# Excel template for the calculation of trend statistics of annual time series

Anu Määttä, Timo Salmi, Pia Anttila, Tuija Ruoho-Airola
Finnish Meteorological Institute
Sahaajankatu 20 E
FIN-00810 Helsinki
Finland

## Table of Contents



## 1. Introduction

An Excel template is developed for the calculatíon of the annual trend statistics. This template is created for the research project "Air quality Assessment in the Baltic countries as a consequence of local pollution and long range transport - a co-operation between Nordic and Baltic counties within the framework of EMEP's 20-years Assessment" financed by the Nordiska Ministerrådet. The template can be exploited to calculation of trend statistics of any annual time serie. The procedure is based on the nonparametric Mann-Kendall test for trend and the nonparametric Sen's method for the magnitude of the trend (Gilbert 1987). This procedure (Mann-Kendall test) is used since missing values are allowed and the data need not conform any particular distribution. Sen's method is not greatly affected by gross data errors or outliers, and also it can be computed when data are missing. Sen's estimator is closely related to the Mann-Kendall test.

The calculation method, user's manual and the macro text are given here.

## 2. Calculation of Mann-Kendall test and magnitude of the trend with the Sen's method

The procedure of the calculation of the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend of annual time serie is described here step by step. The details of the theory are described in Gilbert 1987.

- Step 1.

The number of annual values in the studied data serie is denoted by $n$. Missing values are allowed so $n$ can be smaller than the number of years in the studied time serie.

The differences of annual values $x$ are determined to compute the Mann-Kendall statistics.

The Mann-Kendall statistic is computed using formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k)$$

where $\text{sgn}(x_j - x_k)$ is an indicator function that takes on the values 1, 0 or -1 according to sign of difference $x_j - x_k$, where $j > k$:

$$\text{sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}.$$

Values $x_j$ and $x_k$ are the annual values in the year $j$ and $k$ respectively. During this computing also the slope estimates $Q_i$ are calculated because these same differences are needed. The number $N$ of the slope estimates $Q_i$, $N = n(n-1)/2$, are computed by the formula

$$Q_i = \frac{x_j - x_k}{j - k}$$

where $j > k$.

- Step 2.

Next the variance of $S$ is computed by following equation which takes into account that ties (equal-valued) may be present:

$$VAR(S) = \frac{1}{18}\left[ n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right].$$

where $q$ is the number of tied groups and $t_p$ is the number of data in the $p$ th group. But before computing $VAR(S)$ the data is checked to find all the tied groups and number of data in each tied group.

- Step 3.

$S$ and $VAR(S)$ are used to compute the test statistic $Z$ as follows

$$Z = \begin{cases} \dfrac{(S-1)}{[VAR(S)]^{1/2}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{(S+1)}{[VAR(S)]^{1/2}} & if\ S < 0 \end{cases}$$

The presence of trend is evaluated using $Z$ value. A positive (negative) value of $Z$ indicates an upward (downward) trend. The statistics Z has a normal distribution. The null hypothesis, $H_0$, is true if there is no trend and thus we use the standard normal table to decide whether to reject $H_0$. To test for either upward or downward trend (a two-tailed test) at $\alpha$ level of significance, $H_0$ is rejected if the absolute value of $Z$ is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from the standard normal tables.

In this procedure the existence and significance of trend is tested by using four different $\alpha$ levels of significance. The different $\alpha$ levels used are $\alpha = 0.1$, $\alpha = 0.05$, $\alpha = 0.01$ and $\alpha = 0.001$.

In the worksheet **Trend statistics** it is given as a result the significance level of that trend marked by

| | |
|---|---|
| + | if there is a trend at the $\alpha = 0.1$ level, |
| * | if there is a trend at the $\alpha = 0.05$ level, |
| ** | if there is a trend at the $\alpha = 0.01$ level and |
| *** | if there is a trend at $\alpha = 0.001$ level respectively. |

This means that when the mark is "***" the trend is very significant and when the mark is "+" the signifigance of the trend is fairly poor, only 10%. If the mark is missing then there is not trend at significance level $\alpha < 0.1$.

- Step 4.

To estimate the true slope of existing trend (change per year) Sen's nonparametric procedure is used. The $N = n(n-1)/2$ slope estimates $Q_i$ have already been computed earlier in the step 1.

The Sen's estimator of slope is the median of these $N$ values of $Q_i$. The median of the $N$ slope estimates is obtained in the usual way. That is $N$ values of $Q_i$ are ranked from smallest to largest and we compute

Sen'n estimator = $Q_{[(N+1)/2]}$ if $N$ is odd and

$\dfrac{1}{2}\left(Q_{[N/2]} + Q_{[(N+2)/2]}\right)$ if $N$ is even

- Step 5.

The $100(1-\alpha)$ % two-sided confidence interval about the true slope is obtained by the nonparametric technique. The used procedure is based on the normal distribution, that is valid for $n$ as small as 10 unless there are many ties.

This procedure computes the confidence interval at two different confidence coefficient; $\alpha = 0.01$ and $\alpha = 0.05$, resulting two different confidence intervals. The $Z_{1-\alpha/2}$ value is obtained from the standard normal tables.

At first it is computed $C_\alpha = Z_{1-\alpha/2}[VAR(S)]^{1/2}$, where $VAR(S)$ has been calculated earlier (step 2).

Next $M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$ are computed. The lower and upper limits of the confidence interval are the $M_1$ th largest and the $(M_2 + 1)$ th largest of the $N$ ordered slope estimates $Q_i$.

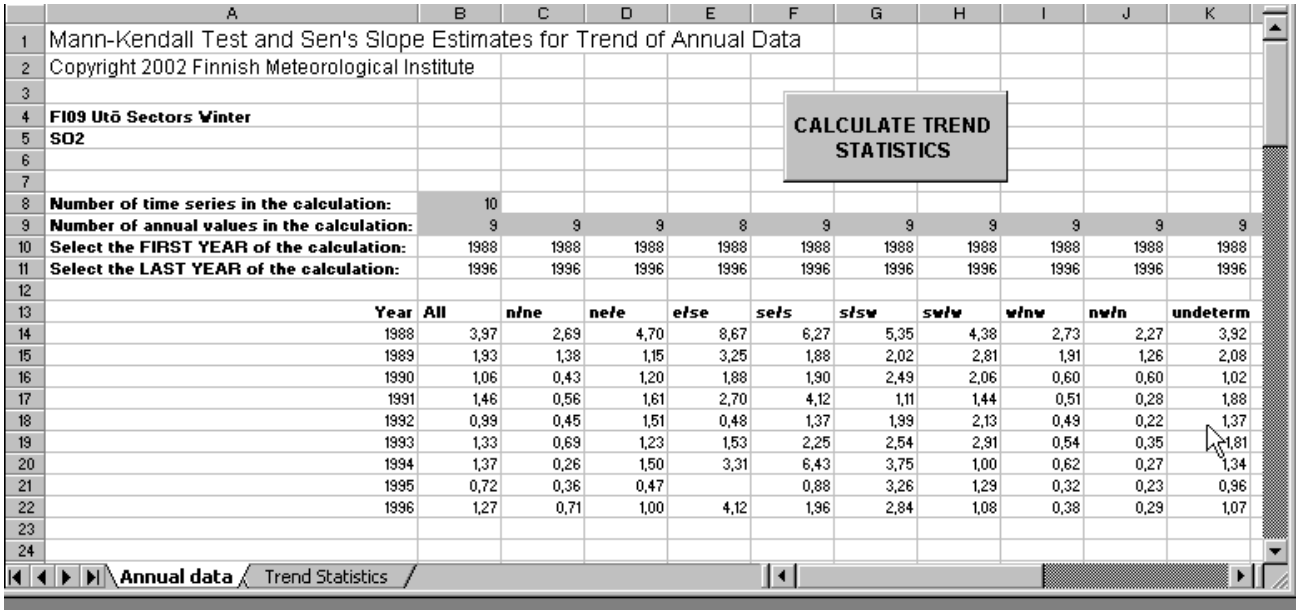
## 3. Users manual for this trend statistics template

This template has been made by Microsoft Excel 97 and trend-macro has been coded by using Microsoft Visual Basic. Above described steps are also marked in the code as comments.
The template consists of two worksheets: **Annual data** and **Trend statistics**. Put (e.g. copy and paste special/values) your annual time series to the worksheet **Annual data**. Then activate the trend macro by pushing the **Calculate button** in the worksheet. The worksheet **Trend statistics** will contain the results of calculation..

### 3.1 Inputting the time series data

The only place where you can type input values is in the worksheet **Annual data**. You have to type/paste time series data to the fixed places of worksheet.

You can input from 1 to 25 annual time series at once. Each time serie is located into one column. If you have missing annual values you leave the cell empty. Only one value per year is expected.



| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mann-Kendall Test and Sen's Slope Estimates for Trend of Annual Data | | | | | | | | | | |
| 2 | Copyright 2002 Finnish Meteorological Institute | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | **FI09 Utö Sectors Winter** | | | | | | | | | | |
| 5 | **SO2** | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | **Number of time series in the calculation:** | 10 | | | | | | | | | |
| 9 | **Number of annual values in the calculation:** | 9 | 9 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 9 |
| 10 | **Select the FIRST YEAR of the calculation:** | 1988 | 1988 | 1988 | 1988 | 1988 | 1988 | 1988 | 1988 | 1988 | 1988 |
| 11 | **Select the LAST YEAR of the calculation:** | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 |
| 12 | | | | | | | | | | | |
| 13 | **Year** | **All** | **nne** | **ene** | **ese** | **ses** | **ssw** | **sww** | **wnw** | **nwn** | **undeterm** |
| 14 | 1988 | 3,97 | 2,69 | 4,70 | 8,67 | 6,27 | 5,35 | 4,38 | 2,73 | 2,27 | 3,92 |
| 15 | 1989 | 1,93 | 1,38 | 1,15 | 3,25 | 1,88 | 2,02 | 2,81 | 1,91 | 1,26 | 2,08 |
| 16 | 1990 | 1,06 | 0,43 | 1,20 | 1,88 | 1,90 | 2,49 | 2,06 | 0,60 | 0,60 | 1,02 |
| 17 | 1991 | 1,46 | 0,56 | 1,61 | 2,70 | 4,12 | 1,11 | 1,44 | 0,51 | 0,28 | 1,88 |
| 18 | 1992 | 0,99 | 0,45 | 1,51 | 0,48 | 1,37 | 1,99 | 2,13 | 0,49 | 0,22 | 1,37 |
| 19 | 1993 | 1,33 | 0,69 | 1,23 | 1,53 | 2,25 | 2,54 | 2,91 | 0,54 | 0,35 | 1,81 |
| 20 | 1994 | 1,37 | 0,26 | 1,50 | 3,31 | 6,43 | 3,75 | 1,00 | 0,62 | 0,27 | 1,34 |
| 21 | 1995 | 0,72 | 0,36 | 0,47 | | 0,88 | 3,26 | 1,29 | 0,32 | 0,23 | 0,96 |
| 22 | 1996 | 1,27 | 0,71 | 1,00 | 4,12 | 1,96 | 2,84 | 1,08 | 0,38 | 0,29 | 1,07 |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |

CALCULATE TREND STATISTICS

Annual data | Trend Statistics

Input data expected from you:

- Row **13** starting from column **B** at most to **Z** (max 25 time series): Titles of the time series.

- Column **A** starting from row **14:** the continuous serie of years to be included in the statistics calculation. The number of years is not limited.

- Rows **10** and **11** starting from column **B**: First year and last year of data to be handled in trend calculation. Every time serie have to get own starting and ending years. With these rows you can easily determine various time spans for trend statistics calculation of each time serie.

- Starting from row **14** and columns from **B** at most to **Z**: Time series data values according to the years given in the first column **A**. One time serie at one column. Columns must be filled from left starting from the column **B**. The maximum number of data series you can give is 25. If the annual value is missing, leave the cell empty.

Please don't add or remove rows in the beginning of this worksheet or add columns.
You can add your own text to the empty cells below the title of the worksheet (rows **3-6**).

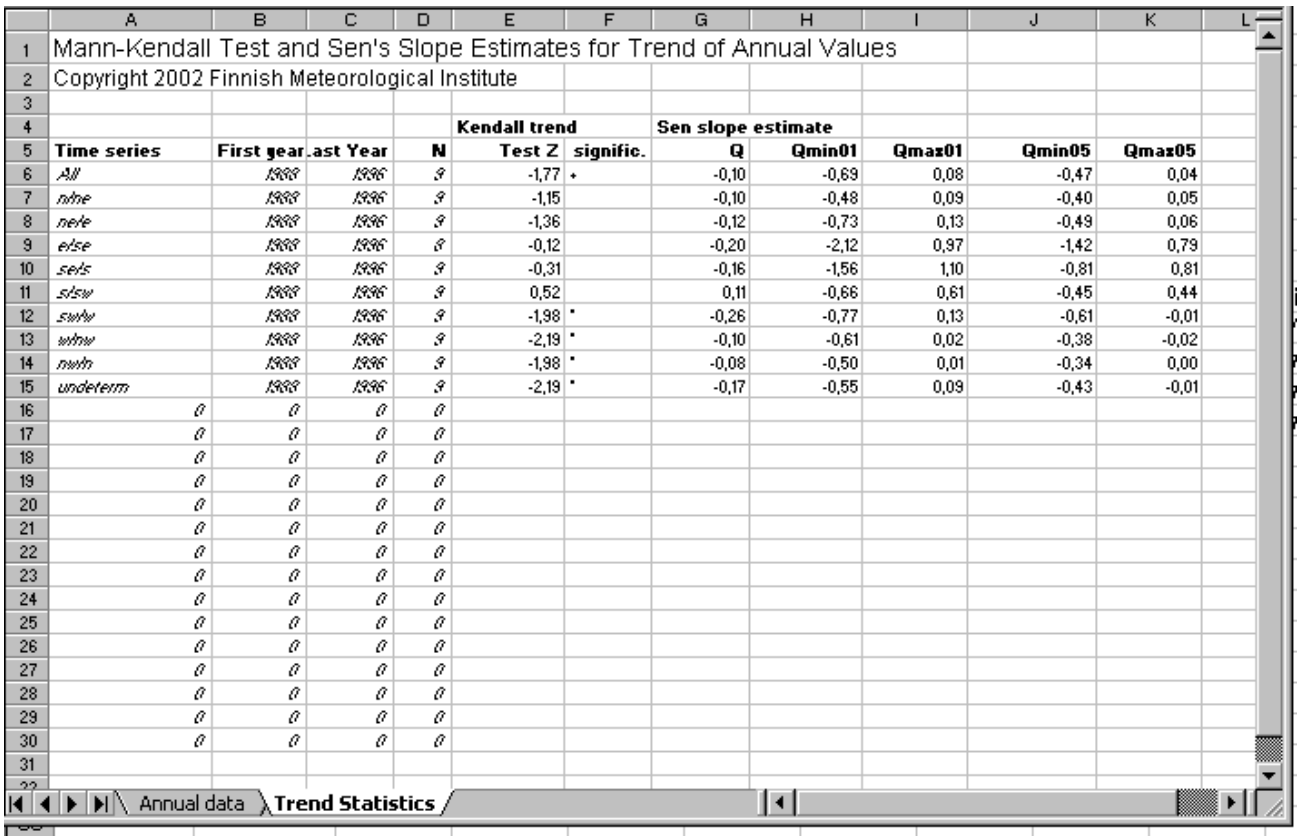
There is no input data checkings in the trend-macro at all. If you get strange results or even errors, please check the input data you have given. It is important that you fill the right cells. Those cells that you mustn't change are protected.

Any kind of homogeneity test between time series are not done.

You start calculation of the trend statistics by pushing the **Calculate -button** in the worksheet. The Status bar near the bottom of the screen shows when the calculation process is ready. And then the results of calculation appear to the **Trend statistics** worksheet.

### 3.2 Trend statistics results

The results of trend statistic calculation are given in the worksheet **Trend statistics**. Results are given for each time series in rows starting from row **6**.



| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mann-Kendall Test and Sen's Slope Estimates for Trend of Annual Values | | | | | | | | | | | |
| 2 | Copyright 2002 Finnish Meteorological Institute | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | Kendall trend | | Sen slope estimate | | | | | |
| 5 | Time series | First year | Last Year | N | Test Z | signific. | Q | Qmin01 | Qmax01 | Qmin05 | Qmax05 | |
| 6 | All | 1908 | 1996 | 89 | -1,77 | + | -0,10 | -0,69 | 0,08 | -0,47 | 0,04 | |
| 7 | nne | 1908 | 1996 | 89 | -1,15 | | -0,10 | -0,48 | 0,09 | -0,40 | 0,05 | |
| 8 | ene | 1908 | 1996 | 89 | -1,36 | | -0,12 | -0,73 | 0,13 | -0,49 | 0,06 | |
| 9 | ese | 1908 | 1996 | 89 | -0,12 | | -0,20 | -2,12 | 0,97 | -1,42 | 0,79 | |
| 10 | sse | 1908 | 1996 | 89 | -0,31 | | -0,16 | -1,56 | 1,10 | -0,81 | 0,81 | |
| 11 | ssw | 1908 | 1996 | 89 | 0,52 | | 0,11 | -0,66 | 0,61 | -0,45 | 0,44 | |
| 12 | wsw | 1908 | 1996 | 89 | -1,98 | * | -0,26 | -0,77 | 0,13 | -0,61 | -0,01 | |
| 13 | wnw | 1908 | 1996 | 89 | -2,19 | * | -0,10 | -0,61 | 0,02 | -0,38 | -0,02 | |
| 14 | nwn | 1908 | 1996 | 89 | -1,98 | * | -0,08 | -0,50 | 0,01 | -0,34 | 0,00 | |
| 15 | undeterm | 1908 | 1996 | 89 | -2,19 | * | -0,17 | -0,55 | 0,09 | -0,43 | -0,01 | |
| 16 | 0 | 0 | 0 | 0 | | | | | | | | |
| 17 | 0 | 0 | 0 | 0 | | | | | | | | |
| 18 | 0 | 0 | 0 | 0 | | | | | | | | |
| 19 | 0 | 0 | 0 | 0 | | | | | | | | |
| 20 | 0 | 0 | 0 | 0 | | | | | | | | |
| 21 | 0 | 0 | 0 | 0 | | | | | | | | |
| 22 | 0 | 0 | 0 | 0 | | | | | | | | |
| 23 | 0 | 0 | 0 | 0 | | | | | | | | |
| 24 | 0 | 0 | 0 | 0 | | | | | | | | |
| 25 | 0 | 0 | 0 | 0 | | | | | | | | |
| 26 | 0 | 0 | 0 | 0 | | | | | | | | |
| 27 | 0 | 0 | 0 | 0 | | | | | | | | |
| 28 | 0 | 0 | 0 | 0 | | | | | | | | |
| 29 | 0 | 0 | 0 | 0 | | | | | | | | |
| 30 | 0 | 0 | 0 | 0 | | | | | | | | |
| 31 | | | | | | | | | | | | |

Annual data | Trend Statistics

The four first columns **A-D** are filled automatically by the macro and these values are derived from the worksheet Annual data. The trend calculation procedure is filling in the rest of columns **D-J** when you push the **Calculate-button**.

The columns in this worksheet have the following meanings:

- **Time series** (column **A**): the titles of the time series are derived from worksheet **Annual data** (from the row **9**)
- **First year** (column **B**): starting year of each time serie (from the worksheet **Annual data**)
- **Last year** (column **C**): ending year of each time serie (from the worksheet **Annual data**)
- **N** the number of annual values in the calculation
- **Test Z** (column **D**): test statistics of the existence and significance of the trend. A positive (negative) value of $Z$ indicates an upward (downward) trend. The absolute value of $Z$ is compared to the standard normal table to decide if there is a trend or not at the $\alpha$ level of significance.

- **Kendall trend signific.**(column **E**): the trend significance. There is value
  - *** if trend at $\alpha = 0.001$ level of significance
  - ** if trend at $\alpha = 0.01$ level of significance
  - * if trend at $\alpha = 0.05$ level of significance
  - + if trend at $\alpha = 0.1$ level of significance
- **Sen's slope estimate Q** (column **F**): Sen's estimator for the true slope of the trend i.e. change per unit time (in this case a year)
- **Qmin01** (column **G**): the lower limit of the confidence interval when the confidence coefficient $\alpha = 0.01$
- **Qmax01** (column **H**): the upper limit of the confidence interval when the confidence coefficient $\alpha = 0.01$
- **Qmin05** (column **I**): the lower limit of the confidence interval when the confidence coefficient $\alpha = 0.05$
- **Qmax05** (column **J**): the upper limit of the confidence interval when the confidence coefficient $\alpha = 0.05$

## 4. Litterature

Gilbert, R.O., 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold , New York.

## Appendix 1. The trend statistics calculation macro of the template

```
Private Sub CB_Calculate_Click()
’   Copyright 2002 Finnish Meteorological Institute
'   Anu Määttä & Timo Salmi
'   Version 1.0

    Dim firstDataYear, nofCol, Col_i, startPlace As Integer

    'the result cells are better to be empty in the worksheet "Trend Statistics"
before calculation starts
    Worksheets("Trend Statistics").Range("E6:K30") = ""

    firstDataYear = Worksheets("Annual data").Range("FirstDataYear").value  'First
year of all data
    nofCol = Worksheets("Annual data").Range("TsCount").value   'Number of columns
i.e. time series
    'Next calculate the trend statistics for each time series one at a time
    For Col_i = 1 To nofCol
        'First year of data of this time serie
        firstYear = Worksheets("Annual data").Cells(10, Col_i + 1)
        'Find the row where the calculation is about to begin
        startPlace = 14 + firstYear - firstDataYear
        Call CalculateTrendStatistics(Col_i + 1, startPlace)   'call the subroutine
    Next Col_i
End Sub

Sub CalculateTrendStatistics(colno, rowno)
'This subroutine is called for each of the data series of Excel worksheet "Annual
Data".
'First the existence of trend is tested using Mann-Kendall test tool.
'After that the Sen's slope estimator is evaluated.
'The results are displayed in the other worksheet of this Excel template named
"Trend Statistics".
'The two subroutine input parameters are:
'colno - tells the column number which data is under consideration (data series
order number+1) and
'rowno - tells the row number where the handling of this time series begins

    Dim nofYears As Integer       'number of years under consideration
    Dim n As Long      'true number of annual data i.e. missing values are not
considered
    Dim S As Integer        'Mann-kendall statistic
    Dim varS As Double    'the variance of S
    Dim Z As Double       'test statistic
    Dim nofQ As Integer    'number of slope estimates
    Dim i As Integer

    'Calculate the number of years from given starting and ending year
    nofYears = Worksheets("Annual data").Cells(11, colno) - Worksheets("Annual
data").Cells(10, colno) + 1
```

```
    'The real number of annual values n have to be determined for computing trend
statistics.
    'If the cell is empty it is understand as a missing value.
    n = 0
    For i = 0 To nofYears - 1
        If Not IsEmpty(Worksheets("Annual data").Cells(rowno + i, colno)) Then
            n = n + 1
        End If
    Next i

    '1. First Compute the Mann-Kendall statistic S.
    'In the same time as S is computed, also the slope estimates are computed
because
    'both the calculation methods are based in the same differences of annual
values.
    'The slope estimates are stored into the table named Qtable for the later use.
    Dim sign As Double        'sign variable, is used in calculation of S
    Dim Qtable() As Double    'table for the slope estimates
    nofQ = n * (n - 1) / 2    'number of slope estimates.
    ReDim Qtable(nofQ - 1) As Double

    S = 0
    i = 0   'used as index to table Qtable
    For k = 0 To nofYears - 2      'goes through all the years under consideration,
except the last year
        If Not IsEmpty(Worksheets("Annual data").Cells(k + rowno, colno)) Then
            'the cell is not empty i.e. the value is not missing
            kk = k + 1
            For j = kk To nofYears - 1
                If Not IsEmpty(Worksheets("Annual data").Cells(j + rowno, colno))
Then
                    'the cell is not empty i.e. the value is not missing
                    sign = Worksheets("Annual data").Cells(j + rowno, colno) -
Worksheets("Annual data").Cells(k + rowno, colno)
                    If sign > 0 Then
                        S = S + 1
                    ElseIf sign < 0 Then
                        S = S - 1
                    End If
                    'compute now also the slope estimate and store it into the
table Qtable
                    Qtable(i) = sign / (j - k)
                    i = i + 1
                End If
            Next j
        End If
    Next k

    '2. Next compute the variance VAR(S) of S.

    'Before that it is checked if ties are present i.e. equal-valued annual data.
    'These ties are taking into account when calculating VAR(S)
    Dim tiedSum As Integer   'correction factor due to ties in VAR(S) formula
    tiedSum = 0
    Call ConsiderTies(nofYears, rowno, colno, tiedSum)   'call subroutine

    'Now the VAR(S) is actually calculated
```

```
    varS = (n * (n - 1) * (2 * n + 5) - tiedSum) / 18

    '3. Now compute the test statistic Z using S and its variance VAR(S)
    If S > 0 Then
        Z = (S - 1) / Sqr(varS)
    ElseIf S < 0 Then
        Z = (S + 1) / Sqr(varS)
    Else
        Z = 0
    End If

    'output Z value
    Worksheets("Trend Statistics").Cells(4 + colno, 5) = Z

    'The absolute value of Z is compared to critical value Z[1-alpha/2] which is
    'obtained from standard normal table. The presence and significance of the
trend
    'is evaluated by testing four different alpha levels of significance.
    'alpha=0.1
    If Abs(Z) > 1.645 Then
        Worksheets("Trend Statistics").Cells(4 + colno, 6) = "+"
    End If
    'alpha=0.05
    If Abs(Z) > 1.96 Then
        Worksheets("Trend Statistics").Cells(4 + colno, 6) = "*"
    End If
    'alpha=0.01
    If Abs(Z) > 2.576 Then
        Worksheets("Trend Statistics").Cells(4 + colno, 6) = "**"
    End If
    'alpha=0.001
    If Abs(Z) > 3.292 Then
        Worksheets("Trend Statistics").Cells(4 + colno, 6) = "***"
    End If

    '4. Next we compute the Sen's estimator of slope (here change per year).
    'We already have computed nofQ values of slope estimates Q into the table
Qtable .
    'The median of these slope estimates is the Sen's estimator of slope.
    'To compute the median slope the slope estimates have to be ranked from
smallest to largest.
    'The ranked values are stored into the other table called QtableSort. During
sorting
    'the values of original Qtable are distorted by a value smaller than the
minimum of Q estimates.

    Dim QtableSort() As Double     'table of sorted slope estimates
    ReDim QtableSort(nofQ - 1) As Double
    Dim ind As Integer
    Dim minV, maxV As Double
    Dim ignoreV As Double    'value that is ignored in the original Qtable when
sorting

    'The slope estimates are sorted using SELECTION SORT
    ind = 0
    minV = Qtable(0)  'initialize the smallest value
```

```
    maxV = Qtable(0)  'initialize the largest value that we need when comparing
values
    'Find first the smallest and largest value
    For i = 1 To nofQ - 1
        If Qtable(i) < minV Then
            minV = Qtable(i)
            ind = i
        End If
        If Qtable(i) > maxV Then
            maxV = Qtable(i)
        End If
    Next i
    QtableSort(0) = minV    'Store the smallest Q value
    ignoreV = minV - 10    'gets a value that is smaller than the smallest Q value
    Qtable(ind) = ignoreV  'when this value is found in Qtable, it is ignored in
sorting
    'now sort the values
    For j = 1 To nofQ - 1
        minV = maxV
        For i = 0 To nofQ - 1
            'find the minimum from the rest of the table
            If Qtable(i) <= minV And Qtable(i) > ignoreV Then
                minV = Qtable(i)
                ind = i
            End If
        Next i
        QtableSort(j) = minV
        Qtable(ind) = ignoreV   'from now on this element of Qtable is ignored
    Next j

    'Sen's estimator = median of the slope estimates
    If nofQ Mod 2 = 0 Then  'nofQ is even
        i = nofQ / 2
        Q = (QtableSort(i) + QtableSort(i - 1)) / 2
    Else                    'nofQ is odd
        i = (nofQ + 1) / 2
        i = i - 1    'because the first index is zero
        Q = QtableSort(i)
    End If

    'output Sen'n estimator of slope
    Worksheets("Trend Statistics").Cells(4 + colno, 7) = Q

    '5. Finally compute the 100(1-alpha)% two-sided confidence interval about the
true slope.
    'The confidence intervals are computed by using two different confidence
coefficients alpha;
    'alpha=0.01 and alpha=0.05.
    'The used procedure is based on the normal distribution. The values of Z[1-
alpha/2] are obtained
    'from the standard normal table.
    Dim Calpha As Double
    Dim M1 As Double        'lower limit is the M1:th largest ordered slope
estimate
    Dim M2 As Double        'upper limit is the M2+1:th largest ordered slope
estimate
    Dim M1int As Integer      'integer part of M1 (>0)
```

```
    Dim M2int As Integer      'integer part of M2 (>0)
    Dim lowerLimit As Double
    Dim upperLimit As Double

    'In the first case alpha=0.01. Then the corresponding Z[1-alpha/2] value used
here is Z[0.995]=2.576
    Calpha = 2.576 * Sqr(varS)
    Call CalculateConfidenceInterval(Calpha, nofQ, QtableSort, lowerLimit,
upperLimit)   'call subroutine

    'output the lower and upper limits of the confidence interval when the
confidence coefficient is 0.01
    Worksheets("Trend Statistics").Cells(4 + colno, 8) = lowerLimit
    Worksheets("Trend Statistics").Cells(4 + colno, 9) = upperLimit

    'In the second case alpha=0.05. Then the corresponding value is Z[1-
alpha/2]=1.96
    Calpha = 1.96 * Sqr(varS)
    Call CalculateConfidenceInterval(Calpha, nofQ, QtableSort, lowerLimit,
upperLimit)   'call subroutine

    'output the lower and upper limits of the confidence interval when the
confidence coefficient is 0.05
    Worksheets("Trend Statistics").Cells(4 + colno, 10) = lowerLimit
    Worksheets("Trend Statistics").Cells(4 + colno, 11) = upperLimit

End Sub

Sub ConsiderTies(nofYears, rowno, colno, tiedSum)
'This subroutine checks if ties (equal-valued data) are present.
'It stores number of data of all the found tied groups into the temporary table.
'Then it calculates the correction factor (sum) due to ties, that is part of the
VAR(S) formula.
'Input parameters:
'nofYears - number of years under consideration
'rowno - tells the row number where the handling of this time series begins
'colno - tells the column number which data is under consideration
'Subroutine returns the tiedSum - the correction factor to add VAR(S) formula.

    Dim tiedTable() As Double     'number of data in each tied group is stored into
table
    Dim maxt As Integer                'maximum number of tied groups
    maxt = nofYears / 2
    ReDim tiedTable(maxt - 1) As Double
    Dim nofTiedGroups, nofEqualValues As Integer
    Dim exist_already As Boolean  'boolean variable that tells if the value is
already in tiedgroup
    Dim comparativeV As Double   'value that is compared to other values
    'initialize the table by zeroes
    For i = 0 To maxt - 1
        tiedTable(i) = 0
    Next i

    nofTiedGroups = 0
    For i = 0 To nofYears - 1      'i goes through all the years under
consideration
        exist_already = False   'initializing
```

```
        nofEqualValues = 1      'initializing
        If Not IsEmpty(Worksheets("Annual data").Cells(i + rowno, colno)) Then
            'if the cell is not empty compare it to other values
            comparativeV = Worksheets("Annual data").Cells(i + rowno, colno)
            If i <> 1 Then    'first compare to preceding values.
                For j = 0 To i - 1
                    If Worksheets("Annual data").Cells(j + rowno, colno) =
comparativeV Then
                        exist_already = True   'this value is already in tiedgroup
                    End If
                Next j
            End If
            If exist_already <> True Then   'this value is NOT already in tiedgroup
                For j = i + 1 To nofYears - 1  'compare now this value to
subsequent values
                    If Worksheets("Annual data").Cells(j + rowno, colno) =
comparativeV Then
                        nofEqualValues = nofEqualValues + 1
                    End If
                Next j
                If nofEqualValues > 1 Then
                    tiedTable(nofTiedGroups) = nofEqualValues
                    nofTiedGroups = nofTiedGroups + 1
                End If
            End If
        End If
    Next i

    'Now the correction factor (sum) is actually calculated
    Dim tp As Integer      'number of data in the p th tied group of table
tiedTable
    tiedSum = 0

    If nofTiedGroups > 0 Then
    'ties are present and they must be taken into account in equation
        For i = 0 To nofTiedGroups - 1
            tp = tiedTable(i)
            tiedSum = tiedSum + tp * (tp - 1) * (2 * tp + 5)
        Next i
    End If

End Sub

Sub CalculateConfidenceInterval(Calpha, nofQ, QtableSort, lowerLimit, upperLimit)
'This subroutine computes the confidence interval (upper limit and lower limit)
'about the true slope.
'Input parameters:  Calpha=Z[1-alpha/2],
'                   nofQ - number of slope estimates Q
'                   QtableSort - table containing sorted slope estimates Q
'Subroutine returns the lowerLimit and upperLimit.

    'compute M1 ja M2
    M1 = (nofQ - Calpha) / 2 'The lower limit is the M1:th largest ordered slope
estimate
    M2 = (nofQ + Calpha) / 2 'The upper limit is the M2+1:th largest ordered slope
estimate
```

```
    If M1 > 1 Then
    'to be sure that index does not point outside QtableSort
        M1 = M1 - 1     'because the indexing of QtableSort begins from zero
        M1int = Int(M1) 'find the integer part of M1
        'Interpolate the lower limit
        lowerLimit = QtableSort(M1int) + (M1 - M1int) * (QtableSort(M1int + 1) -
QtableSort(M1int))
    Else
        lowerLimit = QtableSort(0) 'usually in the case when no trend exist
    End If

    If M2 < nofQ - 1 Then
    'to be sure that index does not point outside QtableSort
        M2int = Int(M2)   'because the indexing of QtableSort begins from zero
        'Interpolate the upper limit
        upperLimit = QtableSort(M2int) + (M2 - M2int) * (QtableSort(M2int + 1) -
QtableSort(M2int))
    Else
        upperLimit = QtableSort(nofQ - 1)
    End If

End Sub
```