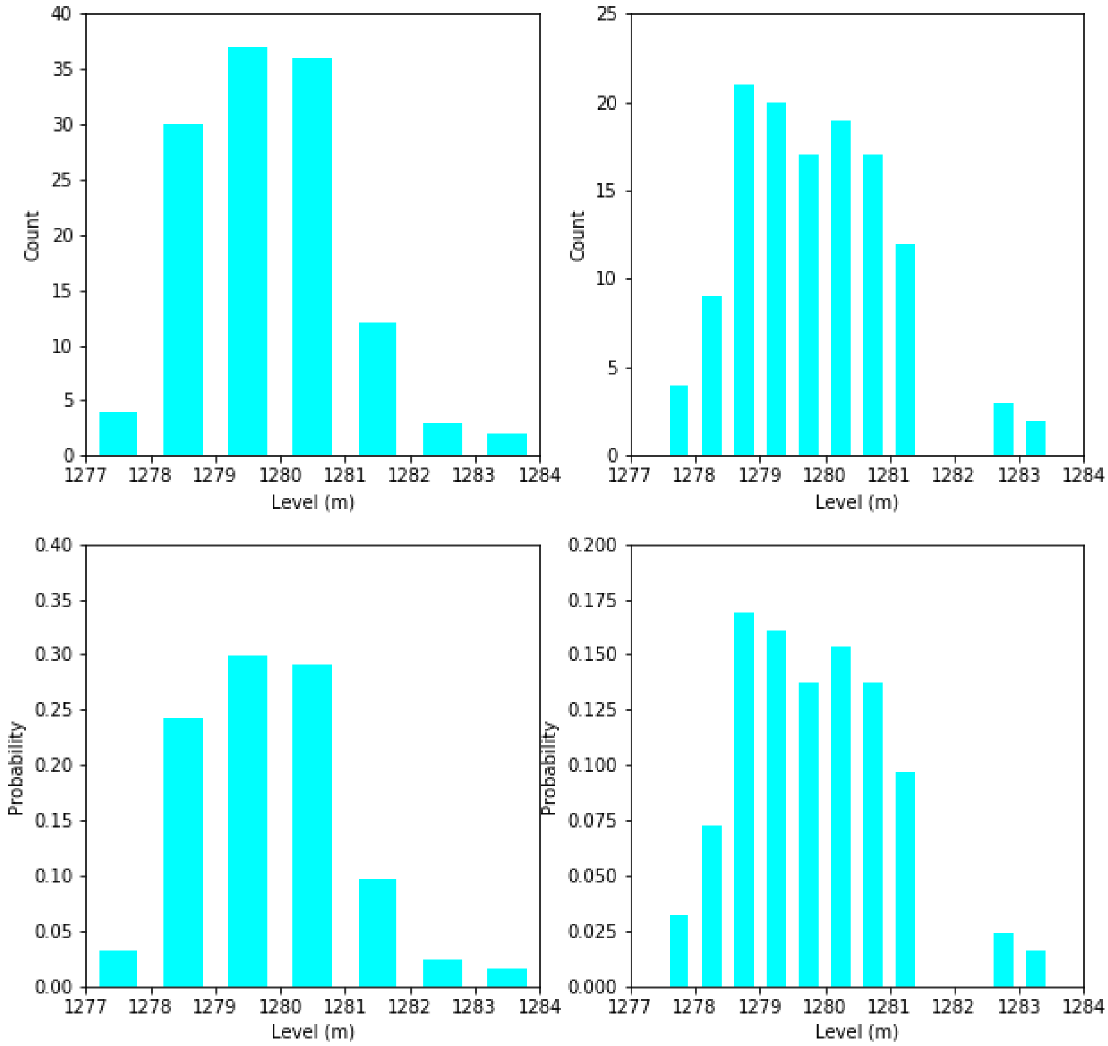
In [7]:
```
#sort the values from smallest to largest using numpy
levsort = np.sort(lev)
print(levsort)
#compute the range
range_lev = np.max(lev) - np.min(lev)
print('range',range_lev)
```

```
[1277.75208 1277.93496 1277.96544 1277.96544 1278.08736 1278.14832
 1278.1788  1278.27024 1278.3312  1278.36168 1278.36168 1278.39216
 1278.4836  1278.54456 1278.54456 1278.57504 1278.57504 1278.60552
 1278.636   1278.66648 1278.66648 1278.69696 1278.75792 1278.75792
```

```
 1278.7884  1278.7884  1278.7884  1278.81888 1278.81888 1278.81888
 1278.81888 1278.87984 1278.9408  1278.9408  1279.00176 1279.03224
 1279.06272 1279.06272 1279.12368 1279.12368 1279.15416 1279.18464
 1279.21512 1279.21512 1279.21512 1279.2456  1279.2456  1279.27608
 1279.30656 1279.30656 1279.33704 1279.33704 1279.33704 1279.398
 1279.51992 1279.5504  1279.7028  1279.7028  1279.73328 1279.73328
 1279.76376 1279.82472 1279.8552  1279.8552  1279.91616 1279.91616
 1279.91616 1279.94664 1279.94664 1279.97712 1279.97712 1280.03808
 1280.09904 1280.12952 1280.12952 1280.12952 1280.16    1280.16
 1280.19048 1280.25144 1280.25144 1280.28192 1280.28192 1280.3124
 1280.3124  1280.3124  1280.4648  1280.49528 1280.49528 1280.49528
 1280.55624 1280.55624 1280.58672 1280.58672 1280.70864 1280.70864
 1280.70864 1280.7696  1280.80008 1280.80008 1280.83056 1280.83056
 1280.86104 1280.89152 1280.89152 1280.922   1280.98296 1281.01344
 1281.01344 1281.04392 1281.04392 1281.0744  1281.16584 1281.19632
 1281.28776 1281.31824 1281.3792  1281.40968 1281.40968 1282.53744
 1282.53744 1282.87272 1283.29944 1283.32992]
range 5.577839999999696
```

In [8]:
```
#this will seem odd but the matplotlib hist function doesn't work for noninteger inter
#so using numpy version and then plotting
fig2,ax = plt.subplots(2,2,figsize=(10,10))
x1 = np.arange(1277,1285,1)
hist_val1,bins1 = np.histogram(lev,x1)
width1 = 0.6 * (bins1[1] - bins1[0])
center1 = (bins1[:-1] + bins1[1:]) / 2
ax1 = ax[0,0]
ax1.bar(center1,hist_val1,align='center',width=width1,color='cyan')
ax1.set(xlim=(1277,1284),ylim=(0,40))
ax1.set(xlabel="Level (m)",ylabel='Count')

x2 = np.arange(1277.,1285.01,0.5)
hist_val2,bins2 = np.histogram(lev,x2)
width2 = 0.6 * (bins2[1] - bins2[0])
center2 = (bins2[:-1] + bins2[1:]) / 2
ax2 = ax[0,1]
ax2.bar(center2,hist_val2,align='center',width=width2,color='cyan')
ax2.set(xlim=(1277,1284),ylim=(0,25))
ax2.set(xlabel="Level (m)",ylabel='Count')

#display probabilities
#get total number of values
N = len(lev)
#need to weight each of the values so each one is a probability
weights = np.ones_like(lev)/float(N)
hist_val3,bins3 = np.histogram(lev,x1,weights=weights)
ax3 = ax[1,0]
```

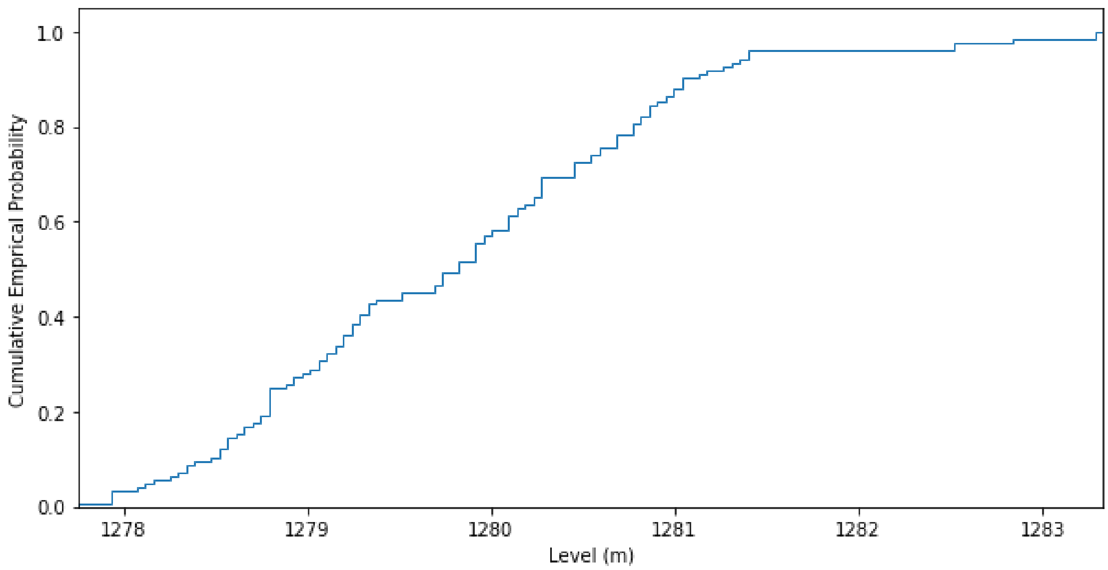
```
ax3.bar(center1,hist_val3,align='center',width=width1,color='cyan')
ax3.set(xlim=(1277,1284),ylim=(0,0.4))
ax3.set(xlabel="Level (m)",ylabel='Probability')

hist_val4,bins4 = np.histogram(lev,x2,weights=weights)
ax4 = ax[1,1]
ax4.bar(center2,hist_val4,align='center',width=width2,color='cyan')
ax4.set(xlim=(1277,1284),ylim=(0,0.2))
ax4.set(xlabel="Level (m)",ylabel='Probability')


plt.savefig('figure_2.2_2019_python.png')
```



7 Figure 2.3

Cumulative probability distribution

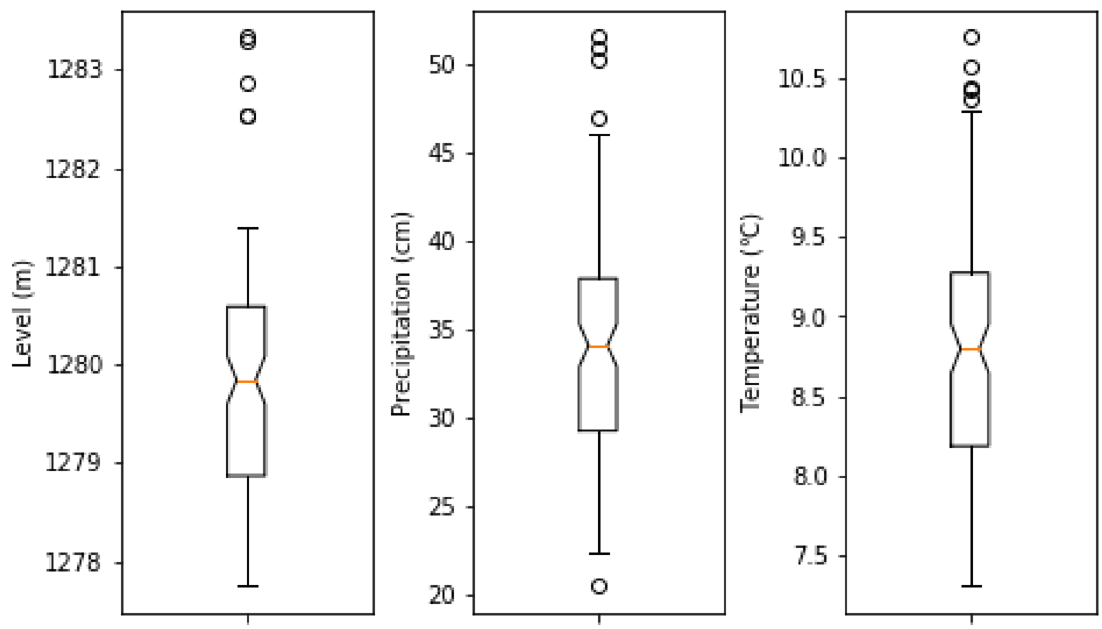
```
In [9]: # plot the cumulative histogram
        fig3,ax = plt.subplots(1,1,figsize=(10,5))
        n_bins = 124
        n, bins, patches = ax.hist(lev, n_bins, density='True', histtype='step',
                                   cumulative=True, label='Empirical')
        ax.set(xlabel="Level (m)",ylabel='Cumulative Emprical Probability')
        ax.set(xlim=(min(lev),max(lev)))


        plt.savefig('figure_2.3_2019_python.png')
```



8 Figure 2.4 Boxplot

```
In [10]: #fig4,(ax1,ax2,ax3) = plt.subplots(1,3,figsize=(10,4))
         fig = plt.figure(1)
         ax1 = fig.add_axes([.05, .05, .25, .9])
         ax2 = fig.add_axes([.40, .05, .25, .9])
         ax3 = fig.add_axes([.77, .05, .25, .9])
         #whiskers are different in python (75th percentile + wis *IQR, for example)
         # in matlab 1.5 *IQR + median
         ax1.boxplot(lev,notch=True,whis=1)
         ax1.set(xticklabels=" ",ylabel='Level (m)')
```

```
ax2.boxplot(ppt,notch=True,whis=1)
ax2.set(xticklabels=' ',ylabel="Precipitation (cm)")

ax3.boxplot(temp,notch=True,whis=1)
ax3.set(xticklabels=' ', ylabel="Temperature ()")

plt.savefig('figure_2.4_2019_python.png')

#Note: the length of the whiskers is computed differently in numpy boxplot than in Ma
```



9 Measures of central tendency

We will use a mix of scipy stats and pandas routines to illustrate the basic statistical commands.

```
In [11]: # create one 3 column array for all 3 variables of length N years
         array = np.ones((N,3),dtype=np.float_)
         array[:,0] = lev
         array[:,1] = ppt
         array[:,2] = temp

In [12]: print(array)
```

```
[[1280.58672     30.226        7.40722222]
 [1280.49528     29.9466      8.49555556]
 [1280.55624     40.9194      7.70388889]
```

```
[1280.4648      28.6004        7.30555556]
[1280.3124      31.7754        7.90722222]
[1280.25144     24.0538        9.05555556]
[1279.91616     28.2702        8.89333333]
[1279.30656     25.7302        8.37944444]
[1279.21512     28.702         7.38888889]
[1279.33704     31.0642        8.48166667]
[1279.18464     39.0652        7.98166667]
[1279.30656     50.3174        8.28222222]
[1279.97712     40.005         8.89833333]
[1280.28192     39.8018        7.61555556]
[1280.70864     46.9646        8.065     ]
[1281.04392     29.9974        9.46277778]
[1280.89152     37.0586        8.12944444]
[1280.80008     36.8554        7.47666667]
[1280.86104     33.7312        7.71277778]
[1281.01344     37.846         8.65277778]
[1280.89152     35.5346        8.36555556]
[1280.7696      42.3672        7.81944444]
[1280.922       31.1404        7.73611111]
[1281.01344     37.211         8.62055556]
[1280.70864     28.6512        8.19      ]
[1280.55624     39.497         7.88888889]
[1280.83056     38.1           9.42111111]
[1281.16584     38.0746        7.96277778]
[1281.40968     37.1348        7.74055556]
[1281.40968     26.3652        7.93055556]
[1281.28776     35.687         8.61555556]
[1281.19632     31.5976        9.26388889]
[1280.98296     43.8658        8.77777778]
[1280.70864     29.3116        8.77777778]
[1280.49528     32.4612        8.01388889]
[1280.3124      36.6776        7.92111111]
[1279.97712     26.1874        8.685     ]
[1279.7028      34.6456        7.77777778]
[1279.51992     26.9494        8.46777778]
[1279.00176     22.4282       10.75944444]
[1278.66648     28.321         8.91222222]
[1278.60552     39.8272        9.38444444]
[1278.7884      36.2458        8.44      ]
[1278.81888     36.322         8.98611111]
[1278.7884      27.1526        9.08777778]
[1278.54456     37.6682        9.81944444]
[1278.57504     51.5366        8.51388889]
[1278.7884      25.4254        8.41222222]
[1278.75792     31.1912        9.52333333]
[1278.81888     31.6738        7.96277778]
[1278.81888     37.2364        8.435     ]
```

[1279.03224	36.1442	9.01833333]
[1279.15416	36.83	8.82388889]
[1279.21512	29.7434	8.09722222]
[1279.33704	37.465	7.75944444]
[1279.5504	24.2316	8.87944444]
[1279.82472	37.0332	8.26388889]
[1280.12952	32.004	8.29611111]
[1280.09904	26.3398	9.125]
[1279.7028	29.337	9.67111111]
[1279.33704	28.1686	7.89333333]
[1279.2456	20.5486	8.90277778]
[1279.12368	46.101	8.56]
[1279.06272	25.1206	9.63444444]
[1278.75792	27.9908	9.19888889]
[1278.36168	26.8732	8.99555556]
[1277.96544	33.7312	8.79166667]
[1277.93496	28.2448	8.87055556]
[1277.75208	32.3088	9.13888889]
[1277.96544	32.4866	7.86111111]
[1278.27024	45.6438	8.41666667]
[1278.4836	26.67	8.96777778]
[1278.36168	35.2552	8.63444444]
[1278.57504	34.671	8.11555556]
[1278.9408	38.8874	8.94]
[1278.87984	33.6804	8.625]
[1279.27608	34.6202	8.17611111]
[1279.73328	32.3088	8.97222222]
[1280.03808	35.2298	7.94]
[1280.19048	24.6634	8.78222222]
[1280.3124	34.5694	7.66666667]
[1280.49528	23.3172	8.64333333]
[1280.12952	27.4574	9.45388889]
[1279.91616	43.4086	8.86111111]
[1279.76376	29.7688	8.185]
[1279.91616	43.8912	9.19]
[1279.94664	38.6334	10.04166667]
[1280.16	44.704	8.04166667]
[1281.31824	50.9016	8.80111111]
[1282.53744	39.8526	7.75444444]
[1282.87272	37.5412	8.37944444]
[1283.32992	37.9984	9.63444444]
[1283.29944	37.4142	9.14333333]
[1282.53744	28.3718	9.185]
[1281.3792	22.86	9.24055556]
[1281.04392	30.8102	9.30555556]
[1280.58672	34.2646	8.625]
[1280.16	32.9692	9.46777778]
[1280.12952	39.6494	8.28222222]

```
 [1279.8552      33.2232       9.86555556]
 [1279.8552      39.4208       9.59277778]
 [1279.94664     35.9156       9.815     ]
 [1280.28192     42.4942       9.03222222]
 [1280.80008     44.1452       9.09722222]
 [1281.0744      31.5214       9.58333333]
 [1280.83056     34.3154      10.17111111]
 [1280.25144     29.6926      10.04166667]
 [1279.73328     22.9108       9.38888889]
 [1279.12368     29.1846      10.375     ]
 [1278.69696     38.735        9.30555556]
 [1278.9408      42.3164       9.67111111]
 [1279.21512     36.5506       9.58333333]
 [1279.06272     28.575        9.99055556]
 [1278.66648     29.5148       9.        ]
 [1278.636       29.845        9.18055556]
 [1278.54456     43.6626       9.10166667]
 [1279.2456      37.2364       8.72666667]
 [1279.398       27.0764      10.56944444]
 [1278.81888     33.4264       8.80111111]
 [1278.39216     33.7566      10.29611111]
 [1278.14832     39.0906      10.44      ]
 [1278.08736     33.9598      10.16111111]
 [1278.3312      35.5346      10.42777778]
 [1278.1788      34.2646      10.22222222]]
```

10 Using pandas DataFrame

Documentation on pandas: http://pandas.pydata.org/pandas-docs/stable/
How to load indices and data into a DataFrame

```
In [13]: df = pd.DataFrame(array, index=year.astype(str),columns=['Great Salt Lake Level','Utal
```

```
In [14]: #Pthyon notebooks display frames as html tables
         df
```

Out[14]:

	Great Salt Lake Level	Utah Precipitation	Utah Temperature
1895.0	1280.58672	30.2260	7.407222
1896.0	1280.49528	29.9466	8.495556
1897.0	1280.55624	40.9194	7.703889
1898.0	1280.46480	28.6004	7.305556
1899.0	1280.31240	31.7754	7.907222
1900.0	1280.25144	24.0538	9.055556
1901.0	1279.91616	28.2702	8.893333
1902.0	1279.30656	25.7302	8.379444
1903.0	1279.21512	28.7020	7.388889
1904.0	1279.33704	31.0642	8.481667

1905.0	1279.18464	39.0652	7.981667
1906.0	1279.30656	50.3174	8.282222
1907.0	1279.97712	40.0050	8.898333
1908.0	1280.28192	39.8018	7.615556
1909.0	1280.70864	46.9646	8.065000
1910.0	1281.04392	29.9974	9.462778
1911.0	1280.89152	37.0586	8.129444
1912.0	1280.80008	36.8554	7.476667
1913.0	1280.86104	33.7312	7.712778
1914.0	1281.01344	37.8460	8.652778
1915.0	1280.89152	35.5346	8.365556
1916.0	1280.76960	42.3672	7.819444
1917.0	1280.92200	31.1404	7.736111
1918.0	1281.01344	37.2110	8.620556
1919.0	1280.70864	28.6512	8.190000
1920.0	1280.55624	39.4970	7.888889
1921.0	1280.83056	38.1000	9.421111
1922.0	1281.16584	38.0746	7.962778
1923.0	1281.40968	37.1348	7.740556
1924.0	1281.40968	26.3652	7.930556
...	...	...	...
1989.0	1281.37920	22.8600	9.240556
1990.0	1281.04392	30.8102	9.305556
1991.0	1280.58672	34.2646	8.625000
1992.0	1280.16000	32.9692	9.467778
1993.0	1280.12952	39.6494	8.282222
1994.0	1279.85520	33.2232	9.865556
1995.0	1279.85520	39.4208	9.592778
1996.0	1279.94664	35.9156	9.815000
1997.0	1280.28192	42.4942	9.032222
1998.0	1280.80008	44.1452	9.097222
1999.0	1281.07440	31.5214	9.583333
2000.0	1280.83056	34.3154	10.171111
2001.0	1280.25144	29.6926	10.041667
2002.0	1279.73328	22.9108	9.388889
2003.0	1279.12368	29.1846	10.375000
2004.0	1278.69696	38.7350	9.305556
2005.0	1278.94080	42.3164	9.671111
2006.0	1279.21512	36.5506	9.583333
2007.0	1279.06272	28.5750	9.990556
2008.0	1278.66648	29.5148	9.000000
2009.0	1278.63600	29.8450	9.180556
2010.0	1278.54456	43.6626	9.101667
2011.0	1279.24560	37.2364	8.726667
2012.0	1279.39800	27.0764	10.569444
2013.0	1278.81888	33.4264	8.801111
2014.0	1278.39216	33.7566	10.296111
2015.0	1278.14832	39.0906	10.440000

```
2016.0            1278.08736           33.9598          10.161111
2017.0            1278.33120           35.5346          10.427778
2018.0            1278.17880           34.2646          10.222222

[124 rows x 3 columns]
```

```
In [15]: #some basic info + output precentiles
         basic_vals = df.describe(percentiles=[.01,.10,.25,.33,.50,.66,.75,.90,.99])
         print(basic_vals)
```

```
       Great Salt Lake Level  Utah Precipitation  Utah Temperature
count             124.000000          124.000000        124.000000
mean             1279.819312           34.068569          8.800018
std                 1.140610            6.368632          0.780497
min              1277.752080           20.548600          7.305556
1%               1277.941970           22.527514          7.393106
10%              1278.501888           26.347420          7.790278
25%              1278.864600           29.279850          8.182778
33%              1279.172143           30.570678          8.414844
50%              1279.839960           34.112200          8.796389
66%              1280.281920           36.887404          9.089478
75%              1280.586720           37.884100          9.274306
90%              1281.065256           42.456100          9.851722
99%              1283.201294           50.767234         10.539672
max              1283.329920           51.536600         10.759444
```

11 Basic pandas descriptive statistics

https://pandas.pydata.org/pandas-docs/stable/basics.html#descriptive-statistics

12 useful panda info

https://jeffdelaney.me/blog/useful-snippets-in-pandas/

```
In [16]: #In what year did the min values happen?
         df.idxmin()
```

```
Out[16]: Great Salt Lake Level    1963.0
         Utah Precipitation       1956.0
         Utah Temperature         1898.0
         dtype: object
```

```
In [17]: #In what year did the max values happen?
         df.idxmax()
```

```
Out[17]: Great Salt Lake Level    1986.0
         Utah Precipitation       1941.0
```

```
Utah Temperature         1934.0
dtype: object
```

```
In [18]: modes = stats.mode(array,axis=0)
         print(modes)
```

```
ModeResult(mode=array([[1278.81888   ,   32.3088    ,    7.96277778]]), count=array([[4, 2, 2]
```

```
In [19]: #compute mean of the values between the 10th and 90th percentile in the sample
         xbar_trim = stats.trim_mean(array,0.1)
         print('Trimmed mean',xbar_trim)
```

```
Trimmed mean [1279.7610168    33.81883       8.76438333]
```

```
In [20]: #compute interquartile ranges
         iqr_var=stats.iqr(array,axis=0)
         print('IQR',iqr_var)
```

```
IQR [1.72212    8.60425    1.09152778]
```

```
In [21]: #median absolute deviation
         df.mad()
```

```
Out[21]: Great Salt Lake Level    0.926286
         Utah Precipitation       5.138789
         Utah Temperature         0.629731
         dtype: float64
```

13 Illustrating robust and reliant central tendency metrics

%put in a bad value

```
In [22]: #put in one bad value
         array_wbad = np.ones((N,3),dtype=np.float_)
         array_wbad[:,0] = lev
         array_wbad[:,1] = ppt
         array_wbad[:,2] = temp

         array_wbad[1,:] = -9999
         xbar_wbad = np.mean(array_wbad,axis=0);
         xmed_wbad = np.median(array_wbad,axis=0);
         xbar_trim_wbad = stats.trim_mean(array_wbad,0.1);
         print('mean',xbar_wbad)
         print('median',xmed_wbad)
         print('trimmed_mean',xbar_trim_wbad)
```

```
mean [1188.85564065  -46.81003226  -71.9055914 ]
median [1279.79424      34.1122        8.79638889]
trimmed_mean [1279.7399856    33.781238      8.75702222]
```

```
In [23]: # unbiased estimate of pop standard deviation and variance
         std0 = np.std(array,ddof=1,axis=0)
         var0 = np.var(array,ddof=1,axis=0)
         # sample standard deviation and variance
         std1 = np.std(array,axis=0)
         var1 = np.var(array,axis=0)
         print('pop standard deviation and variance',std0,var0)
         print('sample standard deviation and variance',std1,var1)
```

```
pop standard deviation and variance [1.14060981 6.36863201 0.78049722] [ 1.30099073 40.5594736
sample standard deviation and variance [1.13600126 6.34290006 0.77734369] [ 1.29049887 40.23238
```

```
In [24]: #skewness
         skew = stats.skew(array,axis=0)
         print('skewness',skew)
```

```
skewness [0.60493347 0.34543439 0.31201076]
```

14 Anomalies

```
In [25]: #sample means
         xbar= np.mean(array,axis=0)
         array_a = array - xbar;
         print(array_a)
```

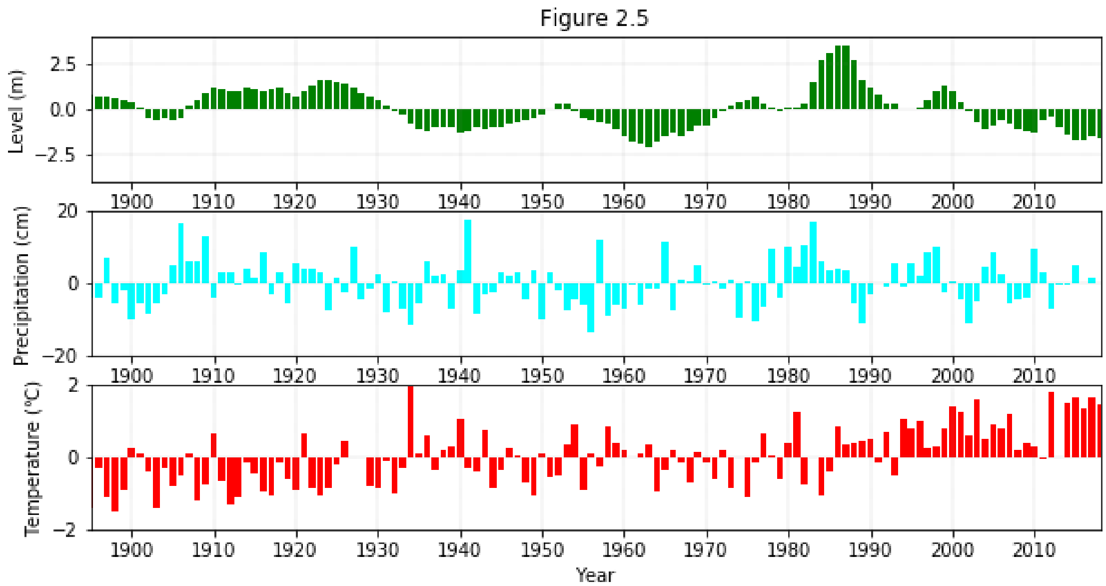
```
[[ 7.67407742e-01 -3.84256935e+00 -1.39279570e+00]
 [ 6.75967742e-01 -4.12196935e+00 -3.04462366e-01]
 [ 7.36927742e-01  6.85083065e+00 -1.09612903e+00]
 [ 6.45487742e-01 -5.46816935e+00 -1.49446237e+00]
 [ 4.93087742e-01 -2.29316935e+00 -8.92795699e-01]
 [ 4.32127742e-01 -1.00147694e+01  2.55537634e-01]
 [ 9.68477419e-02 -5.79836935e+00  9.33154122e-02]
 [-5.12752258e-01 -8.33836935e+00 -4.20573477e-01]
 [-6.04192258e-01 -5.36656935e+00 -1.41112903e+00]
 [-4.82272258e-01 -3.00436935e+00 -3.18351254e-01]
 [-6.34672258e-01  4.99663065e+00 -8.18351254e-01]
 [-5.12752258e-01  1.62488306e+01 -5.17795699e-01]
 [ 1.57807742e-01  5.93643065e+00  9.83154122e-02]
 [ 4.62607742e-01  5.73323065e+00 -1.18446237e+00]
 [ 8.89327742e-01  1.28960306e+01 -7.35017921e-01]
 [ 1.22460774e+00 -4.07116935e+00  6.62759857e-01]
```

```
[ 1.07220774e+00  2.99003065e+00 -6.70573477e-01]
[ 9.80767742e-01  2.78683065e+00 -1.32335125e+00]
[ 1.04172774e+00 -3.37369355e-01 -1.08724014e+00]
[ 1.19412774e+00  3.77743065e+00 -1.47240143e-01]
[ 1.07220774e+00  1.46603065e+00 -4.34462366e-01]
[ 9.50287742e-01  8.29863065e+00 -9.80573477e-01]
[ 1.10268774e+00 -2.92816935e+00 -1.06390681e+00]
[ 1.19412774e+00  3.14243065e+00 -1.79462366e-01]
[ 8.89327742e-01 -5.41736935e+00 -6.10017921e-01]
[ 7.36927742e-01  5.42843065e+00 -9.11129032e-01]
[ 1.01124774e+00  4.03143065e+00  6.21093190e-01]
[ 1.34652774e+00  4.00603065e+00 -8.37240143e-01]
[ 1.59036774e+00  3.06623065e+00 -1.05946237e+00]
[ 1.59036774e+00 -7.70336935e+00 -8.69462366e-01]
[ 1.46844774e+00  1.61843065e+00 -1.84462366e-01]
[ 1.37700774e+00 -2.47096935e+00  4.63870968e-01]
[ 1.16364774e+00  9.79723065e+00 -2.22401434e-02]
[ 8.89327742e-01 -4.75696935e+00 -2.22401434e-02]
[ 6.75967742e-01 -1.60736935e+00 -7.86129032e-01]
[ 4.93087742e-01  2.60903065e+00 -8.78906810e-01]
[ 1.57807742e-01 -7.88116935e+00 -1.15017921e-01]
[-1.16512258e-01  5.77030645e-01 -1.02224014e+00]
[-2.99392258e-01 -7.11916935e+00 -3.32240143e-01]
[-8.17552258e-01 -1.16403694e+01  1.95942652e+00]
[-1.15283226e+00 -5.74756935e+00  1.12204301e-01]
[-1.21379226e+00  5.75863065e+00  5.84426523e-01]
[-1.03091226e+00  2.17723065e+00 -3.60017921e-01]
[-1.00043226e+00  2.25343065e+00  1.86093190e-01]
[-1.03091226e+00 -6.91596935e+00  2.87759857e-01]
[-1.27475226e+00  3.59963065e+00  1.01942652e+00]
[-1.24427226e+00  1.74680306e+01 -2.86129032e-01]
[-1.03091226e+00 -8.64316935e+00 -3.87795699e-01]
[-1.06139226e+00 -2.87736935e+00  7.23315412e-01]
[-1.00043226e+00 -2.39476935e+00 -8.37240143e-01]
[-1.00043226e+00  3.16783065e+00 -3.65017921e-01]
[-7.87072258e-01  2.07563065e+00  2.18315412e-01]
[-6.65152258e-01  2.76143065e+00  2.38709677e-02]
[-6.04192258e-01 -4.32516935e+00 -7.02795699e-01]
[-4.82272258e-01  3.39643065e+00 -1.04057348e+00]
[-2.68912258e-01 -9.83696935e+00  7.94265233e-02]
[ 5.40774194e-03  2.96463065e+00 -5.36129032e-01]
[ 3.10207742e-01 -2.06456935e+00 -5.03906810e-01]
[ 2.79727742e-01 -7.72876935e+00  3.24982079e-01]
[-1.16512258e-01 -4.73156935e+00  8.71093190e-01]
[-4.82272258e-01 -5.89996935e+00 -9.06684588e-01]
[-5.73712258e-01 -1.35199694e+01  1.02759857e-01]
[-6.95632258e-01  1.20324306e+01 -2.40017921e-01]
[-7.56592258e-01 -8.94796935e+00  8.34426523e-01]
```

```
[-1.06139226e+00 -6.07776935e+00  3.98870968e-01]
[-1.45763226e+00 -7.19536935e+00  1.95537634e-01]
[-1.85387226e+00 -3.37369355e-01 -8.35125448e-03]
[-1.88435226e+00 -5.82376935e+00  7.05376344e-02]
[-2.06723226e+00 -1.75976935e+00  3.38870968e-01]
[-1.85387226e+00 -1.58196935e+00 -9.38906810e-01]
[-1.54907226e+00  1.15752306e+01 -3.83351254e-01]
[-1.33571226e+00 -7.39856935e+00  1.67759857e-01]
[-1.45763226e+00  1.18663065e+00 -1.65573477e-01]
[-1.24427226e+00  6.02430645e-01 -6.84462366e-01]
[-8.78512258e-01  4.81883065e+00  1.39982079e-01]
[-9.39472258e-01 -3.88169355e-01 -1.75017921e-01]
[-5.43232258e-01  5.51630645e-01 -6.23906810e-01]
[-8.60322581e-02 -1.75976935e+00  1.72204301e-01]
[ 2.18767742e-01  1.16123065e+00 -8.60017921e-01]
[ 3.71167742e-01 -9.40516935e+00 -1.77956989e-02]
[ 4.93087742e-01  5.00830645e-01 -1.13335125e+00]
[ 6.75967742e-01 -1.07513694e+01 -1.56684588e-01]
[ 3.10207742e-01 -6.61116935e+00  6.53870968e-01]
[ 9.68477419e-02  9.34003065e+00  6.10931900e-02]
[-5.55522581e-02 -4.29976935e+00 -6.15017921e-01]
[ 9.68477419e-02  9.82263065e+00  3.89982079e-01]
[ 1.27327742e-01  4.56483065e+00  1.24164875e+00]
[ 3.40687742e-01  1.06354306e+01 -7.58351254e-01]
[ 1.49892774e+00  1.68330306e+01  1.09318996e-03]
[ 2.71812774e+00  5.78403065e+00 -1.04557348e+00]
[ 3.05340774e+00  3.47263065e+00 -4.20573477e-01]
[ 3.51060774e+00  3.92983065e+00  8.34426523e-01]
[ 3.48012774e+00  3.34563065e+00  3.43315412e-01]
[ 2.71812774e+00 -5.69676935e+00  3.84982079e-01]
[ 1.55988774e+00 -1.12085694e+01  4.40537634e-01]
[ 1.22460774e+00 -3.25836935e+00  5.05537634e-01]
[ 7.67407742e-01  1.96030645e-01 -1.75017921e-01]
[ 3.40687742e-01 -1.09936935e+00  6.67759857e-01]
[ 3.10207742e-01  5.58083065e+00 -5.17795699e-01]
[ 3.58877419e-02 -8.45369355e-01  1.06553763e+00]
[ 3.58877419e-02  5.35223065e+00  7.92759857e-01]
[ 1.27327742e-01  1.84703065e+00  1.01498208e+00]
[ 4.62607742e-01  8.42563065e+00  2.32204301e-01]
[ 9.80767742e-01  1.00766306e+01  2.97204301e-01]
[ 1.25508774e+00 -2.54716935e+00  7.83315412e-01]
[ 1.01124774e+00  2.46830645e-01  1.37109319e+00]
[ 4.32127742e-01 -4.37596935e+00  1.24164875e+00]
[-8.60322581e-02 -1.11577694e+01  5.88870968e-01]
[-6.95632258e-01 -4.88396935e+00  1.57498208e+00]
[-1.12235226e+00  4.66643065e+00  5.05537634e-01]
[-8.78512258e-01  8.24783065e+00  8.71093190e-01]
[-6.04192258e-01  2.48203065e+00  7.83315412e-01]
```

```
 [-7.56592258e-01 -5.49356935e+00  1.19053763e+00]
 [-1.15283226e+00 -4.55376935e+00  1.99982079e-01]
 [-1.18331226e+00 -4.22356935e+00  3.80537634e-01]
 [-1.27475226e+00  9.59403065e+00  3.01648746e-01]
 [-5.73712258e-01  3.16783065e+00 -7.33512545e-02]
 [-4.21312258e-01 -6.99216935e+00  1.76942652e+00]
 [-1.00043226e+00 -6.42169355e-01  1.09318996e-03]
 [-1.42715226e+00 -3.11969355e-01  1.49609319e+00]
 [-1.67099226e+00  5.02203065e+00  1.63998208e+00]
 [-1.73195226e+00 -1.08769355e-01  1.36109319e+00]
 [-1.48811226e+00  1.46603065e+00  1.62775986e+00]
 [-1.64051226e+00  1.96030645e-01  1.42220430e+00]]
```

```
In [26]: fig,(ax1,ax2,ax3) = plt.subplots(3,1,figsize=(10,5))
         ax1.bar(year,array_a[:,0],color='green')
         ax1.set(xlim=(1895,2018),ylim=(-4,4))
         ax1.set(xlabel="Year",ylabel='Level (m)')
         ax1.set(xticks=decade_ticks)
         ax1.set(title="Figure 2.5")
         ax2.bar(year,array_a[:,1],color='cyan')
         ax2.set(xlim=(1895,2018),ylim=(-20,20))
         ax2.set(xlabel="Year",ylabel='Precipitation (cm)')
         ax2.set(xticks=decade_ticks)
         ax3.bar(year,array_a[:,2],color='red')
         ax3.set(xlim=(1895,2018),ylim=(-2,2))
         ax3.set(xlabel="Year",ylabel='Temperature ()')
         ax3.set(xticks=decade_ticks)

         ax1.grid(linestyle='--', color='grey', linewidth=.2)
         ax2.grid(linestyle='--', color='grey', linewidth=.2)
         ax3.grid(linestyle='--', color='grey', linewidth=.2)

         plt.savefig('figure_2.5_2019_python.png')
```



15 1981-2010 climate normal

define climate normal for 1981-2010 period. find those years cyr_beg = find(year == 1981); cyr_end = find(year == 2010);

cnorm = mean(array(cyr_beg:cyr_end,:)); cnorm_array = ones(ny,1)*cnorm; array_cna = array - cnorm;

figure(7); for i=1:3 subplot(3,1,i); bar(year,array_cna(:,i), colors(i)); axis([axis_val(i,:)]) set(gca,'XTick',decade_ticks); set(gca,'XTickLabel',decade_labels); grid on xlabel(xlabels(i)); ylabel(ylabels(i)); end

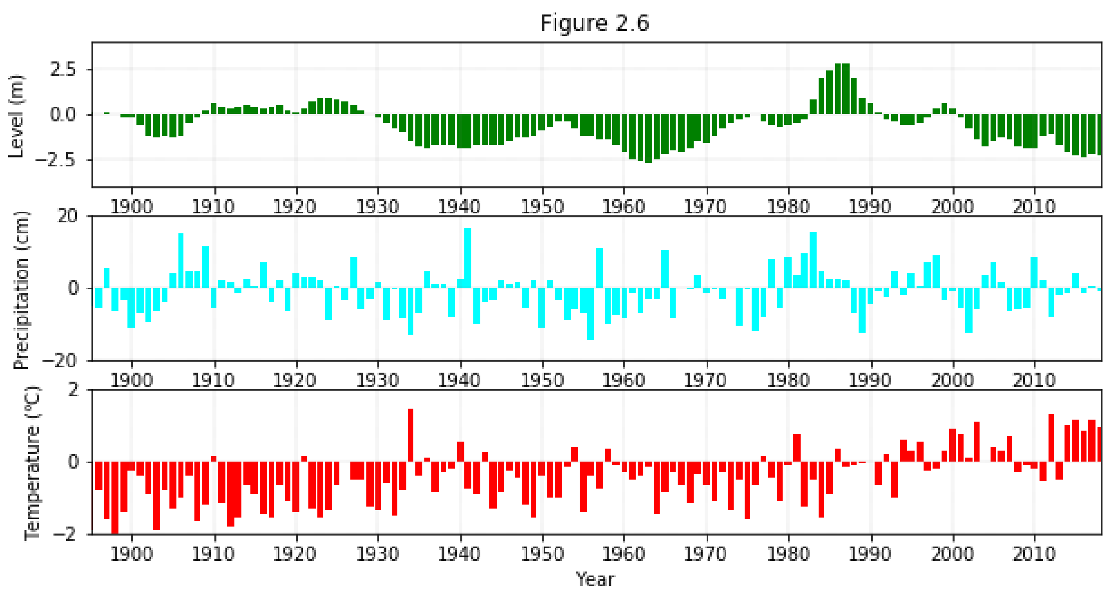
```
In [27]: # define climate normal for 1981-2010 period. find the range of values during those y
         #pandas handles these by index values
         clim_period=df.loc['1981':'2010']
         #print(clim_period)
         cnorm = np.mean(clim_period)
         print(cnorm)
         df_cna = df - cnorm;
         print(df_cna)
```

```
Great Salt Lake Level    1280.492127
Utah Precipitation         35.321766
Utah Temperature            9.296418
dtype: float64
        Great Salt Lake Level  Utah Precipitation  Utah Temperature
1895.0               0.094593           -5.095766         -1.889195
1896.0               0.003153           -5.375166         -0.800862
1897.0               0.064113            5.597634         -1.592529
```

1898.0	-0.027327	-6.721366	-1.990862
1899.0	-0.179727	-3.546366	-1.389195
1900.0	-0.240687	-11.267966	-0.240862
1901.0	-0.575967	-7.051566	-0.403084
1902.0	-1.185567	-9.591566	-0.916973
1903.0	-1.277007	-6.619766	-1.907529
1904.0	-1.155087	-4.257566	-0.814751
1905.0	-1.307487	3.743434	-1.314751
1906.0	-1.185567	14.995634	-1.014195
1907.0	-0.515007	4.683234	-0.398084
1908.0	-0.210207	4.480034	-1.680862
1909.0	0.216513	11.642834	-1.231418
1910.0	0.551793	-5.324366	0.166360
1911.0	0.399393	1.736834	-1.166973
1912.0	0.307953	1.533634	-1.819751
1913.0	0.368913	-1.590566	-1.583640
1914.0	0.521313	2.524234	-0.643640
1915.0	0.399393	0.212834	-0.930862
1916.0	0.277473	7.045434	-1.476973
1917.0	0.429873	-4.181366	-1.560307
1918.0	0.521313	1.889234	-0.675862
1919.0	0.216513	-6.670566	-1.106418
1920.0	0.064113	4.175234	-1.407529
1921.0	0.338433	2.778234	0.124693
1922.0	0.673713	2.752834	-1.333640
1923.0	0.917553	1.813034	-1.555862
1924.0	0.917553	-8.956566	-1.365862
...	...	...	...
1989.0	0.887073	-12.461766	-0.055862
1990.0	0.551793	-4.511566	0.009138
1991.0	0.094593	-1.057166	-0.671418
1992.0	-0.332127	-2.352566	0.171360
1993.0	-0.362607	4.327634	-1.014195
1994.0	-0.636927	-2.098566	0.569138
1995.0	-0.636927	4.099034	0.296360
1996.0	-0.545487	0.593834	0.518582
1997.0	-0.210207	7.172434	-0.264195
1998.0	0.307953	8.823434	-0.199195
1999.0	0.582273	-3.800366	0.286916
2000.0	0.338433	-1.006366	0.874693
2001.0	-0.240687	-5.629166	0.745249
2002.0	-0.758847	-12.410966	0.092471
2003.0	-1.368447	-6.137166	1.078582
2004.0	-1.795167	3.413234	0.009138
2005.0	-1.551327	6.994634	0.374693
2006.0	-1.277007	1.228834	0.286916
2007.0	-1.429407	-6.746766	0.694138
2008.0	-1.825647	-5.806966	-0.296418

```
2009.0               -1.856127           -5.476766         -0.115862
2010.0               -1.947567            8.340834         -0.194751
2011.0               -1.246527            1.914634         -0.569751
2012.0               -1.094127           -8.245366          1.273027
2013.0               -1.673247           -1.895366         -0.495307
2014.0               -2.099967           -1.565166          0.999693
2015.0               -2.343807            3.768834          1.143582
2016.0               -2.404767           -1.361966          0.864693
2017.0               -2.160927            0.212834          1.131360
2018.0               -2.313327           -1.057166          0.925805

[124 rows x 3 columns]
```

```
In [28]: fig,(ax1,ax2,ax3) = plt.subplots(3,1,figsize=(10,5))
         ax1.bar(year,df_cna['Great Salt Lake Level'],color='green')
         ax1.set(xlim=(1895,2018),ylim=(-4,4))
         ax1.set(xlabel="Year",ylabel='Level (m)')
         ax1.set(xticks=decade_ticks)
         ax1.set(title="Figure 2.6")
         ax2.bar(year,df_cna['Utah Precipitation'],color='cyan')
         ax2.set(xlim=(1895,2018),ylim=(-20,20))
         ax2.set(xlabel="Year",ylabel='Precipitation (cm)')
         ax2.set(xticks=decade_ticks)
         ax3.bar(year,df_cna['Utah Temperature'],color='red')
         ax3.set(xlim=(1895,2018),ylim=(-2,2))
         ax3.set(xlabel="Year",ylabel='Temperature ()')
         ax3.set(xticks=decade_ticks)

         ax1.grid(linestyle='--', color='grey', linewidth=.2)
         ax2.grid(linestyle='--', color='grey', linewidth=.2)
         ax3.grid(linestyle='--', color='grey', linewidth=.2)

         plt.savefig('figure_2.6_2019_python.png')
```



16 Handling Monthly Great Salt Lake Level

salt lake level begins in 1903 through 2018 create 2d array levm for processing rows are years and columns are months dates will be the midpoint of the month

```
In [29]: #read the Monthly lake level data
         yearm = np.genfromtxt('../data/gsl_monthly.csv', delimiter=',', usecols=0)
         nym = int(max(yearm) - min(yearm))+1
         print(np.size(yearm))
         monm = np.genfromtxt('../data/gsl_monthly.csv', delimiter=',', usecols=1)
         #convert lake level to meters
         levmon = .3048 * np.genfromtxt('../data/gsl_monthly.csv', delimiter=',', usecols=2)
         #get midpoint of each month as the date
         datemon =  yearm+(monm-0.5)/12.;
```

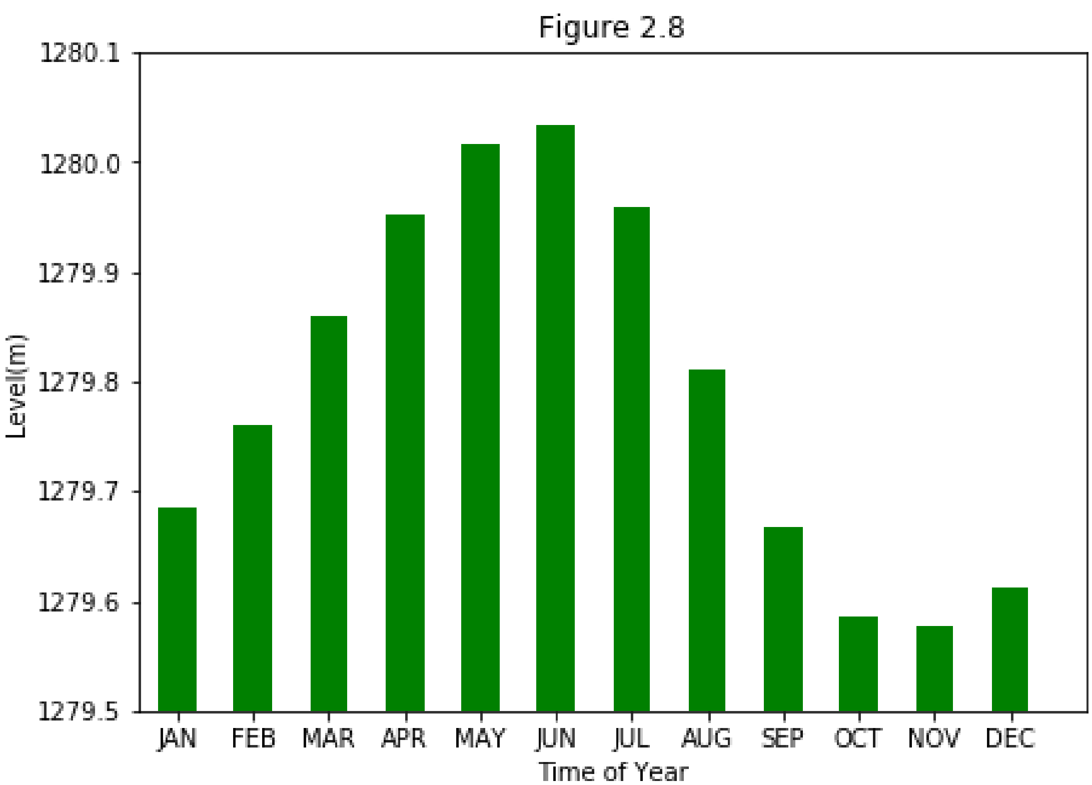
```
1392
```

```
In [30]: #convert from vector to 2D array with rows years and columns months
         levm = levmon.reshape((nym,12))
         datem = datemon.reshape((nym,12))
         #print(levm)
         #print(datem)
```

```
In [31]: #compute monthly mean and sample standard deviation for each month over all years

         mean_m = np.mean(levm,axis=0);
```

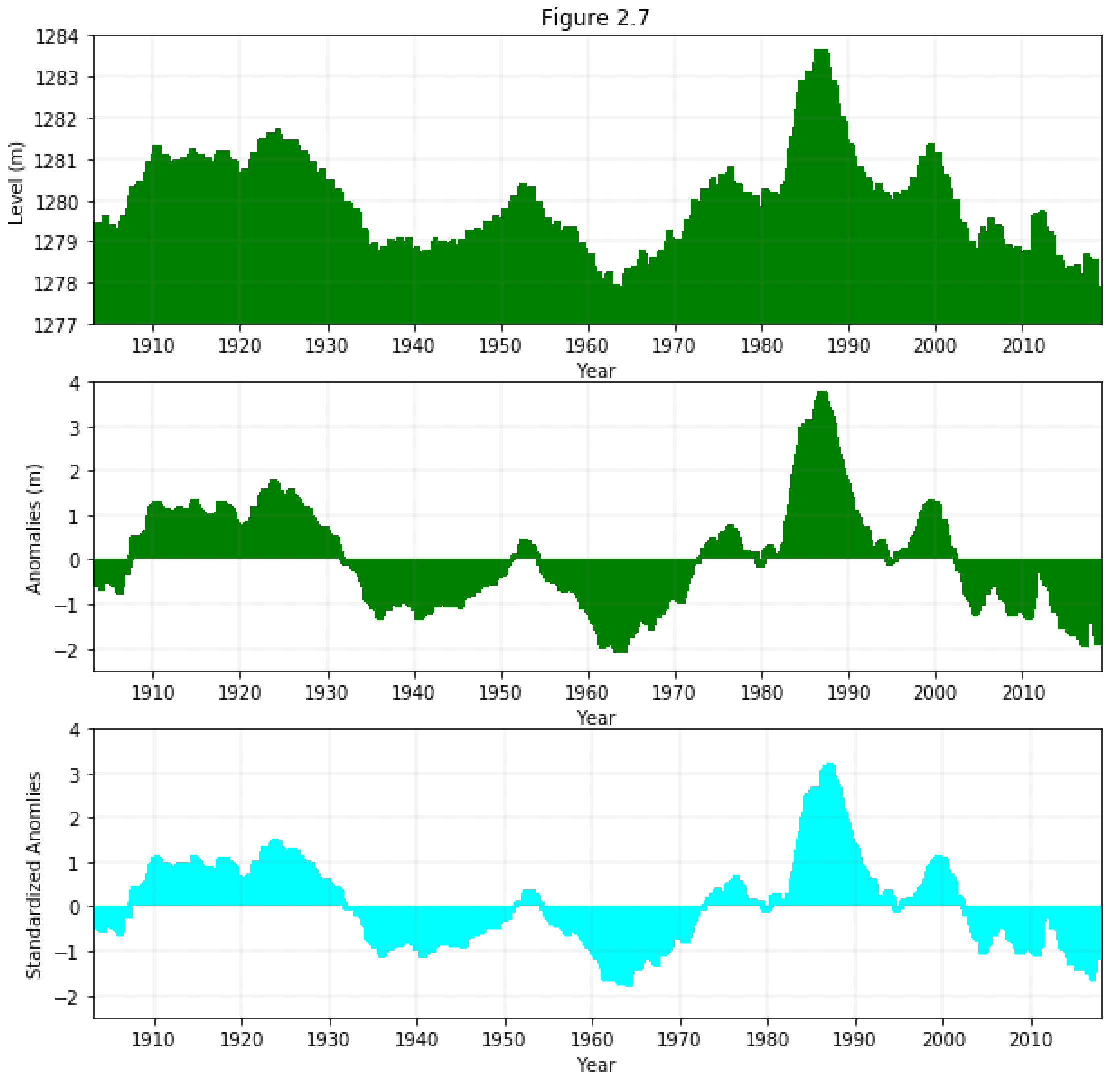
```python
sx_m = np.std(levm,axis=0);
print(mean_m)
print(sx_m)

#plot monthly mean;
xb = np.arange(0.5,12.5,1)
fig8,ax8 = plt.subplots(1,1,figsize=(7,5))
ax8.bar(xb,mean_m,color='g',align='center',width=0.5)
ax8.set(xlabel="Time of Year",ylabel='Level(m)')
ax8.set(xlim=(0,12.5),ylim=(1279.5,1280.1))
ax8.set(xticks=xb,xticklabels=['JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
ax8.ticklabel_format(axis='y',style='plain',useOffset=False)
ax8.set(title="Figure 2.8")
plt.savefig('figure_2.8_2019.png')
```

```
[1279.68427026 1279.75932989 1279.85977988 1279.95109639 1280.0157245
 1280.03407556 1279.95926292 1279.81002391 1279.66689141 1279.58520238
 1279.57633428 1279.61202215]
[1.17872268 1.17455254 1.16278339 1.16079602 1.15969198 1.17142598
 1.17221846 1.18457772 1.18831    1.18749246 1.19527963 1.19356331]
```



In [32]:
```
#compute anomalies from monthly means
levm_a = levm - mean_m;
nom = np.size(levm_a)
levma = levm_a.reshape(nom)
#compute standardized anomalies
z = levm_a/sx_m;
za = z.reshape(nom)
#print(levma)
#print(za)
#print(np.shape(za))
```

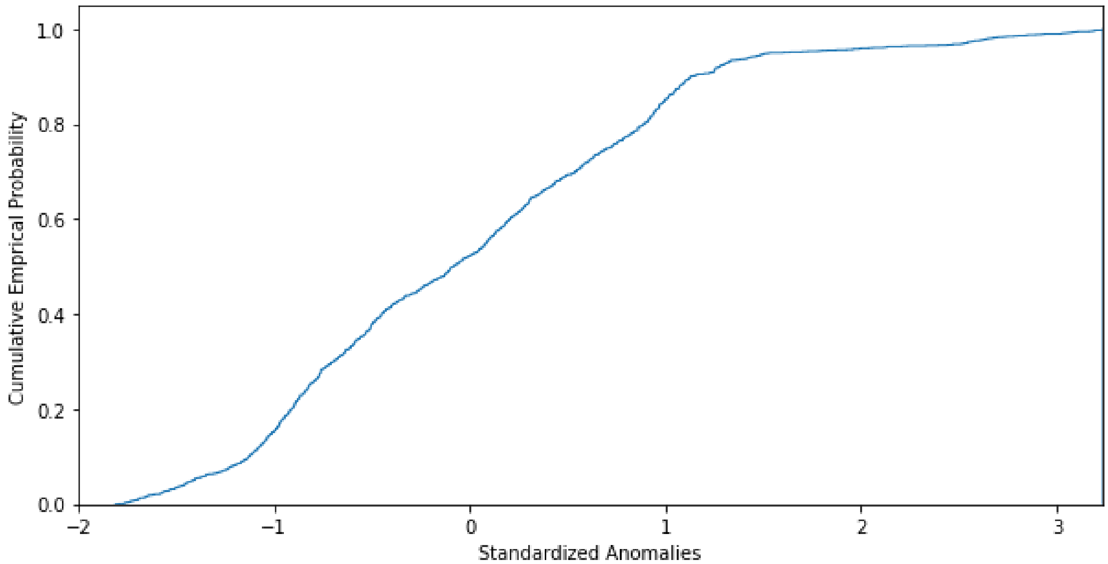
In [33]:
```
fig7,(ax1,ax2,ax3) = plt.subplots(3,1,figsize=(10,10))
decade_ticks = np.arange(1910,2020,10)
ax1.bar(datemon,levmon,color='green')
ax1.set(xlim=(1903,2019),ylim=(1277,1284))
ax1.set(xlabel="Year",ylabel='Level (m)')
ax1.set(xticks=decade_ticks)
ax1.set(title="Figure 2.7")
ax2.bar(datemon,levma,color='green')
ax2.set(xlim=(1903,2019),ylim=(-2.5,4))
ax2.set(xlabel="Year",ylabel='Anomalies (m)')
ax2.set(xticks=decade_ticks)
ax3.bar(datemon,za,color='cyan')
ax3.set(xlim=(1903,2018),ylim=(-2.5,4))
ax3.set(xlabel="Year",ylabel='Standardized Anomlies')
ax3.set(xticks=decade_ticks)

ax1.grid(linestyle='--', color='grey', linewidth=.2)
ax2.grid(linestyle='--', color='grey', linewidth=.2)
ax3.grid(linestyle='--', color='grey', linewidth=.2)

plt.savefig('figure_2.7_2019.png')
```




```
In [34]: # CDF of monthly lake level
         fig9,ax = plt.subplots(1,1,figsize=(10,5))
         print(nom)
         print(za)
         n, bins, patches = ax.hist(za, nom, density='True', histtype='step',
                                    cumulative=True, label='Empirical')
         ax.set(xlabel="Standardized Anomalies",ylabel='Cumulative Emprical Probability')
         ax.set(xlim=(-2,max(za)))


         plt.savefig('figure_2.9_2019.png')
```

```
1392
[-0.44973281 -0.4633338  -0.52819802 ... -1.56935934 -1.52621549
```

```
 -1.53277345]
```



17 Mean and Median smoothers

One way is to use pandas built in functions to handle. These are the sorts of things pandas is intended to handle

```
In [35]: #first get anomalies for Utah Precipitation only just for convenience as a Series
         ppt_vals= df['Utah Precipitation']
         ppt_climo = np.mean(ppt_vals)
         ppt_a = ppt_vals - ppt_climo
         #window is how many values to roll over and compute mean or median
         window = 3
         #iter is number of iterations to repeat
         iter = 5
         #do the first ones
         vals_mean=ppt_a.rolling(window,center=True).mean()
         vals_median=ppt_a.rolling(window,center=True).median()
         for ival in range(0,iter-1):
             #reset the first and last values to the original data
             vals_mean[[0]]=ppt_a.iloc[[0]]
             vals_mean[[-1]]=ppt_a.iloc[[-1]]
             vals_median[[0]]=ppt_a.iloc[[0]]
             vals_median[[-1]]=ppt_a.iloc[[-1]]
             vals_mean=vals_mean.rolling(window,center=True).mean()
             vals_median=vals_median.rolling(window,center=True).median()
```

```
# replace first and last values for final pass
vals_mean[[0]]=ppt_a.iloc[[0]]
vals_mean[[-1]]=ppt_a.iloc[[-1]]
vals_median[[0]]=ppt_a.iloc[[0]]
vals_median[[-1]]=ppt_a.iloc[[-1]]
```

In [36]:
```
# plot Utah precipitation with mean and medians superimposed
decade_ticks = np.arange(1900,2020,10)
fig10, ax = plt.subplots(1,1,figsize=(10,5))
ax.bar(year,array_a[:,1],color='cyan')
ax.plot(year,vals_mean.values,color='green',linewidth=2);
ax.plot(year,vals_median.values,color='red',linewidth=2);
ax.set(xlim=(1895,2018),ylim=(-20,20))
ax.set(xlabel="Year",ylabel='Precipitation Anomalies (cm)')
ax.set(xticks=decade_ticks)
ax.grid(linestyle='--', color='grey', linewidth=.2)
ax.set_title("Figure 2.10")
plt.savefig('figure_2.10_2019_python.png')
```