Tutorial 1.1. Wind Speed Computation

Description: The wind velocity is measured at a reference height and values are reported (generally) as the maxima of given duration. In this tutorial the yearly maxima are analyzed to fit a distribution from the given data. The design wind velocity is computed for the chosen return period. Some exercises are proposed. This is based upon 2.3 from J. D. Holmes., Wind loading of structures“, 2nd ed.

Students are advised to complete the exercises.

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In [1]:

```
# import
import matplotlib.pyplot as plt
import numpy as np
```

Get the data files from 'east_sale.dat', data from J. D. Holmes., Wind loading of structures“, 2nd ed. (https://ebookcentral.proquest.com/lib/Munchentech/detail.action?docID=356271)

In [2]:

```
winddata = np.loadtxt('east_sale.dat')
year = winddata[:,0]
maxgust = winddata[:,1]
```

Let us evaluate the mean and standard deviation of the wind data.

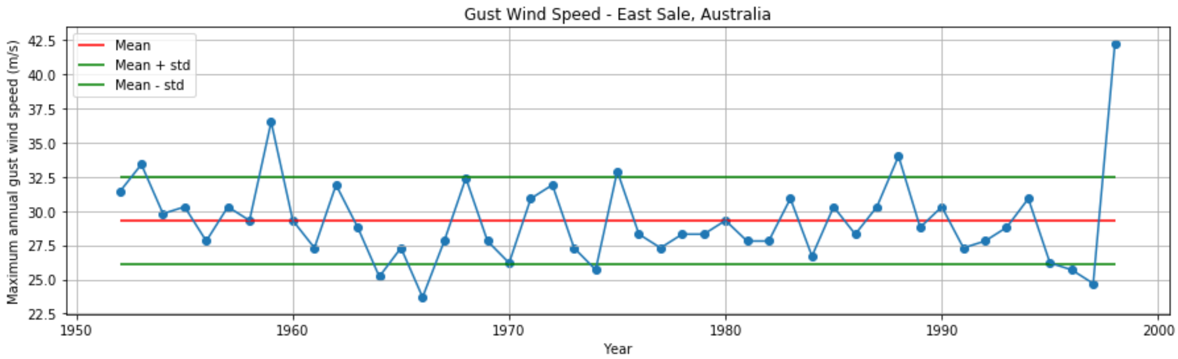
In [3]:

```
gust_m = np.mean(maxgust)
gust_std = np.std(maxgust)
```

Let us look at the plot

In [4]:

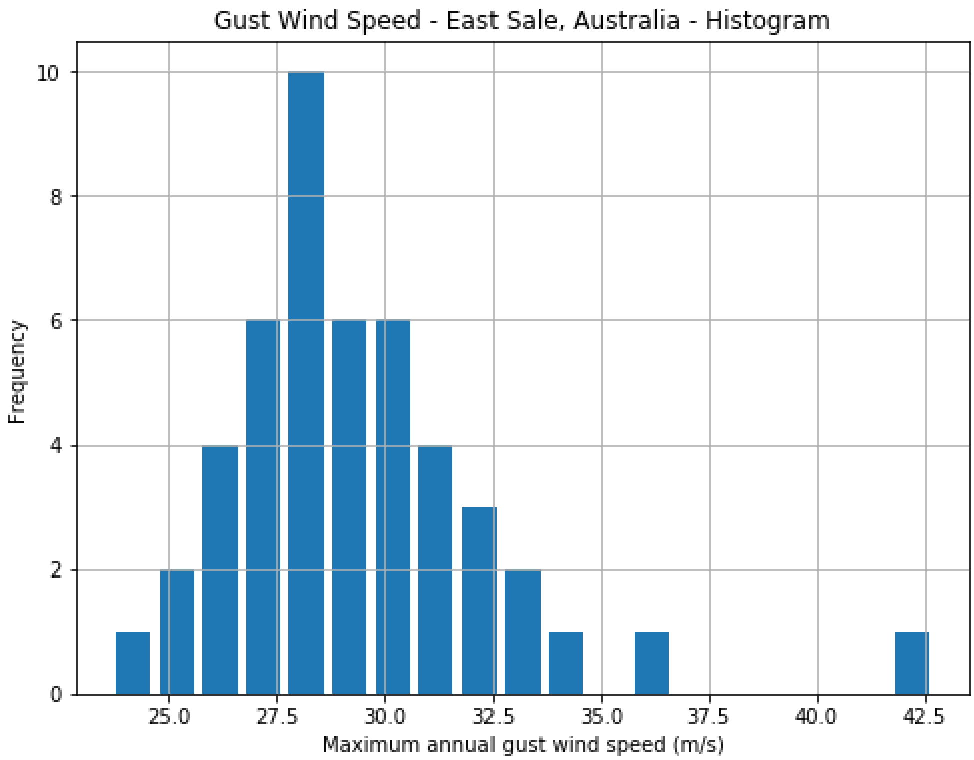
```
plt.figure(num=1, figsize=(15, 4))
plt.plot(year, maxgust)
plt.scatter(year, maxgust)
plt.hlines(gust_m, min(year), max(year), color='r', label = 'Mean')
plt.hlines(gust_m + gust_std, min(year), max(year), color='g', label = 'Mean + std')
plt.hlines(gust_m - gust_std, min(year), max(year), color='g', label = 'Mean - std')
plt.ylabel('Maximum annual gust wind speed (m/s)')
plt.xlabel('Year')
plt.title('Gust Wind Speed - East Sale, Australia')
plt.legend()
plt.grid(True)
```



To better understand the data, a histogram may be plotted. The histogram represents the frequency of data in each class interval. The inbuilt function for [plotting histogram (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.hist.html)](https://matplotlib.org/api/_as_gen/matplotlib.pyplot.hist.html) in python is used.

In [5]:

```
plt.figure(num=2, figsize=(8, 6))
plt.hist(maxgust, bins=np.arange(min(maxgust), max(maxgust)+1), rwidth=0.8)
plt.ylabel('Frequency')
plt.xlabel('Maximum annual gust wind speed (m/s)')
plt.title('Gust Wind Speed - East Sale, Australia - Histogram')
plt.grid(True)
```



Extreme wind estimation based upon measured data

3 methods are used in this tutorial for extreme wind estimation

1. Gumbel’s method
2. Gringorten’s method
3. The method of moments

1. Gumbel's method

A cumulative probability distribution function for extreme values of Type I (Gumbel) is considered

$$F_u(U) = e^{-e^{-\frac{U-u}{a}}}$$

The following steps are followed to obtain the extreme wind statistics in Gumbel's method.

step 1 The largest wind speed in each calendar year of the record is extracted U - 'maxgust'.

step 2 The series is ordered (ranked) $1, 2, \dots m, \dots N$.

step 3 Each value is assigned a probability of non-exceedence $p \approx m/(N+1)$.

step 4 A reduced variate is formed $y = -ln - ln(p)$.

step 5 A straight line is fit for the data reduced variate y and gust wind speed U.

step 6 The slope a and mode u of the best fit line is obtained.

step 7 For a chosen return period an estimate for the maximum gust wind speed can be obtained as

$$U_R = u + a\Big\{ - ln\Big[- ln\Big(1 - \frac{1}{R}\Big)\Big]\Big\}$$

What does the return period indicate?

step 1 The largest wind speed in each calendar year of the record is extracted (U) - 'maxgust' .

step 2 The series is ordered based on the absolute value of wind speed and ranked as $rank = 1, 2, \ldots m, \ldots N$ with N being the maximum rank

In [6]:

```
gust_sorted = np.sort(maxgust)
max_rank = len(gust_sorted) # the highest rank
rank = np.arange(1, max_rank + 1) # the rank of ordered wind speed values.
```

step 3 Each wind speed value is assigned a **probability of non-exceedance** $p \approx m/(N+1)$. The probability of non-exceedance is the expected chance that the wind speed value will not exceed the speed considered.

step 4 A reduced variate is formed $y = -ln - ln(p)$.

In [7]:

```
gumbel_prob_nonexc = rank / (max_rank + 1)
gumbel_red_var = -np.log(-np.log(gumbel_prob_nonexc))
```

step 5 A straight line is fit for the data reduced variate y and gust wind speed U.

Check out the [polyfit (https://docs.scipy.org/doc/numpy/reference/generated/numpy.polyfit.html)](https://docs.scipy.org/doc/numpy/reference/generated/numpy.polyfit.html) function

step 6 The slope a and mode u of the best fit line is obtained.

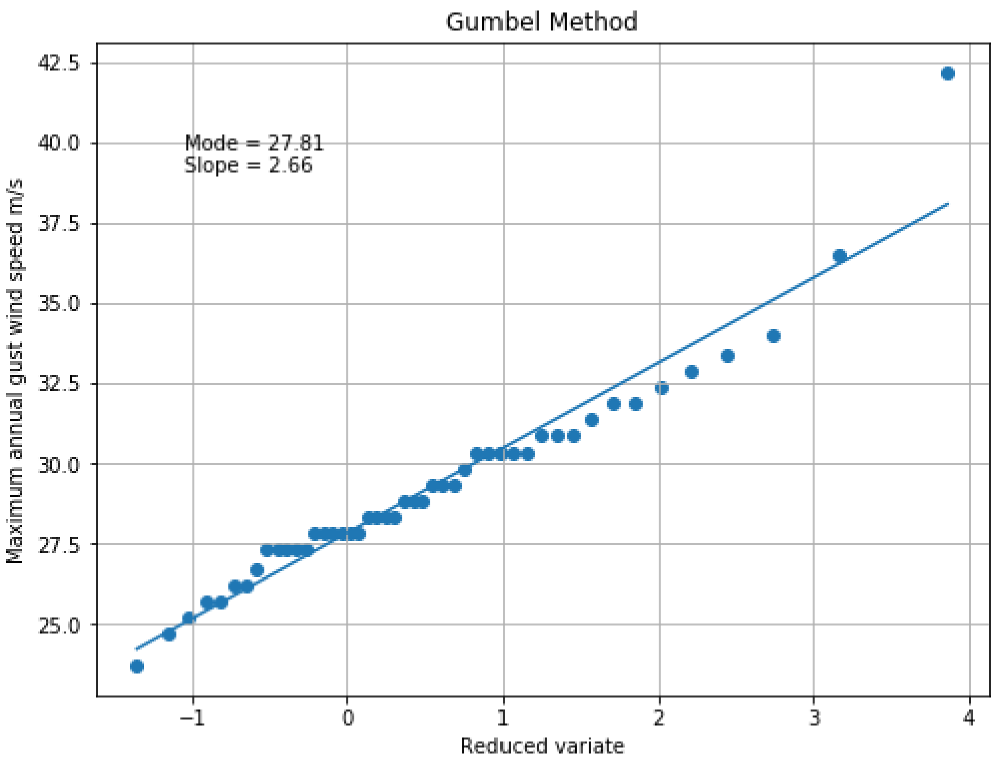
In [8]:

```
[gumbel_slope, gumbel_mode] = np.polyfit(gumbel_red_var, gust_sorted, 1)
```

Let us look at the plot

In [9]:

```
plt.figure(num=3, figsize=(8, 6))
plt.scatter(gumbel_red_var, gust_sorted)
x = np.linspace(min(gumbel_red_var), max(gumbel_red_var), 50)
plt.plot(x, gumbel_mode + gumbel_slope * x)
plt.text(0.1, 0.8,'Mode = ' + str(round(gumbel_mode,2)) +
         '\nSlope = ' + str(round(gumbel_slope,2)),
         transform=plt.gca().transAxes)
plt.ylabel('Maximum annual gust wind speed m/s')
plt.xlabel('Reduced variate')
plt.title('Gumbel Method')
plt.grid(True)
```



step 7 For a chosen return period an estimate for the maximum gust wind speed can be obtained as

$$U_R = u + a\Big\{ - ln\Big[- ln\Big(1 - \frac{1}{R}\Big)\Big]\Big\}$$

The [return period (https://en.wikipedia.org/wiki/Return_period)](https://en.wikipedia.org/wiki/Return_period) is the estimate of time in which the maximum annual gust wind speed will exceed the design wind speed. The return period is selected based on the design life of the structure.

In [10]:

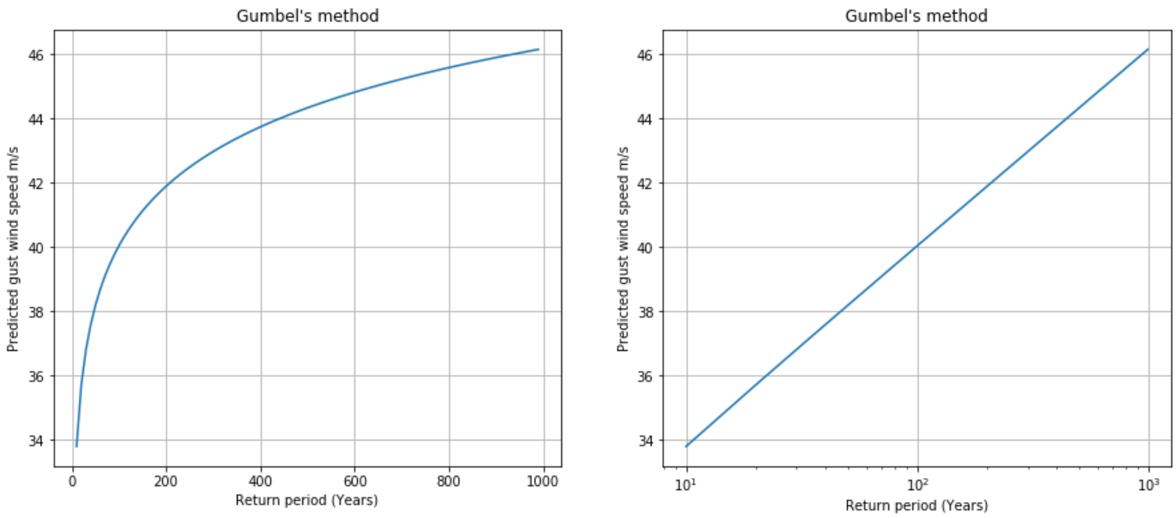
```
return_period = np.arange(10, 1000, 10)
gumbel_predicted_gustwind = gumbel_mode + gumbel_slope * (-np.log(-np.log(1-1/return_perioc
# for 50 years return period
n_years_return_period = 50
gumbel_predicted_gustwind_50 = gumbel_mode + gumbel_slope * (-np.log(-np.log(1-1/n_years_re
```

Let us look at the plot

In [11]:

```
plt.figure(num=4, figsize=(15, 6))
plt.subplot(1,2,1)
plt.plot(return_period, gumbel_predicted_gustwind)
plt.ylabel('Predicted gust wind speed m/s')
plt.xlabel('Return period (Years)')
plt.title('Gumbel\'s method')
plt.grid(True)

plt.subplot(1,2,2)
plt.plot(return_period, gumbel_predicted_gustwind)
plt.xscale('log')
plt.ylabel('Predicted gust wind speed m/s')
plt.xlabel('Return period (Years)')
plt.title('Gumbel\'s method')
plt.grid(True)
```



2. Gringorten's method

The steps are similar to that of Gumbel's method, except that

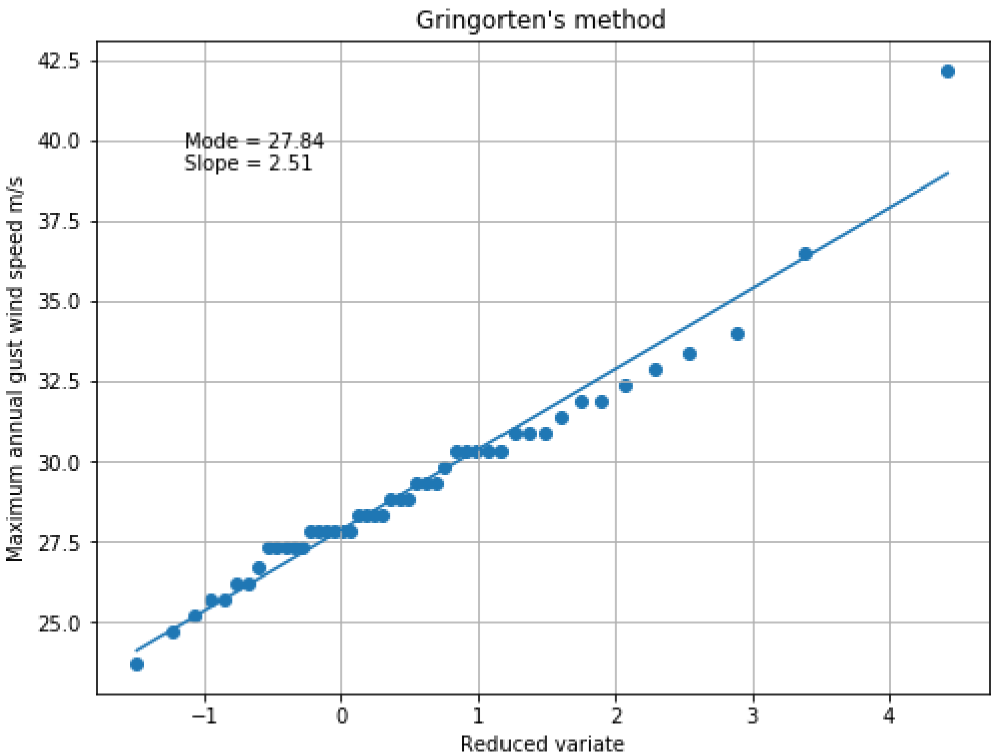
step 3 Each value is assigned a probability of non-exceedence $p \approx \frac{(m-0.44)}{(N+0.12)}$.

In [12]:

```
gringorten_prob_nonexc = (rank - 0.44) /(max_rank + 0.12)
gringorten_red_var = -np.log(-np.log(gringorten_prob_nonexc))
[gringorten_slope, gringorten_mode] = np.polyfit(gringorten_red_var, gust_sorted,1)
gringorten_predicted_gustwind = gringorten_mode + gringorten_slope * (-np.log(-np.log(1-1/r
# for 50 years return period
n_years_return_period = 50
gringorten_predicted_gustwind_50 = gringorten_mode + gringorten_slope * (-np.log(-np.log(1-
```

In [13]:

```
plt.figure(num=5, figsize=(8, 6))
plt.scatter(gringorten_red_var, gust_sorted)
x = np.linspace(min(gringorten_red_var), max(gringorten_red_var), 50)
plt.plot(x, gringorten_mode + gringorten_slope * x)
plt.text(0.1, 0.8,'Mode = ' + str(round(gringorten_mode,2)) +
         '\nSlope = ' + str(round(gringorten_slope,2)),
         transform=plt.gca().transAxes)
plt.ylabel('Maximum annual gust wind speed m/s')
plt.xlabel('Reduced variate')
plt.title('Gringorten\'s method')
plt.grid(True)
```



3. The method of moments

The slope and mode is approximated as

Slope $a \approx \left(\frac{\sqrt{6}}{\pi}\right)\sigma$

Mode $u \approx \mu - 0.5772a$

In [14]:

```
moments_slope = np.sqrt(6)/np.pi * gust_std
moments_mode  = gust_m - 0.5772 * moments_slope
moments_predicted_gustwind = moments_mode + moments_slope * (-np.log(-np.log(1-1/return_per
# for 50 years return period
n_years_return_period = 50
moments_predicted_gustwind_50 = moments_mode + moments_slope * (-np.log(-np.log(1-1/n_years
# print the slope and mode values for method of moments :
print('Mode - Method of moments  = ' + str(round(moments_mode,2)))
print('Slope - Method of moments  = ' + str(round(moments_slope,2)))
```

```
Mode - Method of moments  = 27.84
Slope - Method of moments  = 2.47
```

Let us look at the plot

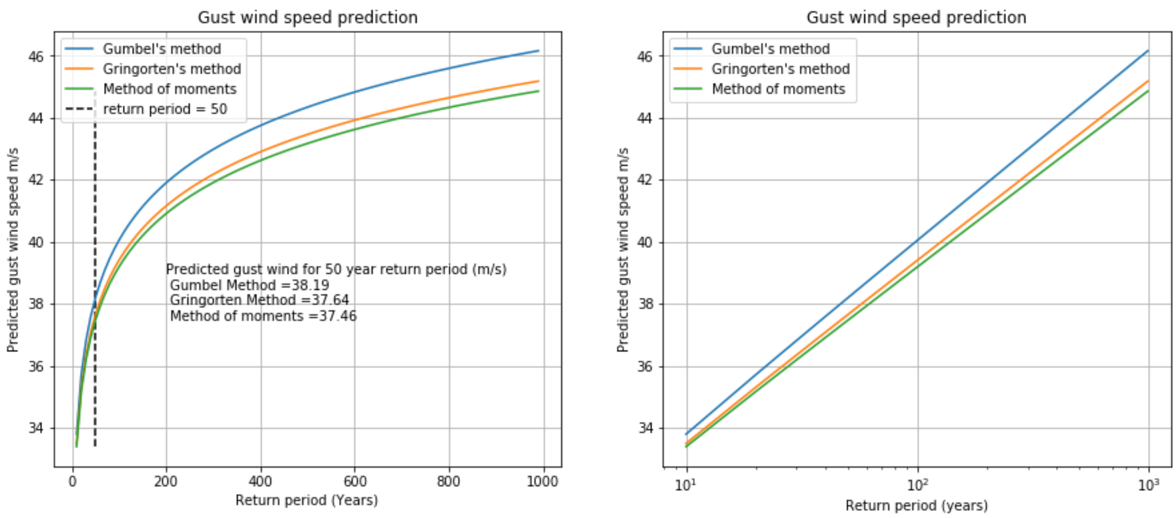
The gust wind speed prediction for the given return period is plotted here. All the three methods mentioned above are plotted in the same graph to compare.

In [15]:

```
plt.figure(num=6, figsize=(15, 6))
plt.subplot(1,2,1)
plt.plot(return_period, gumbel_predicted_gustwind, label ='Gumbel\'s method')
plt.plot(return_period, gringorten_predicted_gustwind, label ='Gringorten\'s method')
plt.plot(return_period, moments_predicted_gustwind, label ='Method of moments')
plt.vlines(50, min(moments_predicted_gustwind), max(moments_predicted_gustwind),
           colors='k', linestyles='--', label = 'return period = 50')
plt.text(200,moments_predicted_gustwind_50,'Predicted gust wind for 50 year return period (
        ' Gumbel Method =' + str(round(gumbel_predicted_gustwind_50,2)) +
        '\n Gringorten Method =' + str(round(gringorten_predicted_gustwind_50,2)) +
        '\n Method of moments =' + str(round(moments_predicted_gustwind_50,2)) )
plt.ylabel('Predicted gust wind speed m/s')
plt.xlabel('Return period (Years)')
plt.title('Gust wind speed prediction')
plt.legend()
plt.grid(True)

plt.subplot(1,2,2)
plt.plot(return_period, gumbel_predicted_gustwind, label ='Gumbel\'s method')
plt.plot(return_period, gringorten_predicted_gustwind, label ='Gringorten\'s method')
plt.plot(return_period, moments_predicted_gustwind, label ='Method of moments')
plt.xscale('log')
plt.ylabel('Predicted gust wind speed m/s')
plt.xlabel('Return period (years)')
plt.title('Gust wind speed prediction')
plt.legend()
plt.grid(True)

plt.show()
```



Exercise: Wind speed computation for Jeddah Airport

For the given data (jeddah_airport.dat) of Jeddah Airport compute the predicted guest wind speed.

What is the predicted gust wind speed for Jeddah Airport location for a return period of 50 years by Gumbel's method ?

Replace the content of block 2 with the contents in block 16 to read in the new file content. (use 'Ctrl' + '/' to uncomment multiple lines)

In [16]:

```
# winddata = np.loadtxt('jeddah_airport.dat')
# year = winddata[:,0]
# maxgust = winddata[:,2]
```

Check Point: Discussion

Discuss amoung groups the observations regading the various methods for wind speed computation.