# Exercise 4 - NAO

November 13, 2019

## 1 North Atlantic Oscillation

**What is the NAO?**

https://www.youtube.com/watch?v=KOYJG7j4Iy8
** How is the NAO calculated ? **
$NAO\ Index$ = $\mathrm{SLP}_{Lisbon}$ - $\mathrm{SLP}_{Stykkisholmur/Reykjavik}$
where SLP refers to the normalized sea level pressure of respective location.
** Now, let's have a look at a timeseries of annual NAO indices**

In [10]:
```
# import python libraries
import pandas as pd
import numpy as np


# read in a time series with NAO index

nao= pd.read_csv('nao.csv', delimiter=r"\s+", header= None)

# do some stuff with the data, so it looks nice, e.g. column names in table
nao.index = nao.iloc[:,0].values
year = nao.index
nao = nao.iloc[:, 1::]
months= [ 'Jan','Feb', 'Mar',  'Apr', 'May', 'Jun', 'Jul','Aug', 'Sep', 'Oct', 'Nov', '
nao.columns = months

# define NaN values
nao[nao < -90 ] = np.nan
```

This is our our dataframe looks like

In [11]:
```
nao
```

Out[11]:

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | \ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1821 | NaN | NaN | NaN | NaN | NaN | NaN | -2.62 | -0.14 | NaN | NaN | NaN | NaN | |
| 1822 | NaN | NaN | 2.99 | -3.19 | 0.59 | -0.86 | -4.05 | -0.19 | -1.09 | -2.00 | -0.05 | -0.73 | |
| 1823 | -3.39 | NaN | NaN | NaN | 4.65 | -0.83 | 0.58 | 2.90 | 0.67 | -1.39 | -0.76 | -0.20 | |
| 1824 | -0.16 | 0.25 | -1.44 | 1.46 | 1.34 | -3.94 | -2.75 | -0.08 | 0.19 | NaN | -0.70 | -0.01 | |
| 1825 | -0.23 | 0.21 | 0.33 | -0.28 | 0.13 | 0.41 | -0.92 | 1.43 | -0.95 | 1.98 | 1.06 | -1.31 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1826 | -3.05 | 4.87 | -0.97 | 1.78 | -1.20 | 0.83 | 1.89 | 2.72 | -0.76 | 0.18 | -2.41 | -0.59 |
| 1827 | -0.45 | -3.72 | 1.83 | -0.83 | 1.20 | -0.07 | 2.02 | -3.56 | -0.07 | -3.02 | -1.42 | 2.70 |
| 1828 | 1.27 | 0.37 | -0.18 | 0.04 | -1.59 | -1.33 | -4.40 | -2.54 | -2.78 | 0.10 | -2.57 | 3.04 |
| 1829 | -2.48 | 0.32 | -2.54 | 0.12 | 1.80 | -0.10 | 0.33 | 0.77 | 0.78 | 0.71 | -0.33 | -0.43 |
| 1830 | -2.33 | 1.20 | 3.58 | 3.08 | -0.05 | -0.85 | 3.19 | -0.35 | 2.04 | 2.04 | 2.19 | -3.13 |
| 1831 | -2.91 | 1.40 | 1.48 | -3.15 | -2.47 | -1.36 | 2.71 | -3.04 | -1.53 | 0.85 | 0.26 | 0.36 |
| 1832 | -0.04 | 0.83 | 2.12 | -1.51 | -1.96 | -3.62 | -2.57 | 0.92 | 1.45 | 2.25 | 0.62 | 3.32 |
| 1833 | -0.36 | 2.52 | -2.89 | 2.02 | 0.69 | -1.52 | 0.13 | -1.74 | -0.93 | -1.75 | 1.40 | 4.17 |
| 1834 | 3.07 | 2.66 | 1.37 | -2.38 | -1.03 | 0.27 | -0.73 | -0.86 | -0.62 | 0.30 | -2.28 | 0.11 |
| 1835 | 0.37 | 3.37 | 1.54 | -1.02 | 0.58 | 0.10 | 0.57 | 2.35 | 0.29 | -0.30 | -1.31 | -1.46 |
| 1836 | 1.47 | 0.06 | 2.28 | 0.87 | -1.50 | 2.95 | 4.33 | 2.80 | -1.59 | -1.17 | 2.04 | -1.41 |
| 1837 | -1.16 | 4.67 | -3.08 | -0.56 | -1.02 | -2.98 | -2.40 | 0.01 | 0.17 | 2.52 | 1.34 | 1.37 |
| 1838 | -2.16 | -1.81 | 1.23 | -0.61 | -2.16 | 1.24 | 0.11 | 1.16 | 1.46 | 0.59 | -2.65 | 2.55 |
| 1839 | 1.24 | 4.20 | 0.79 | 1.40 | -0.94 | 0.01 | 1.14 | 0.04 | 1.09 | -1.27 | -2.89 | -0.63 |
| 1840 | 2.97 | -0.40 | -3.05 | 0.87 | -0.58 | -0.09 | 1.23 | 0.05 | 0.46 | -2.50 | 0.46 | -2.43 |
| 1841 | -0.71 | -1.37 | 2.41 | 1.97 | 1.65 | -0.61 | -0.62 | 2.39 | -2.76 | -2.13 | 1.76 | 0.21 |
| 1842 | 2.45 | 4.26 | 3.43 | -0.44 | -0.85 | -4.30 | -4.05 | 1.03 | -3.80 | -3.73 | -2.66 | 0.51 |
| 1843 | 2.99 | -3.51 | -1.29 | 2.03 | -0.49 | -1.92 | 3.26 | 3.99 | -0.58 | -1.90 | 0.87 | 3.13 |
| 1844 | 0.20 | 0.11 | 1.09 | 3.91 | -2.77 | -0.12 | 0.36 | -1.00 | -1.53 | -0.99 | -0.02 | -1.90 |
| 1845 | 1.17 | 0.06 | -0.54 | 0.56 | -0.97 | 2.07 | -0.16 | -0.29 | -0.23 | 1.14 | 0.49 | 0.83 |
| 1846 | 2.26 | 0.63 | 1.75 | -1.42 | 0.19 | 1.45 | 2.84 | -0.30 | -1.18 | 0.01 | -0.59 | -2.55 |
| 1847 | 0.03 | 0.10 | -1.59 | 1.17 | 1.76 | -0.26 | 0.75 | 1.13 | -0.32 | 0.44 | 2.46 | 1.76 |
| 1848 | -0.79 | 1.77 | 0.76 | -1.02 | 0.69 | -1.78 | 1.87 | 2.64 | -2.55 | -2.44 | -0.84 | 2.55 |
| 1849 | 2.42 | 2.77 | -0.56 | -0.99 | -0.52 | -3.21 | 1.20 | 0.70 | -2.23 | -0.08 | 0.80 | -1.24 |
| 1850 | -0.16 | 4.13 | -2.22 | 0.97 | -1.16 | 0.40 | 0.31 | 0.15 | -2.08 | -2.70 | 2.39 | 2.36 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1988 | 0.53 | -0.11 | 0.78 | -2.39 | -1.24 | -2.75 | 1.46 | 0.73 | 0.80 | -2.02 | -1.47 | 1.85 |
| 1989 | 3.53 | 3.61 | 2.45 | -0.48 | 1.16 | -0.53 | 0.58 | 1.76 | -0.96 | 0.88 | -2.97 | -2.23 |
| 1990 | 3.50 | 5.11 | 3.11 | 1.77 | -1.19 | 0.42 | 1.43 | 3.31 | -0.99 | -0.59 | -1.48 | 0.34 |
| 1991 | 1.87 | -0.02 | -1.37 | 1.48 | -0.04 | -0.31 | -0.28 | 2.71 | -1.12 | -1.77 | 1.68 | 1.24 |
| 1992 | 0.64 | 3.18 | 1.66 | 1.32 | 0.79 | -1.74 | 1.04 | 3.97 | 0.99 | -3.33 | 4.52 | 0.21 |
| 1993 | 3.91 | 0.11 | 1.47 | 0.83 | -2.59 | 0.16 | 0.64 | 0.75 | -2.60 | -4.13 | 0.77 | 2.17 |
| 1994 | 1.28 | 0.07 | 3.68 | 1.38 | -1.43 | 2.98 | -0.09 | -1.59 | -2.85 | -1.88 | 1.68 | 2.86 |
| 1995 | 2.70 | 3.13 | 1.06 | -1.81 | -0.36 | -3.36 | -0.96 | -1.33 | -1.55 | 1.22 | -2.73 | -3.33 |
| 1996 | -3.27 | -0.12 | -2.57 | -0.31 | -1.50 | 1.43 | 1.47 | -0.19 | -2.23 | -0.07 | -0.05 | -4.70 |
| 1997 | -1.95 | 5.26 | 2.09 | -0.97 | -1.35 | -4.05 | 1.18 | 1.78 | -0.67 | -2.26 | -0.99 | -0.20 |
| 1998 | -0.28 | 2.44 | 1.24 | -0.39 | -1.26 | -0.85 | -0.57 | 1.80 | -3.48 | 1.34 | 1.13 | 1.95 |
| 1999 | 0.90 | 1.80 | -0.72 | 0.43 | 1.03 | 1.39 | -1.85 | -3.67 | -0.51 | -0.69 | 0.30 | 2.13 |
| 2000 | 0.35 | 4.37 | 0.54 | -3.34 | 0.31 | 0.89 | -2.99 | 0.78 | -1.10 | 1.37 | -0.24 | -1.41 |
| 2001 | 0.02 | 0.07 | -0.68 | 1.24 | -0.09 | -1.33 | -1.12 | 1.64 | -3.83 | 0.88 | 0.01 | -2.25 |
| 2002 | 2.31 | 3.01 | 0.09 | 0.91 | -0.05 | 0.90 | -0.71 | -0.61 | -3.58 | -1.50 | -0.27 | -0.98 |
| 2003 | 0.15 | 1.34 | 1.08 | -1.74 | 1.17 | -0.86 | 0.09 | -0.99 | 0.35 | -3.68 | 0.31 | -0.85 |
| 2004 | 0.20 | -1.23 | 1.07 | 1.08 | -0.67 | -0.38 | -0.30 | -0.76 | 2.51 | -2.18 | -0.55 | 1.27 |
| 2005 | 1.82 | -2.25 | -1.29 | 0.71 | -0.13 | -1.00 | -0.08 | 0.94 | 0.50 | -0.45 | -1.01 | -0.81 |
| 2006 | -0.10 | -1.24 | -1.12 | 0.57 | -0.22 | -0.41 | 0.83 | -2.47 | -1.02 | -1.97 | 2.00 | 3.03 |
| 2007 | 1.76 | 0.42 | 2.03 | -0.10 | 0.62 | -3.34 | -1.05 | -3.41 | -1.18 | -0.02 | -1.67 | 1.36 |
| 2008 | 1.85 | 1.79 | 0.37 | -2.02 | -3.26 | -1.62 | -1.13 | -0.21 | -2.07 | 0.01 | -1.30 | -0.58 |
| 2009 | 0.60 | -1.43 | 0.15 | 1.74 | 1.52 | -3.05 | -0.92 | 1.07 | -0.63 | -1.53 | 1.68 | -3.73 |

```
2010 -2.38 -3.92 -0.80 -1.03 -1.66 -3.65  0.06 -2.01 -2.38 -2.41 -3.34 -4.61
2011 -1.38  2.79 -0.17  2.39  1.08 -1.58 -3.39 -2.41  2.97  1.31  0.74  3.20
2012  2.05  1.28  1.78 -2.36 -0.83 -2.58 -1.31 -0.44 -1.44 -3.21 -1.11  0.60
2013  1.08 -0.26 -3.75  0.03  1.23  1.40  2.52  2.16 -0.57 -0.36  0.04  3.54
2014  0.71  2.32  1.64  0.84 -0.08 -1.98  0.91 -1.14 -2.10  0.31 -2.17  1.89
2015  2.81  1.47  1.99  1.03  2.09  0.28 -2.16  1.47 -1.65 -1.13  3.54  4.22
2016  1.17  1.61  0.33 -2.06 -0.83 -1.27  2.19  2.14  2.45 -1.47 -1.61  2.10
2017  0.17  1.38  1.05  1.50   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN

      Annual
1821     NaN
1822     NaN
1823     NaN
1824     NaN
1825    0.16
1826    0.27
1827   -0.45
1828   -0.88
1829   -0.09
1830    0.88
1831   -0.62
1832    0.15
1833    0.15
1834   -0.01
1835    0.42
1836    0.93
1837   -0.09
1838   -0.09
1839    0.35
1840   -0.25
1841    0.18
1842   -0.68
1843    0.55
1844   -0.22
1845    0.34
1846    0.26
1847    0.62
1848    0.07
1849   -0.08
1850    0.20
...      ...
1988   -0.32
1989    0.57
1990    1.23
1991    0.34
1992    1.11
1993    0.12
1994    0.51
```

```
1995   -0.61
1996   -1.01
1997   -0.18
1998    0.25
1999    0.04
2000   -0.04
2001   -0.45
2002   -0.04
2003   -0.30
2004    0.01
2005   -0.26
2006   -0.18
2007   -0.38
2008   -0.68
2009   -0.38
2010   -2.35
2011    0.46
2012   -0.63
2013    0.59
2014    0.10
2015    1.16
2016    0.39
2017     NaN

[197 rows x 13 columns]
```

```
In [61]: nao.shape
```

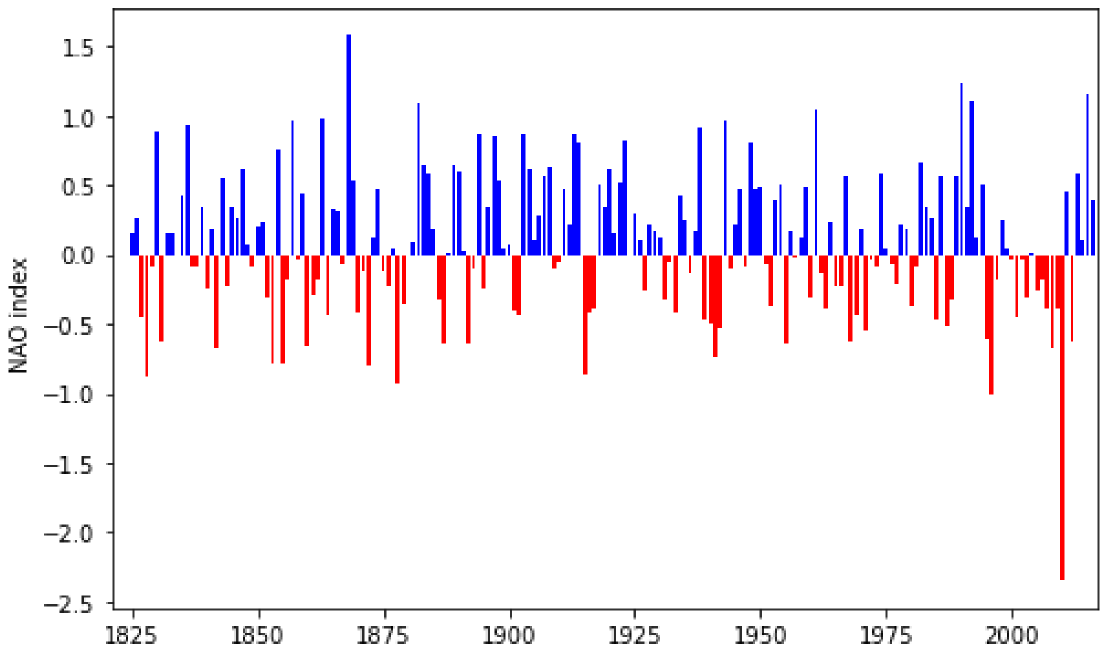
```
Out[61]: (197, 13)
```

We have a data matrix which contains 197 rows and 13 columns. The rows represent the years and the columns represent the months (last column is the annual mean).

```
In [12]: # python library for plotting
         import matplotlib.pyplot as plt

         # plot timeseries
         plt.figure(figsize=(8,5))
         annual_nao = nao.iloc[:, 12]

         plt.bar(year, annual_nao , color=(annual_nao > 0).map({True: 'b', False: 'r'}))
         plt.xlim(np.nanmin(year), np.nanmax(year))
         plt.ylabel('NAO index ')
         plt.show()
```




### 1.1 Can you identify years with strongly negative or positive NAO index values?

In [14]:
```
# get the year with the lowest value
year[annual_nao == np.nanmin(annual_nao)][0]


# can you find out what to type to get the max value?
```

Out[14]:
```
2010
```

In [3]:
```
# look at monthly NAO index in year 2010
nao2010= nao[nao.index == 2010]
nao2010
```

Out[3]:
```
         1     2    3     4     5     6     7     8     9    10    11    12  \
2010 -2.38 -3.92 -0.8 -1.03 -1.66 -3.65  0.06 -2.01 -2.38 -2.41 -3.34 -4.61

         13
2010 -2.35
```

A quick look at the monthly NAO index for 2010 shows us that the index is especially strong during the winter months.

### 1.2 Swedish winter 2010

Your task now is to find some temperature and precipitation data for Sweden for winter 2010 (or another location in Northern Europe) and plot the data. You are free to choose one or more locations. If you have time, you can also compare different places.

*How was winter 2010 in Sweden?*

*What weather pattern can we observe in Northern Europe for strong negative (positive) NAO indices?*

**Possible data sources:**

Time series of precipitation, temperature, humidity - https://www.smhi.se/data/meteorologi/

Additional data sources for gridded data and weather indices (more advanced) - http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php (need for registration) - https://www.ecad.eu/

```
In [3]: # read in data (e.g. read in csv file from SMHI)
```

```
In [4]: # plot your time series here
```

```
In [ ]: # additional visualizations
```