AlaVar 4.5
Allan STD DEV
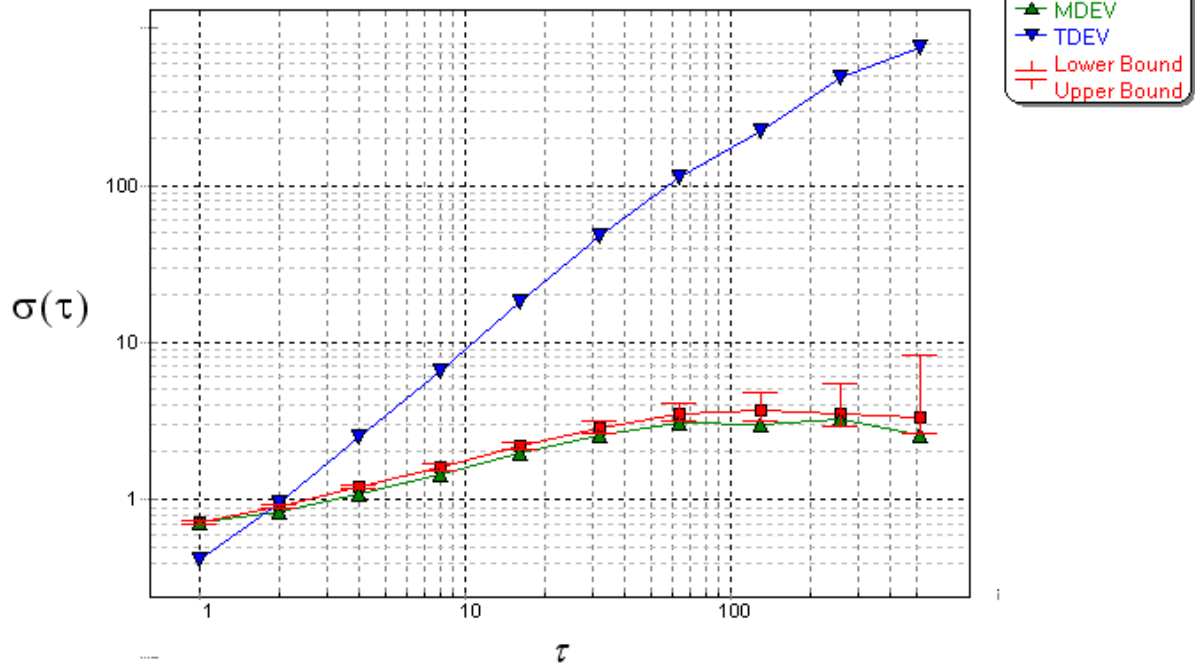

Legend:
- ADEV
- MDEV
- TDEV
- Lower Bound
- Upper Bound

$\sigma(\tau)$

Produced by AlaVar 4.5

```
** The computation of the 3 ALLAN STD DEVs lasted 0.01 seconds
The error bars were computed for a : Random Walk FM
** The computation of the Error bars lasted 0.000000 seconds
    Tau      ADEV          ADEV_Min        ADEV_Max       MDEV      TDEV      EDF
     1     0.72071772     0.7095802      0.73239637    0.72071772        0.416
     2     0.91001726     0.89030615     0.93109748    0.83148003        0.968
     4     1.2191996      1.1823033      1.2597783      1.095825         2.53
     8     1.6127554      1.5448428      1.6904843      1.4420774         6.66
```

** The computation of the 3 ALLAN STD DEVs lasted 0.01 seconds

ALAVAR 4.5

Alaa Makdissi 2003

AlaVar User Guide

Allan Variance Software

by Ala'a MAKDISSI

Table of Contents

1   Introduction

The program computes the three **Allan** Standard Deviations of a Time series :

σ**(t)** = ADEV(tau) = Overlapping Allan STD DEV.

Mod σ**(t)** = MDEV(tau) = Modified Allan STD DEV.

T σ**(tau)** = TDEV(tau) = Allan Time STD DEV.

These variances are computed for Discrete Time series, with a **fixed** sampling period *tau0*.

The error bars are computed for the values of Sigma(tau) for Five noise Types.

Features

INPUT DATA :

- Read numerical data from ascii files with optional text header.
- Data size is unlimited.
- Drag and Drop is supported.

PREPROCESS :

- Preprocess data before computing the variances includes removing outilers, and linear transformation
- Power Spectrum Density plot.
- Automatic estimation of the noise type.

PROCESS :

- Compute and plot the three Allan variances.
- Compute and plot the error bars for the Overlapping Allan Std Dev.

OUTPUTS :

- Produce quality report plots. reports may be saved and exported in PDF, HTML, RTF, GIF, JPEG, BMP, EMF, WMF.
- Customize plot : style, color, print preview, resolution control, legend, zoom, scroll.
- Copy, save and mail plots as images with many options : JPEG, PNG, GIF,PCX, Bitmap, Meta File.
- Export plotted data into TEXT, HTML, EXCEL and XML files.

For more information about the definition of These Variances you may refer to :

- [1] **J.Rutman**: *Characterization of phase and frequency instabilities in precision frequency sources : fifteen years of progress* . Proceedings of the IEEE, vol.66, n° 9, Sept. 1978.
- [2] **D. W. Allan**: *Time and frequency (time domain) characterization, estimation and prediction of precision clocks and oscillators.* IEEE trans. UFFC, vol UFFC - 34, n° 6, Nov. 1987.
- [3] **E.S. Ferre-Pikal et al.** , *"Draft revision of IEEE STD 1139-1988 standard definitions of physical quantities for fundamental frequency and time metrology -Random instabilities*". IEEE International Frequency Control Symposium, pp. 338-357, 1997.

The program was tested with the test suite data in reference [3].

Suggestions, comments and questions are welcome.
You can contact the author **Alaa Makdissi** by E-mail : alavar@club-internet.fr

For new updates, you can visit the AlaVAR Web page at http://perso.club-internet.fr/yazdiet/

2 What's new ?

Version 4.5 (August 2003)

- A bug when the data size is very big was found thanks to your feedback. The bug was in the Fortran DLL.
- No more DLL. A new algorithm for the computation of the three variances is used. If you can write a faster code please let me know.
- The probability p for the computation of the CHI-SQUARED distribution can be modified now. The default value is 68% winch yields a confidence interval of one sigma.
- The Help file is modified.

Version 4.0 (May 2002)

Some bugs were corrected.
French language support.
Report generation added :

- generate reports with all the computation details.
- save reports in many formats : Pdf, html, images (jpeg, wmf), rtf and Fast Report Format (frp)
- Reload a saved report (frp) and print it.

Version 2.3 (May 2001)

Some bugs were corrected, thanks for your feedback.
New features are :
- Customize plot : style, color, print preview, resolution control, legend, zoom, scroll, Add annotations.
- Copy, save and mail plots as images with many options : JPEG, PNG, GIF,PCX, Bitmap, MetaFile.
- Export plot data into TEXT, HTML, EXCEL and XML files.
- Power Spectrum Density plot.
- Automatic detection of the noise type.
- many test suite data are included

Version 2.0 (July 2000)

Every thing is rewritten.
1) Computation in version 1.0 was coded in C++ using a Matrix Class. Computation was done by the program itself. Now, in version 2.0, the computation of the STDs and the error bars is coded in Fortran !!!
Why ?
Computation is simply 30 times faster than that in version 1.0.
2) The computation is done by external Dynamic Link Library (DLL). You can use these DLL (FreeWare) with your program if you know how to do that. The interface to these DLL is explained in the help file.
3) The bug (error) in version 1.0 when computing the last error bar is corrected.
4) A new plot look (Zoom, Move, Shrink, ...).
5) A new Windows help file is included.

3 Theory

- Allan Variance Definition
- Confidence Intervals

3.1   Allan Variance Definition

Allan Variance Theory

The Allan Variance was introduced to solve the problem of characterizing the frequency stability of oscillators.

Given Time deviation (or phase) samples $\{x(i)\}_{i=0,N}$ of length $N+1$; each of them represent the average of the measured phase difference during a fixed period τ_0 ; we can form a frequency deviation series $\{y(i)\}_{i=1,N}$ of length N by :

$$y(k) = \frac{x(k) - x(k-1)}{\tau_0}$$

For an averaging time $\tau = m\tau_0$ we can compute the time series $\{Y(k)\}$ of length $N-m+1$ by :

$$Y(k) = \frac{1}{m} \sum_{j=k}^{k+m-1} y(j)$$

The series $\{Y(k)\}$ is produced from $\{y(i)\}_{i=1,N}$ by a moving average filter of width m.
Let now form the Time series $\{D(k)\}$ defined by :

$$D(k) = Y(k+m) - Y(k)$$

The $\{D(k)\}$ series could be seen as the output of a first order difference filter of width m driven by $\{Y(k)\}$.
The length of $\{D(k)\}$ is $N-2*m+1$.

<u>Implementation :</u>

The computation of D(k) can be done directly from y(k) in a recursive way :

$$D(k) = D(k-1) + [y(k+2m-1) - 2\,y(k+m-1) + y(k-1)] / m$$

The source code in C is :
```
for (k=1;k<n+1-2*m;k++)
D[k]=D[k-1]+(y[k-1]-2*y[k+m-1]+y[k+2*m-1])/m;
```

ALLAN VARIANCE

The Normal Allan Variance is 2 samples variance of the series $\{G(k)\}$ obtained as the output of a decimation filter of length *m* driven by $\{D(k)\}$:

$$G(k) = D\big((k-1)m + 1\big)$$

The length of the series $\{G(k)\}$ is (*N-2m+1*)/m which must be rounded up to (*N/m-1*) $= P$ 1 (Why ?☺).
The Allan Variance is defined by :

$$\sigma_y^2(\tau) = \frac{1}{2}\left\langle G(k)^2 \right\rangle$$

where < > is the Average operator.
The Allan variance could be estimated in terms of $\{Y(k)\}$ by :

$$\sigma_y^2(\tau) = \frac{1}{2(P-1)}\sum_{k=1}^{P-1}\left[Y(1+km) - Y(1+(k-1)m)\right]^2$$

OVERLAPPING ALLAN VARIANCE

The Overlapping Allan Variance **AVAR** uses all the samples of $\{D(k)\}$. It's the 2-sample variance of $\{D(k)\}$:

$$\sigma_y^2(\tau) = \frac{1}{2}\left\langle D(k)^2 \right\rangle$$

In terms of $\{Y(k)\}$ it could be estimated by :

$$\sigma_y^2(\tau) = \frac{1}{2(N-2m+1)}\sum_{i=1}^{N-m+1}\left[Y(i+m) - Y(i)\right]^2$$

The result is usually expressed as the square root of **AVAR**, the Allan deviation, **ADEV**.

The confidence interval of an overlapping Allan deviation estimate is better than that of a

normal Allan variance estimation.

Implementation :

The source code in C is :

```
s=0;
for (k=0;k<n+1-2*m;k++)
{
s=s+D[k]*D[k];
}
ADEV=sqrt(s/(n+1-2*m)/2);
```

MODIFIED ALLAN VARIANCE

Let $R_m(j)$ be a rectangular window of width *m* and starting at index *j*. Let us form the product signal :

$$T(j,k) = R_m(j).D(k)$$

Let $\{V(k)\}$ be the mean value T(j,k) over k for each j :

$$V(k) = \langle T(j,k) \rangle_j$$

The Modified Allan Variance, **MVAR,** is the 2-sample variance of $\{V(k)\}$:

$$\sigma_y^2(\tau) = \frac{1}{2} \langle V(k)^2 \rangle$$

The result is usually expressed as the square root, **MDEV**, the modified Allan deviation

Implementation :

The source code in C is :

```
v=0 ;
for(int j=0;j<n+2-(3*m);L++)
{
  s=0;
  for( k=0;k<m;k++)
  {
    s=s+D[j+k];
  }
  v=v+s*s;
}
v=v/(n+2-3*m);
```

```
MDEV=sqrt(v/2)/m;
```

TIME VARIANCE

The time variance, **TVAR,** is a measure of time stability based on the modified Allan variance. It is defined as:

$$TVAR = (\tau^2/3)\cdot MVAR.$$

The result is usually expressed as the square root, **TDEV**, the Time Allan deviation.

3.2 Confidence Intervals

The confidence interval of a variance estimate depends on :
- The variance type
- The variance nominal value
- The averaging factor τ
- The number of data points N
- The desired statistical confidence factor *p*.

The **AlaVar** program estimates the confidence intervals for the Overlapping Allan variance **AVAR** (only) using the Chi-squared statistics.
Chi-squared statistics is applied to calculate confidence intervals at any desired confidence factor. The desired confidence factor *p* ($0<p<1$) can be set in the process panel. A default value of 68% represents a 1 sigma error for a normally distributed sample.
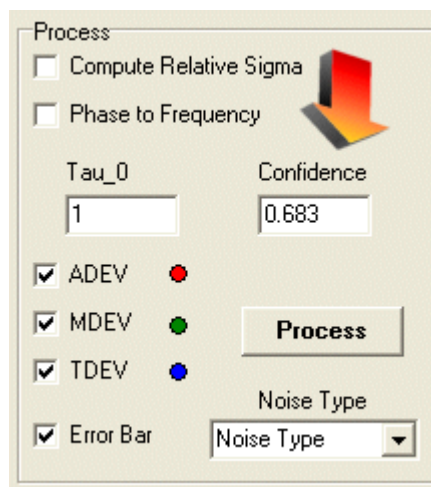
The noise type is estimated by computing the Power Spectrum Density (PSD) during the preprocess step.

Sample variances are distributed according to the expression:

$$\chi^2 = \frac{edf \cdot s^2}{\sigma^2},$$

where $\chi^2(p, edf)$ is the Chi-square probability, s^2 is the sample variance, σ^2 is the true variance, and edf is the number of degrees of freedom.

The edf is computed by the avar.dll and depends on the number of data points and the noise type. The lower bound of the sample variance is

$$\sigma^2_{min} = s^2 \cdot \frac{edf}{\chi^2(p, edf)}$$

and the upper bound is

$$\sigma^2_{max} = s^2 \cdot \frac{edf}{\chi^2(1-p, edf)},$$

4   Using AlaVAR

- Loading a File
- PreProcessing
- Processing
- Fitting

4.1   Loading a File

File Format

Input Data of The program must be in an ascii data File.

The following text is an example of input data File.

```
File produced by XXXXXXXXXXX
First column is the measurement time (s).
Second column is the frequency difference (Hz).
********** 12 Jun 1999 ******************
  6.0000000e+000   1.1649535e+000
  6.0000000e+000   6.2683908e-001
  6.0000000e+000   7.5080155e-002
  6.0000000e+000   3.5160690e-001
  6.0000000e+000  -6.9651254e-001
  6.0000000e+000   1.6961425e+000
  6.0000000e+000   5.9059778e-002
  6.0000000e+000   1.7970718e+000
  6.0000000e+000   2.6406853e-001
  6.0000000e+000   8.7167329e-001
  6.0000000e+000  -1.4461715e+000
  6.0000000e+000  -7.0116535e-001
  6.0000000e+000   1.2459821e+000
  6.0000000e+000  -6.3897700e-001
  6.0000000e+000   5.7735022e-001
  6.0000000e+000  -3.6002963e-001
  6.0000000e+000  -1.3557629e-001

  ......................................
```

Notice that the first 4 lines of the file does not contain useful data to be processed by AlaVAR.
These 4 Lines are called **THE HEADER** of the File.

AlaVAR reads the header of the file and displays it in the Report TEXT window.
After that it expects to find numerical Data in the form of one (or many) column(s).

Loading a File to AlaVAR

In order to load a File to AlaVAR you 2 choices :

A) Drag the file form your Explorer and drop it anywhere on AlaVAR.

B) Use the **File -> Load Data ...** menu and choose a File using the Open Dialogue.
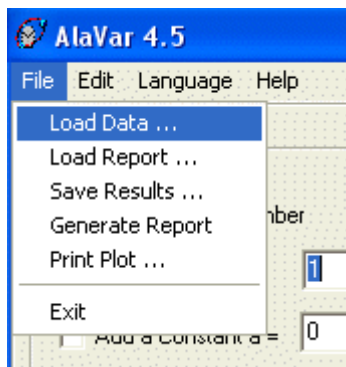
When your Data are read by AlaVAR it displays some information about it in the REPORT TEXT window.

```
---------------- File  Header----------------------
----------------------------------------------------
File [J:\AlaVar 4.5\Data\RW.dat]
contains 1 column(s) of length 2000
The mean value of col# 1 = 9.150867
```

Choose a column data and Press PreProcess
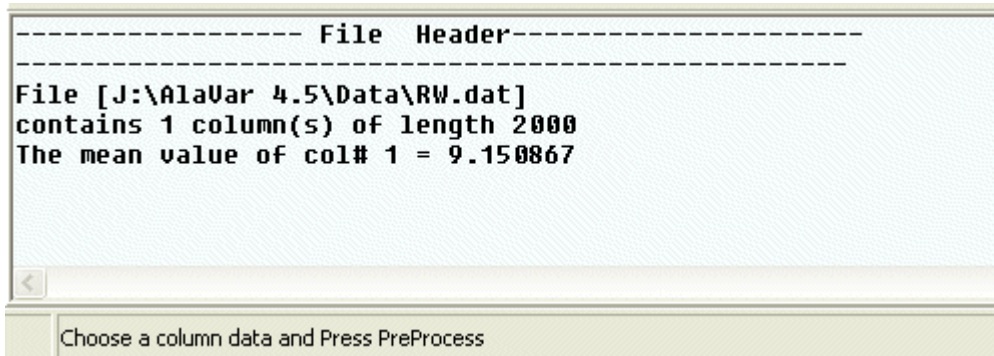
4.2   PreProcessing

Before you click the **PreProcess** button you must choose some options in the PreProcess Panel :

PreProcess

Choose a Colomun Number   1

☐ Multiply by c =   1

☐ Add a Constant a =   0

☐ Remove Outliers

☐ Frequency Domain

PreProcess
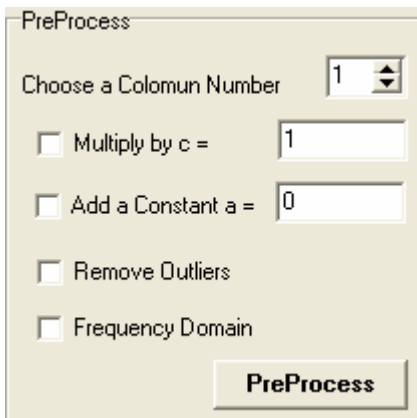
1) Choose a column number : You use the Edit or the Spin of the SpinEdit Control.
The maximum Value of the SpinEdit is set to the Total number of columns found in your INPUT DATA FILE.
If the Data of your File is a Matrix *D*, Then choosing a column *i* will extract a vector

x = Column number i of Matrix D.

2) Multiply by a constant *c* will do :

$$x = c*x$$

if checked

3) Add a Constant **a** will do :

$$x = x + a$$

if the corresponding CheckBox is checked.

4) Remove Outlier will do if checked :

        i) compute **m** = The mean Value of **x**
        ii) Compute **s** = The Classical Standard Deviation STD of **x**
        s = sqrt(Mean((**x-m**)^2))
        iii) Remove all the points **j** from **x** such that
        m + 3 s < x(j) < m - 3 s

5) The resulting **x** data will be ploted in the plot window.

AlaVar 4.5

Data Values

```
--------------------------------------------------------
File [J:\AlaVar 4.5\Data\RW.dat]
contains 1 column(s) of length 2000
The mean value of col# 1 = 9.150867
Power Spectrum Density of the data is fitting to a S(f) = f^(-1.9) low.
The spectrum is close to a :
Random Walk FM
```

You can Start The STD Computation by pressing Process !
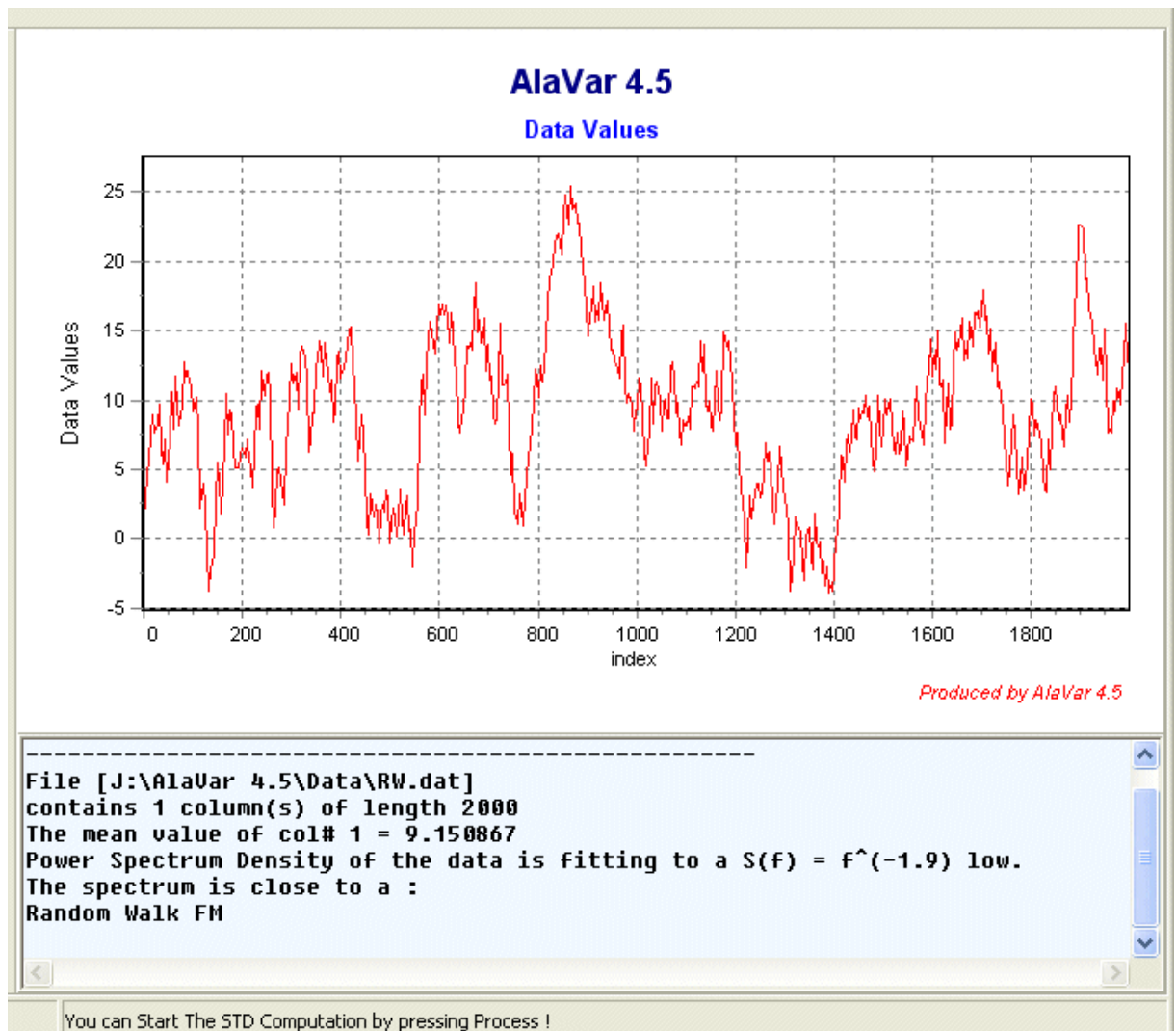
6) Clicking the Frequency Domain checkbox ☐ Frequency Domain will compute the Power Spectral Density(PSD) of the **x** and plot it.

The Noise type will estimated from the PSD in the form PSD(f) = f ^(alpha).

When Ready click the **Process** button.

Note : The above operations (1-4) will be done in the corresponding order. Steps 2 and 3 could be summarized by :

x = c*x +a

4.3 Process

Now you are Ready to launch the computation of the Three ALLAN STD.
Before, You can choose some options from the Process Panel :
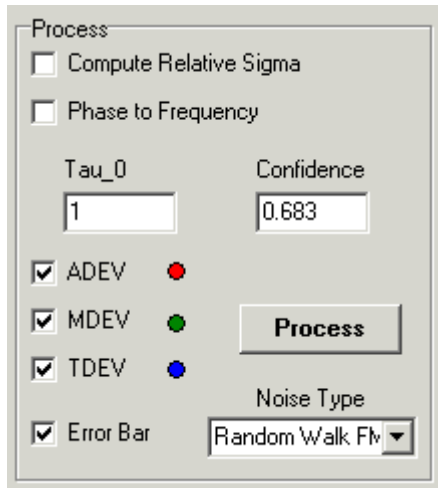
1) Compute Relative Sigma will compute the Three ALLAN STD on the vector :

$$xr = (x - Mean(x)) / Mean(x)$$

instead of the vecrtor **x**.
Note : If the mean value of x is close to zero you must not check this option.

2) Phase to Frequency if checked will let the program compute the STDs for the vector

$$y = diff (x) \text{ such that } y(i) = (x(i+1) - x(i))/tau0$$

3) Tau0 is the value of the sampling period in seconds

4) Confidence is the Chi-squared probability used in the computation of the error bars. The default value is 68%.

5) The CheckBoxs of ADEV, MDEV and TDEV indicate if they will be drawn in plot window or not. Whatever they are checked or not they will be computed.

5) The **Error Bar** CheckBox indicate is the Error Bars on *Sigma* will be computed and Displayed or not .

6) The ComboBox
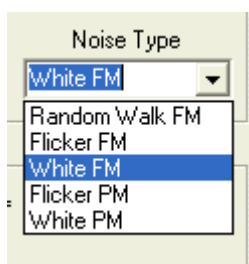
Will set the Noise Type. This is used during the computation of the Error Bars.

Note : During the preprocessing step the Noise type will be estimated and the ComboBox will be positioned to the estimated noise type.

When Ready click the Process button.
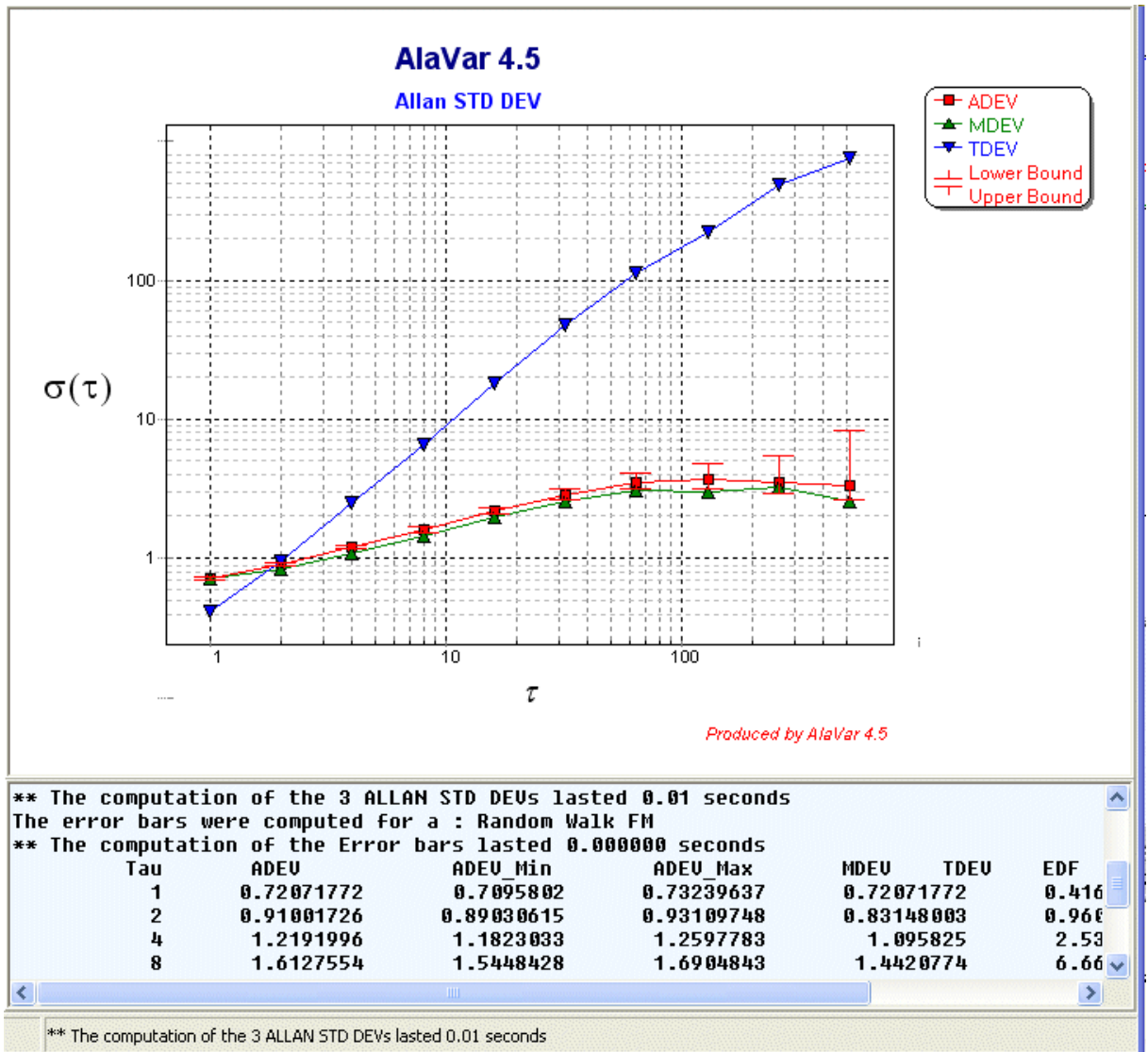
Depending on the length of your data, The computation may last from some milliseconds to some years!!.

4.4 Fitting

When the computation of the Three ALLAN STD is over you may want to fit the curve Sigma (Overlapped) with a linear equation :

$$Log(Sigma) = a + b * Log(tau)$$

The Fit Panel will help you to do this :
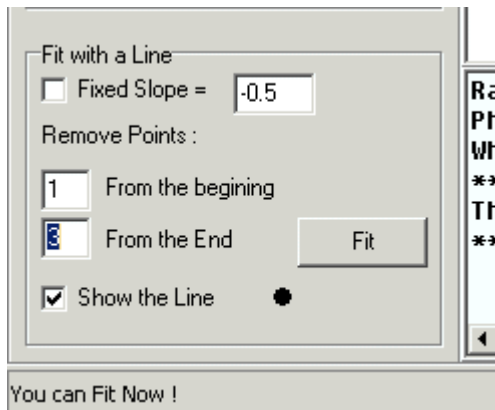
1) The Fixed Slope CheckBox will indicate if the Slope *b* will be fixed or not. If it is checked then you will fit *Log(Sigma) - b * Log(tau)* with a constant *a* . In this case The b value is read from Edit Box at the right (-0,5 in the figure).

2) Normally The Last values of Sigma have a big error bars so you can exclude them from the fit . The two Edit Box in the Fit panel will help you to determine which points to be considered in the Fit.
If the length of Sigma is *N*, Then the Fit will consider the points with index :

(1+From the beginning Value) **UNTIL** (*N* - From the End Value)

In the above figure this will lead to :

2   UNTIL (*N* - 3)

3) The Fit results is displayed in REPORT TEXT Window.
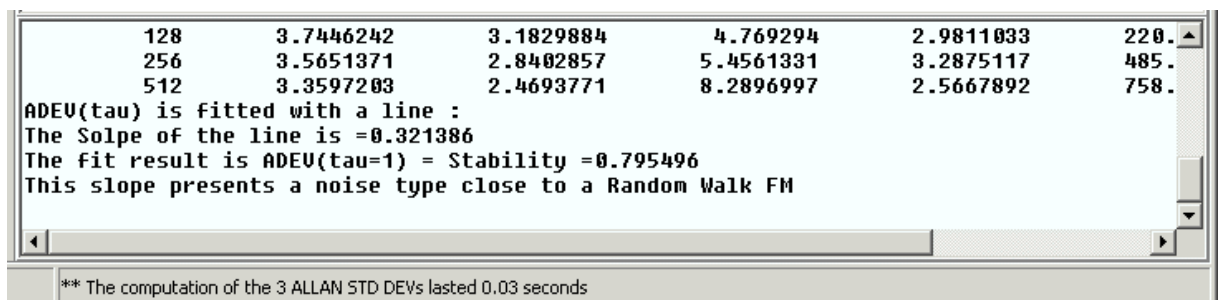
5   Post Processing

- Plot Edition
- Printing
- Exporting Plots
- Exporting Data

5.1 Plot Edition

You can modify the plots displayed in the program by using the **Plot Options Menu** :
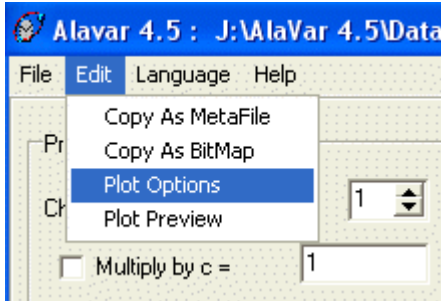
The Plot Edit Dialog has many pages that allow to control and change the plot options :
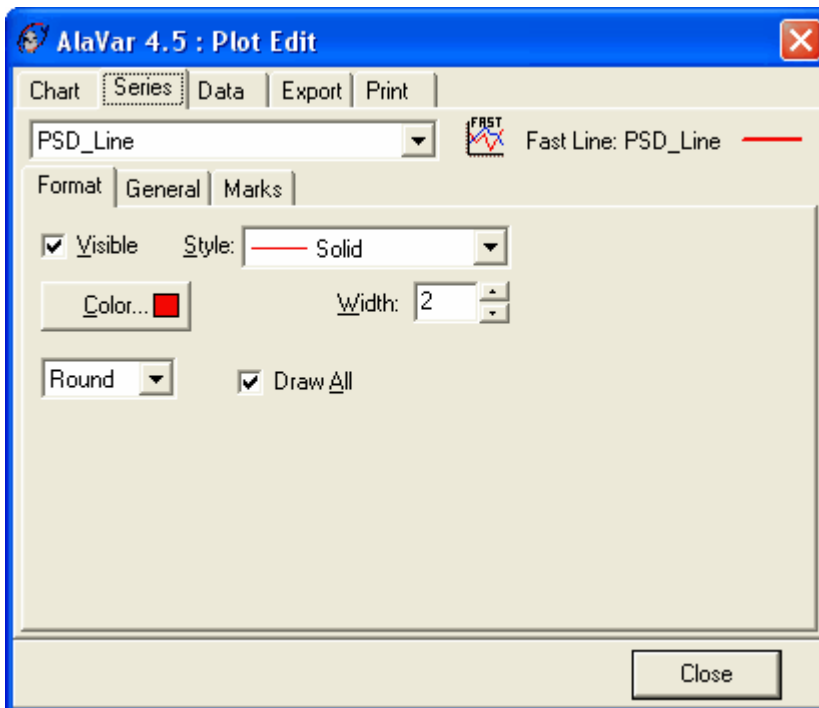
The **Series** page displayed above allow to change the series options.
In order to modify the axis style use the Axis page inside the **Chart** Page as bellow :
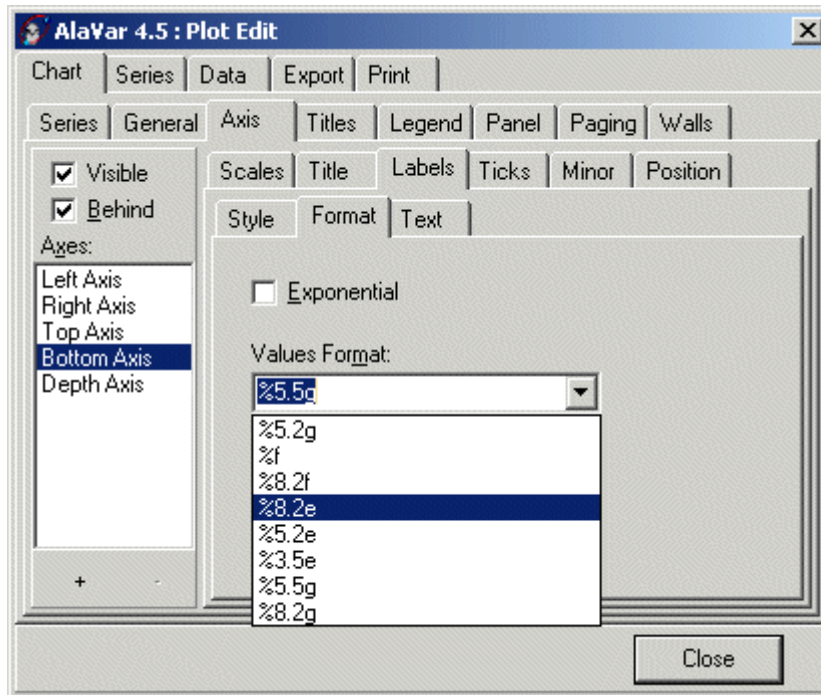
The **Values Format** controls the way **AlaVar** displays the numerical format of numbers. You can type your preferred format or select one from a predefined list of formats. **"%n.mX"** means n digits followed by a dot followed by m digits. X may be **e** to force an Exponential format, **f** to force a float format and **g** to make an automatic format.

The **Titles** page allows to you to modify or add Title, Foot, SubTitle and SubFoot. You may use the Foot to write a small description of your plot.
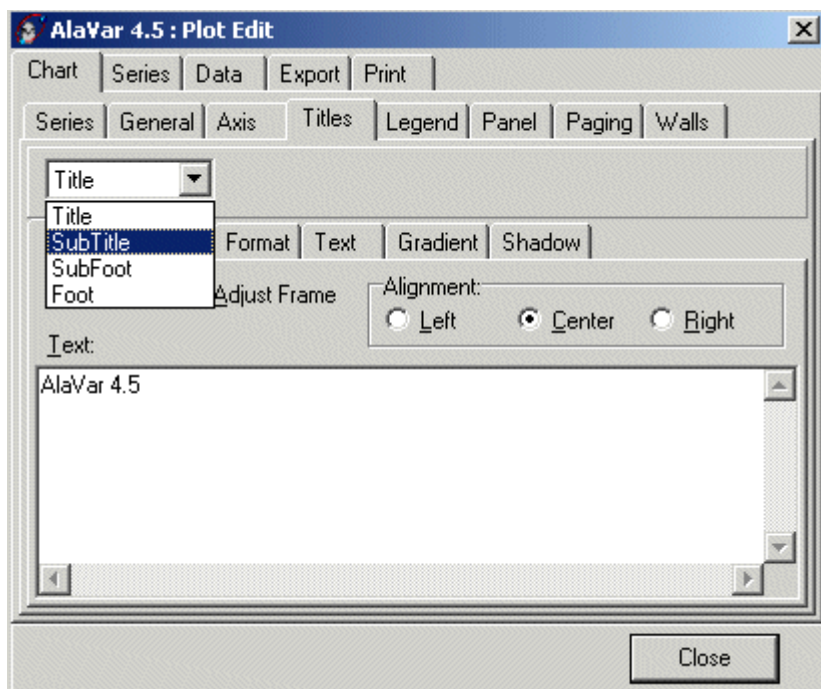
5.2 Printing

The **Plot Preview** menu allows to you to control the way the plots will be printed.
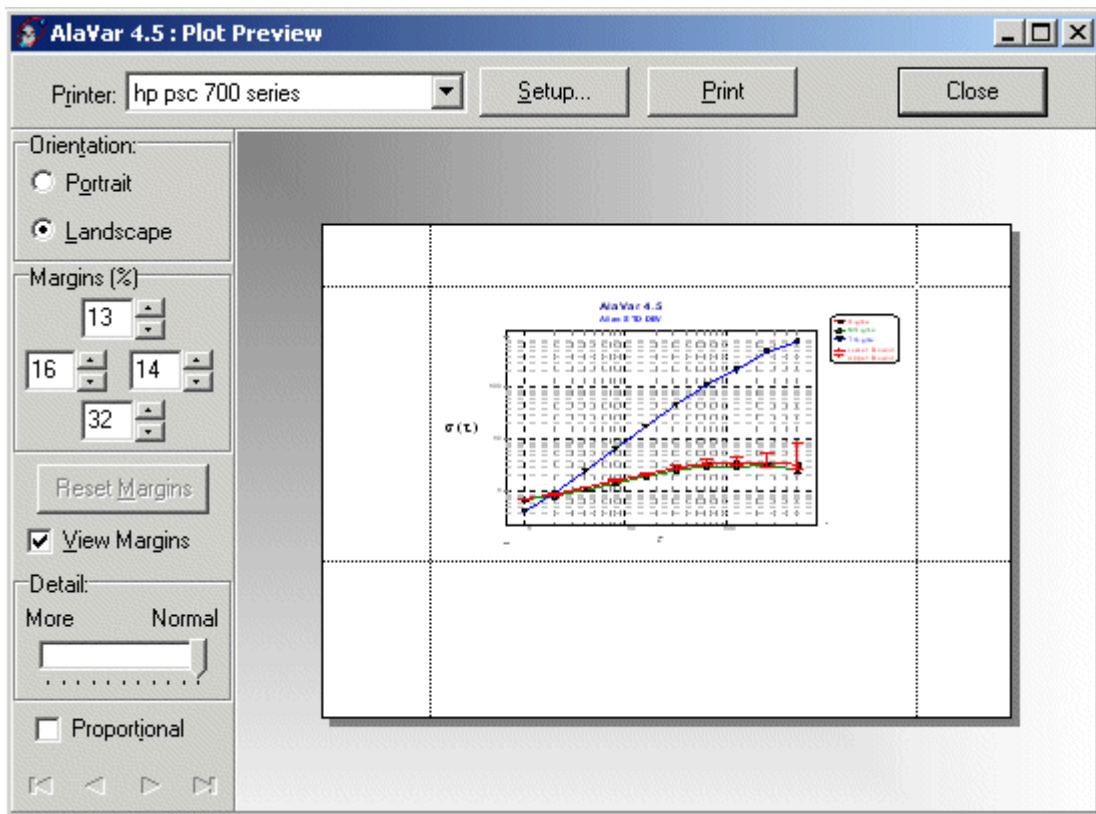
5.3 Exporting Plots

The **Edit menu** allows to you to **copy** the current plot in order to paste it in other software programs like Word.

In the Plot Options Dialog you can export the current plot to many file formats.
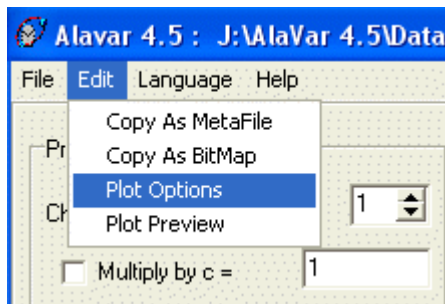
In the **Picture** page inside the **Export** page you can click **Save** in order to export the plot to a graphic file.
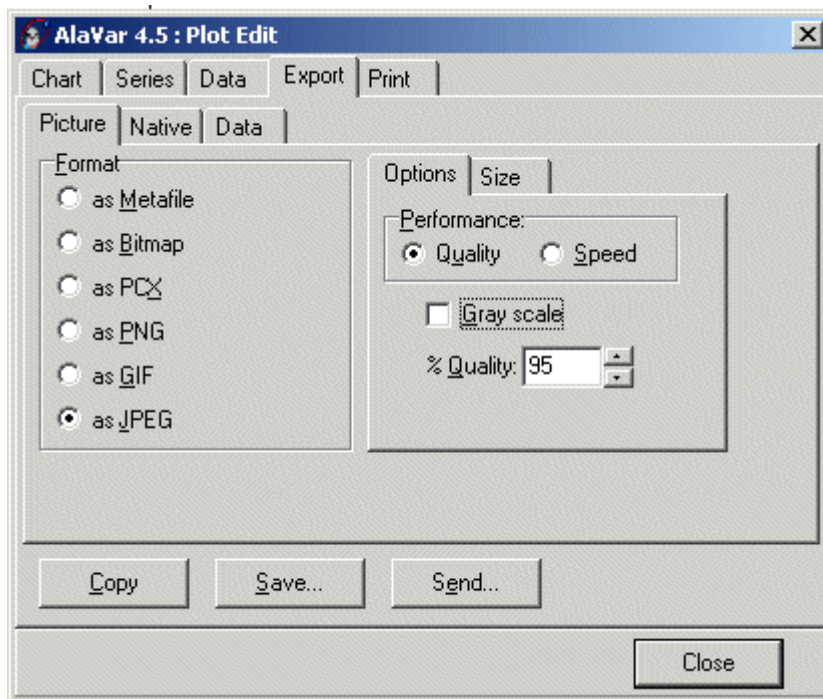
5.4   Exporting Data

The **Data** page show a Grid editor that allows to your to see and modify the data of the current plot.
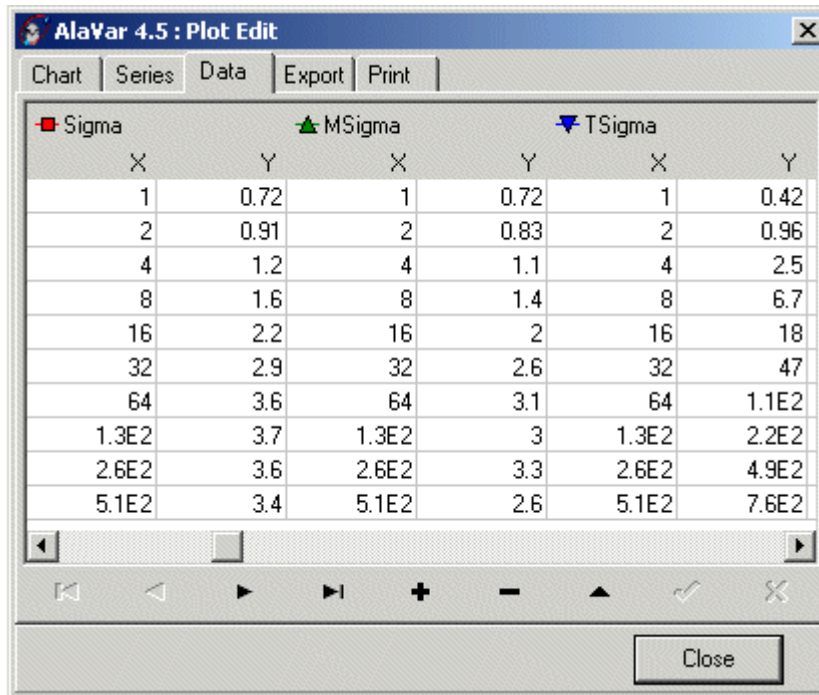
Note : Modifying the data in the Grid Editor will change the plot only and will not modify the data used by the program.

The **Data** page inside the **Export** page allows to you to export the data of the current plot into Text, XML, HTML and Excel Files.
You can also **Send** the selected File format by E-mail as an attached file.
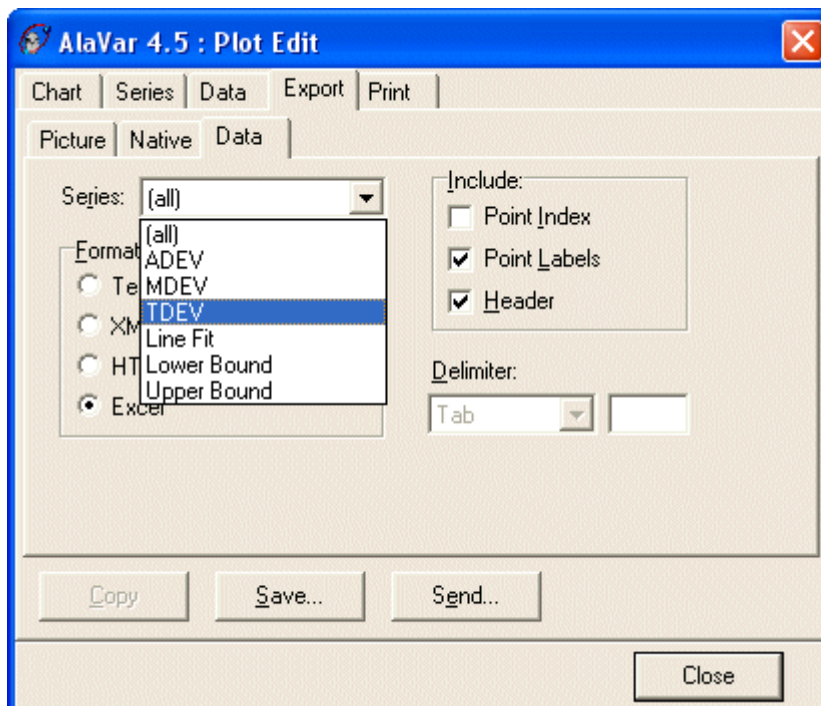
5.5   Generating reports

The **Generate Report** menu pops up a preview of the generated report.
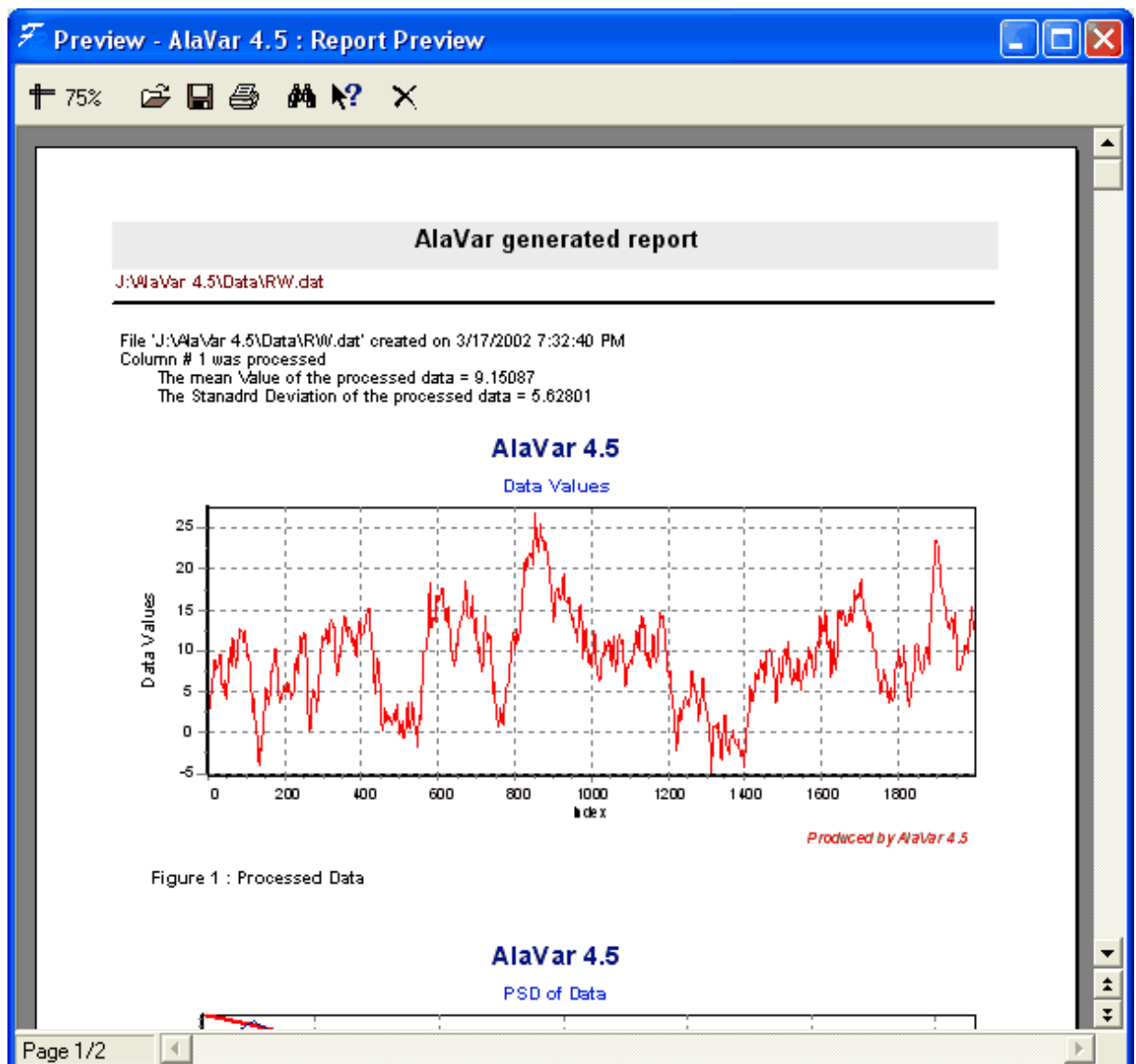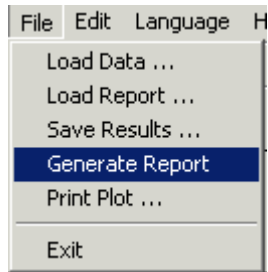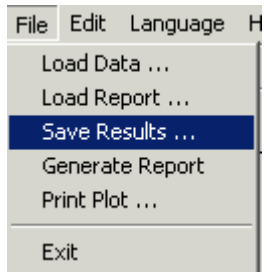

The save button allows to you export the generated report
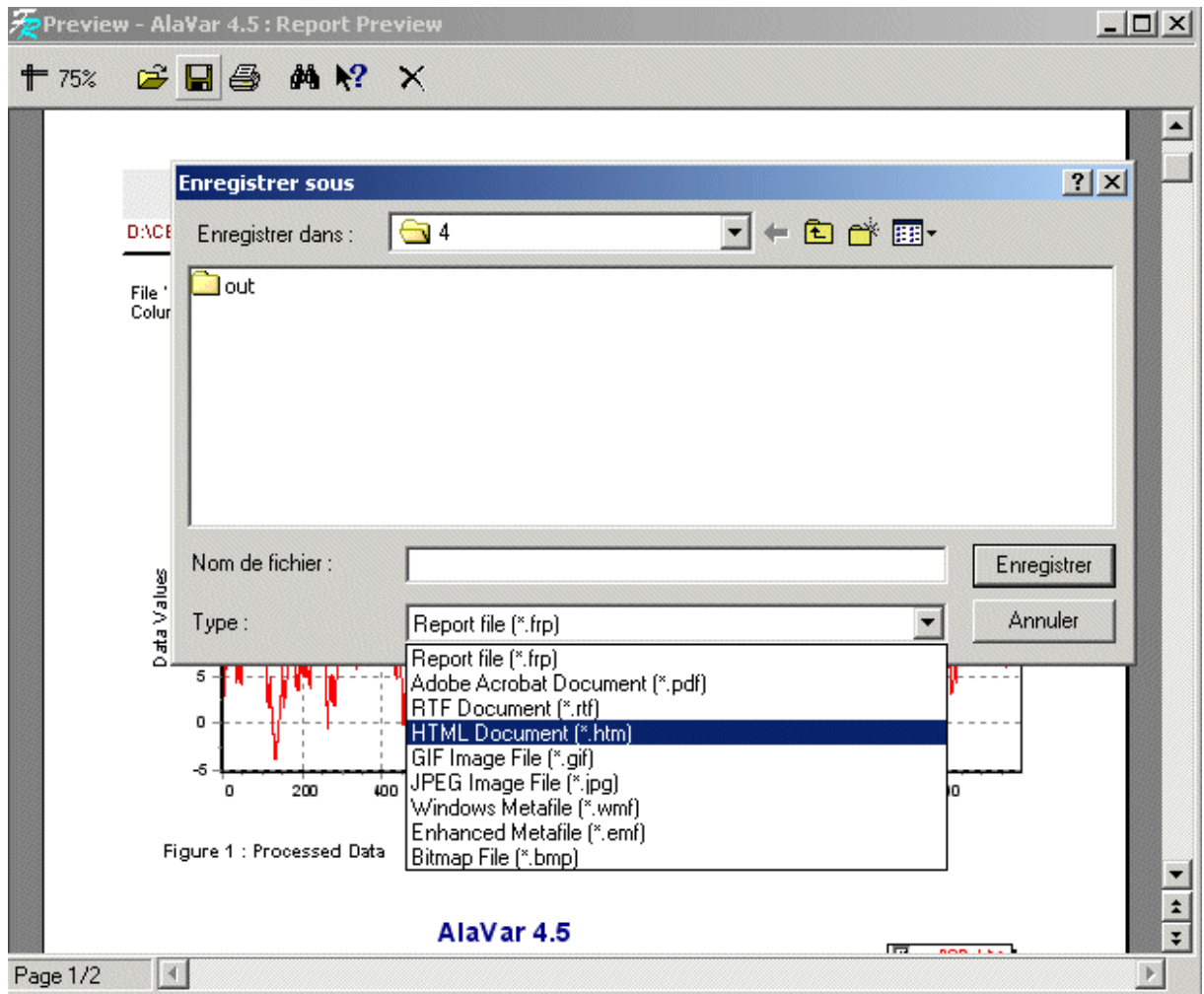
Supported formats are shown above.

The Report file (*.frp) format is a binary format that could be read latter by the AlaVar software using the **Load Report** menu.
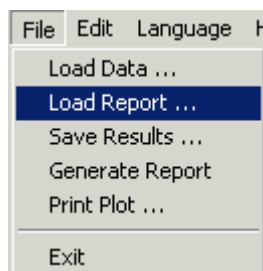
The **Save Results** menu allows to you to save a Report File (*.frp) directly without previewing the report.

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