User manual
Vesper 1.6
April 2004

Introduction

The large number of measurements made by continuous yield monitoring, mobile electrical conductivity systems, kinematic GPS and other 'on-the-go' field sensors have created large data sets (more than 1000 points) within a single field. In most geostatistical software, spatial interpolation requires two separate steps: calculating and modelling/fitting of variogram for the whole area (data points) followed by kriging estimates for unsampled points in the area. There is a need to develop new spatial prediction software in order to accommodate the large number of data and to take into account the local spatial structure. A range of prediction options that considers the nature and quality of the original data and the end use of the mapped output is also required.

VESPER (Variogram Estimation and Spatial Prediction with ERror) is a PC-Windows program developed by the Australian Centre for Precision Agriculture (ACPA) for spatial prediction that is capable of performing kriging with local variograms (Haas, 1990). Applications of the program include generating yield maps, interpolation of digital elevation models, and assessment of topsoil salinity problems. The program also allows conventional kriging with a whole area variogram, with options for manual adjustment and fitting of the whole-area variogram. The user-friendly interface permits the creation of a field boundary and generation of an interpolation grid.

Kriging with local variograms involves:

- searching for the closest neighbourhood for each prediction site,
- estimating the variogram from the neighbourhood,
- fitting a variogram model to the data
- predicting the value and its uncertainty.

The local variogram is modelled in the program by fitting a variogram model automatically through the nonlinear least-squares method (Marquardt, 1963).
Punctual and block kriging is available as interpolation options.
This program adapts itself spatially in the presence of distinct differences in local structure over the whole field.

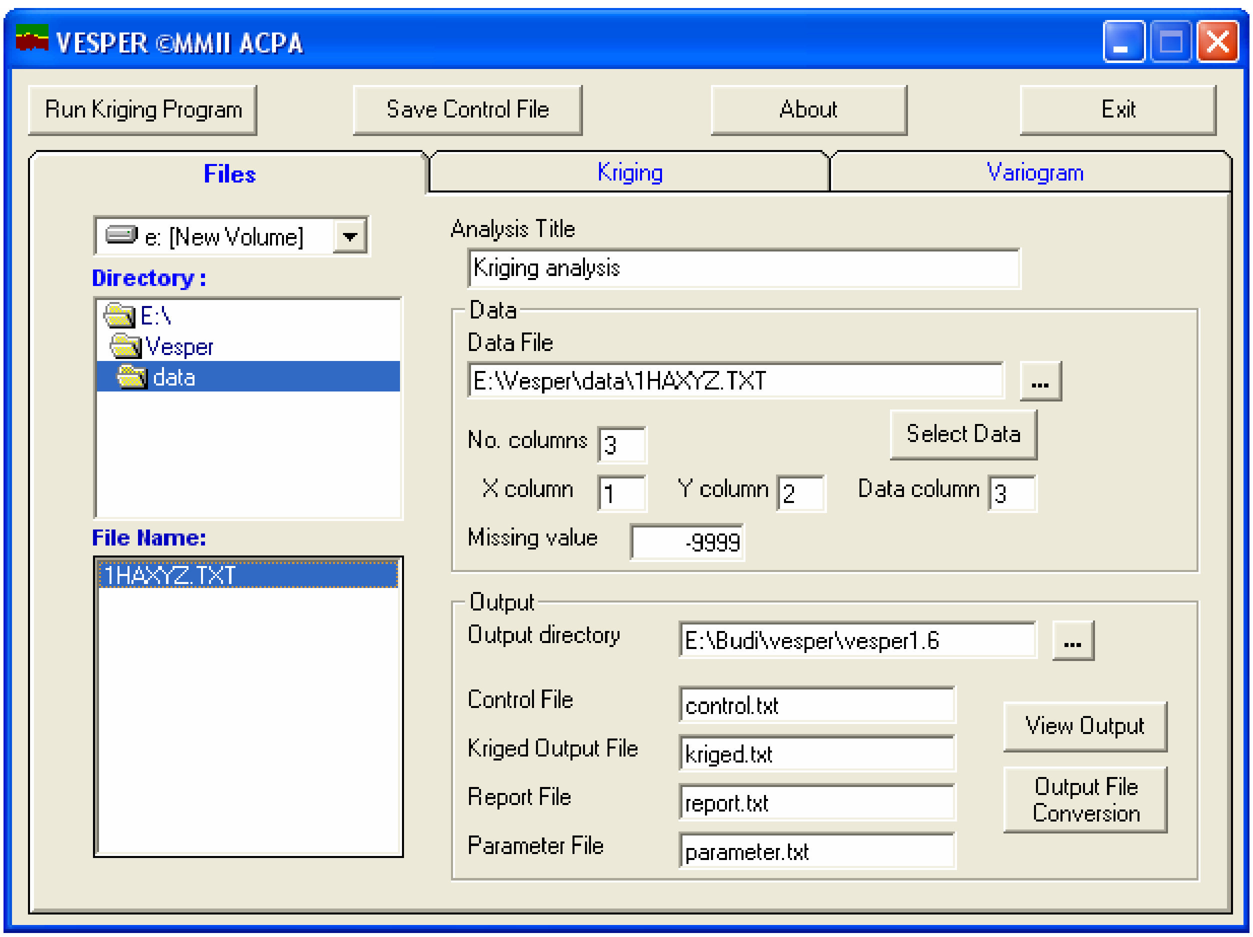
File requirement

Data in a text file with multiple columns (containing x, y, and data), with or without a header separated by tabs, spaces, or commas.

Example:
File 1HAXYZ.TXT
Conatins 3 columns in the file, the first two columns are the Easting & Northing (x & y) coordinates. Column 3 is the data value (Vesper can take up to 50 variables)

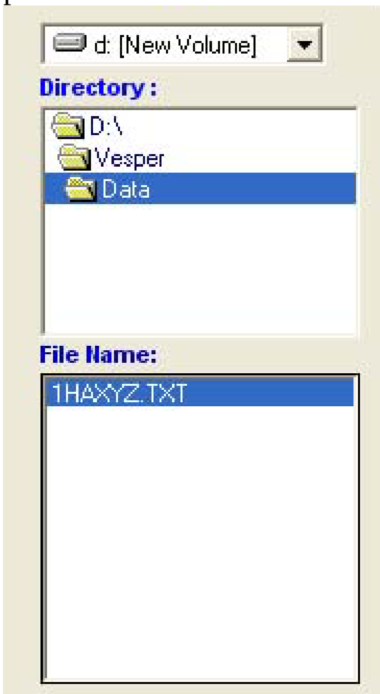
```
x,y,z
50.16571,38.60503,6.73180134
51.81264,38.41478,5.38031385
53.48674,37.77423,4.83549547
.
.
```

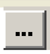
Files Input/output

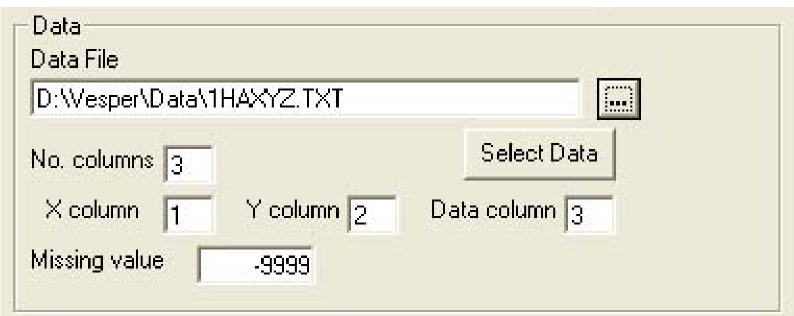


Input File

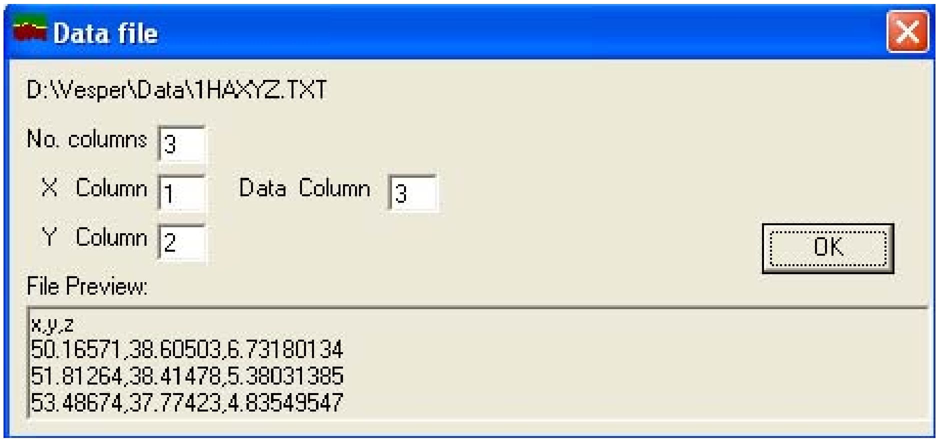
Select a file containing the data by “double-click” the “Directory” and “File” name on the right hand side panel:



or by clicking the  button to browse for the file in your computer.

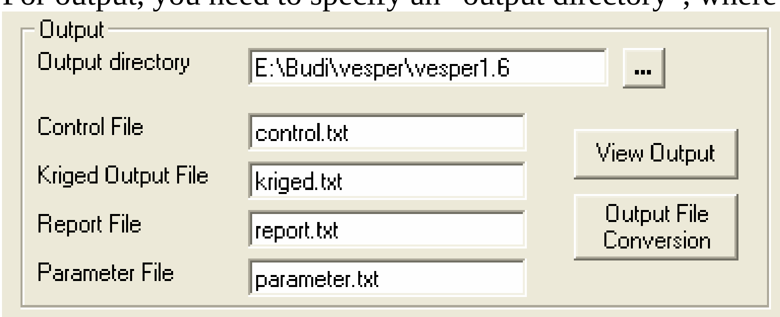


When a data-file is selected, the “Data file browser” window will appear prompting the number of columns in the file, the columns for x, y and data to be interpolated.
Make sure the correct no. of columns, column number for x, y, and z.



Output

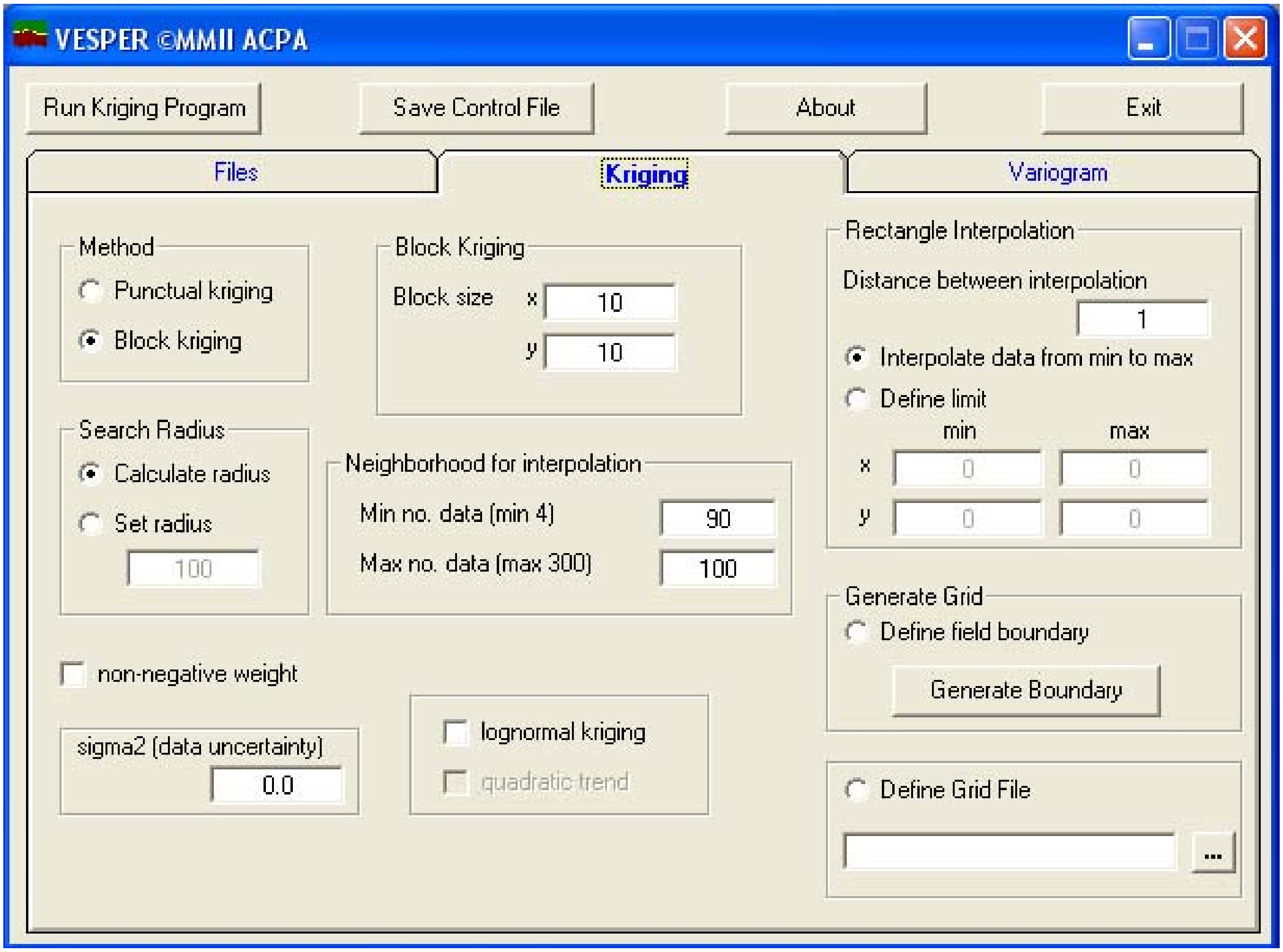
For output, you need to specify an "output directory", where all the output files will be saved.



"control File" is a file containing parameters for running Vesper, this is automatically generated by the program.

The output files produced by Vesper are:

- A report file will contain the parameters and messages regarding the program.
- Kriged output file will be the interpolated points.
- If "Local variogram" is used, a "parameter file" will be created containing the parameter of the variogram for each interpolation point.



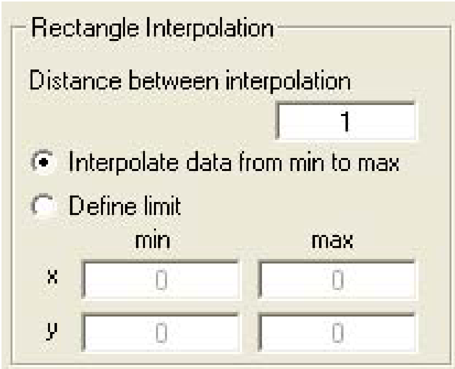
Defining interpolation grid

Interpolation grid can be specified in one of the following options:

- When the field has a rectangle shape, specify the interpolation distance in the "Rectangle interpolation".
- When the field has an irregular shape, you can define or create a boundary, and interpolate only in the boundary area.
- When you have a file containing a pre-defined grid you can specify the name of the file.

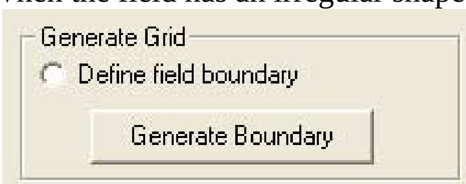
Rectangle interpolation

When the field has a rectangle shape, just simply specify the "distance between interpolation":

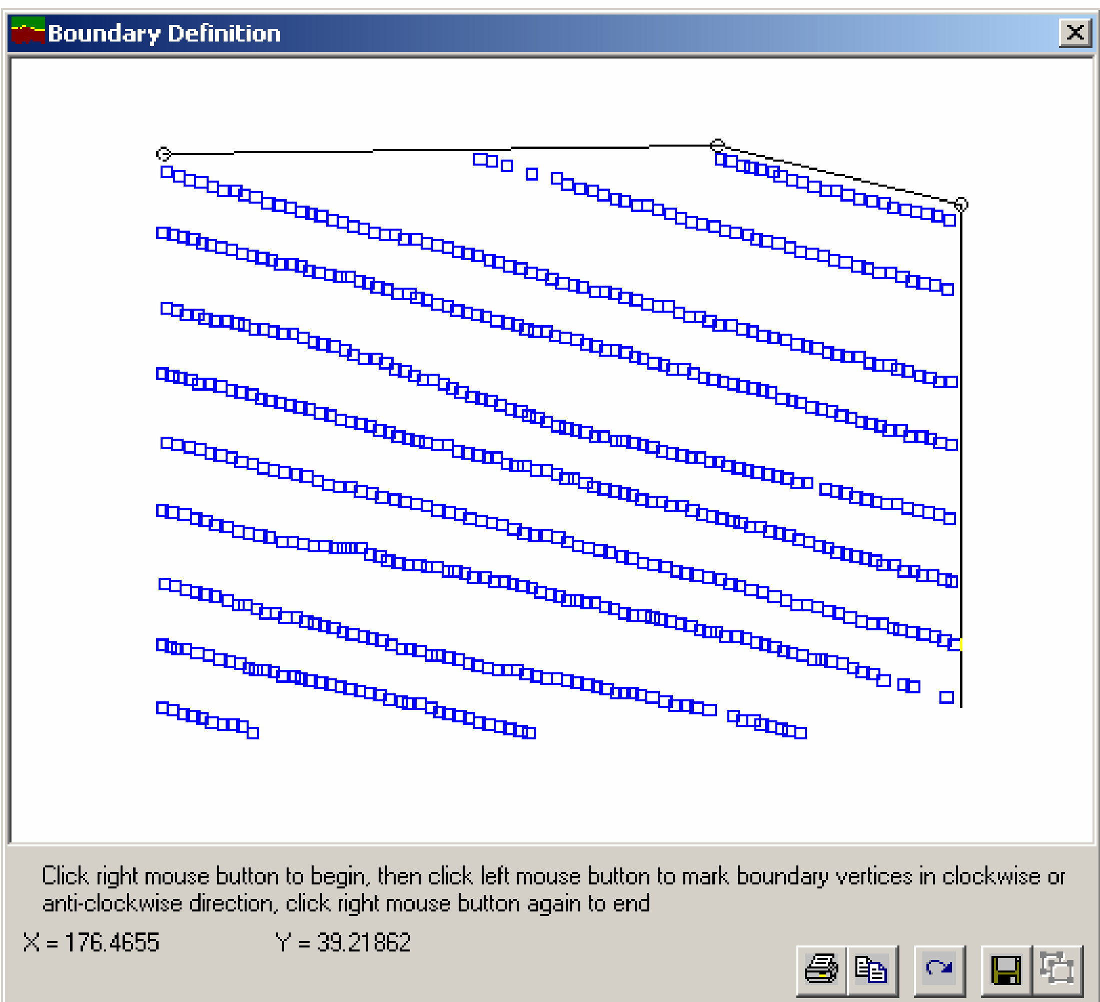


Defining A Field Boundary

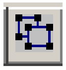
When the field has an irregular shape, you need to create a boundary:



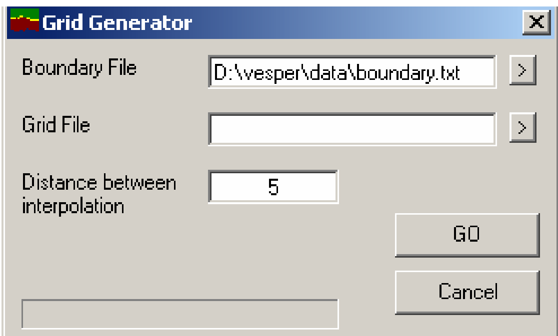
Click "Generate Boundary" Button



The "Boundary Definition" window will appear showing the data points in the x, y coordinates.

Click the right mouse button once to activate the drawing tool.
Click the left mouse button on the vertices of the field's boundary in clockwise or counter-clockwise direction,
To finish, click the right mouse button again.
Save the boundary in a file, this file can be used again.
Click the  button to generate a regular grid.

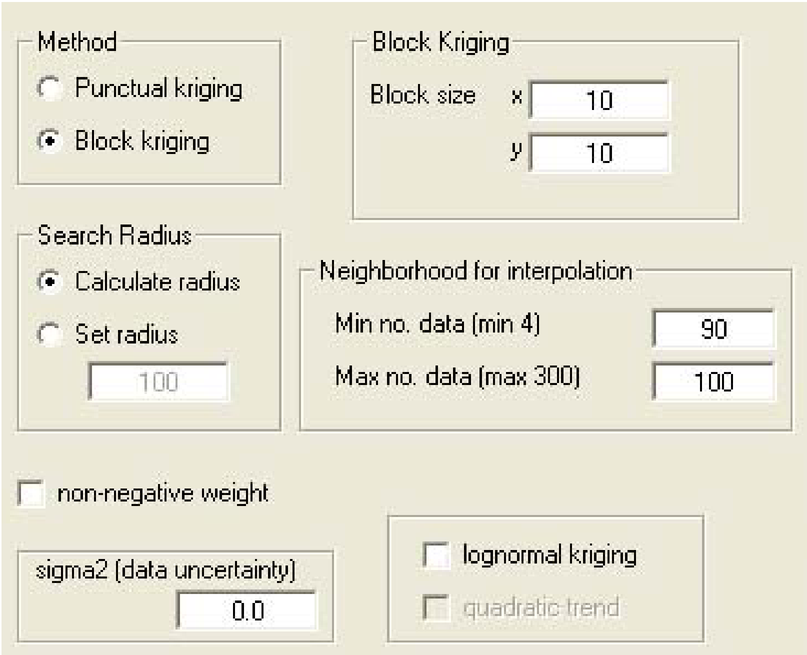
The “Grid Generator” window will appear and define the name of grid distance and the program will generate a square grid into an ASCII text file with x, y coordinates



Specifying a grid file

If you wish to interpolate into certain coordinates, select the "Define Grid File" button.
The grid file should be an ASCII text file with x, y coordinates arranged in 2 columns

Kriging parameter



Method

The Kriging Tab menu provide options for kriging: Punctual or Block kriging.
For theory on kriging, see Webster & Oliver (2002).
For block kriging, you need to specify the “block size”, which should have the same unit as your spatial coordinates.

R. Webster, M.A. Oliver, 2002. Geostatistics for Environmental Statistics. John Wiley & Sons, New York.

Neighbourhood number

Define the minimum & maximum number of neighbourhood points you wish to use for kriging
For kriging with local variograms, minimum 100 data points are recommended as the variogram will be calculated from the neighbourhood points.

Search Radius

Set the radius of the search neighbourhood, where the minimum no. of neighbourhood can be found
If "calculate radius" is selected, the search radius will be calculated based on the density of the data

Other kriging parameters

Lognormal kriging

For data that has a lognormal distribution, lognormal kriging will transform the data into log scale and perform appropriate calculation of prediction & variance of prediction.

Non-negative weight

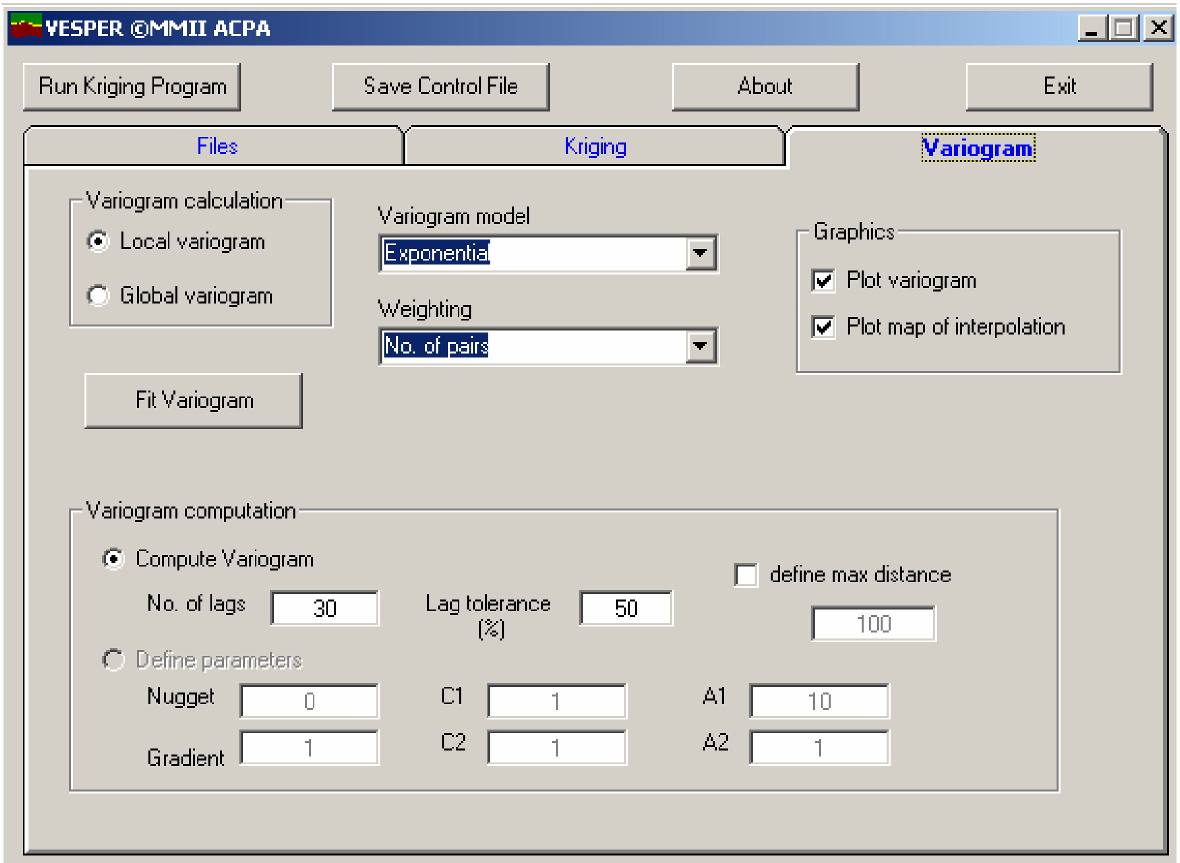
Negative kriging weights applied to “extreme” values can lead to kriging estimates outside the range of the observed data. This feature may cause problems such as non-physical estimates (negative probabilities, probabilities greater than one, negative porosities, or negative thicknesses or concentration). In these situations one would like an estimator that ensures no negative weights (Deutsch, 1996).

Data uncertainty

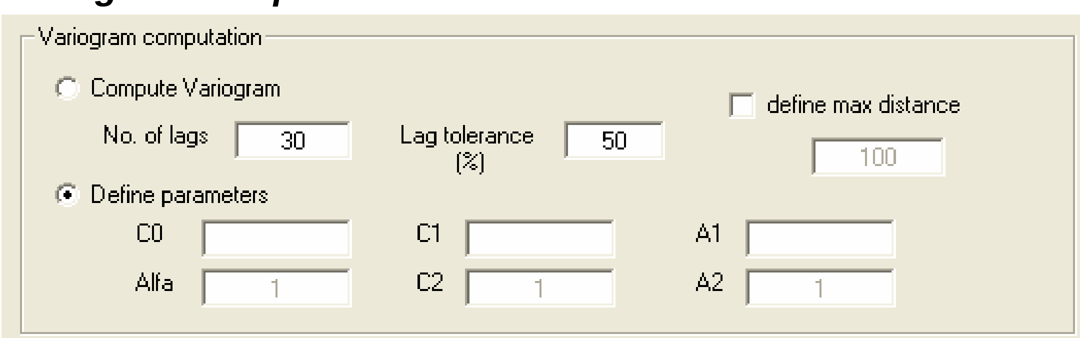
sigma2 is σ^2 that defines the variance or data uncertainty

Variogram Modelling

The "Variogram" tab provides the option for the variogram parameters



Variogram computation



Specify “No. of Lags” (number of lags) you wish to compute for the variogram, you can also define the maximum distance for the variogram computation.

e.g. if the no. of lags is 20 and maximum distance is 400 m, the variance will be calculated for every 20 m increments:

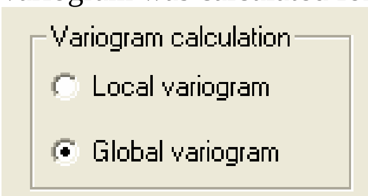
0 - 20, 21-40, ..., 381-400.

Lag tolerance is the tolerance value for particular distance to be put in a “lag”

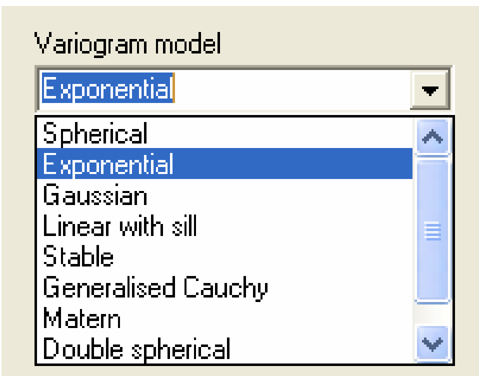
For example 50% of lag tolerance means that a distance of 18 has a tolerance of 9 to 27 and will be put into lags of: 0-20 and 21-40.
Lag tolerance serve to smooth the variogram values, similar to a moving average.

Local/Global variogram

Global variogram refers to calculating a variogram for the whole area. And kriging uses this whole area variogram for prediction. Local variogram is intended for field with high data density, where "local" variogram was calculated for each interpolation point.



Variogram model



SPHERICAL
if (h < A1) then
    $rho = 1 - 1.5\ h/A1 + 0.5 * (h/A1)^3$
else
    rho = 0
endif
gamma = C0 + C1 * (1- rho)

EXPONENTIAL
rho   = exp(-h/A1)
gamma = C0+ C1 * (1 - rho)

GAUSSIAN
$rho = exp(-(h/A1)^2)$
gamma = C0+ C1 * (1 - rho)

LINEAR WITH SILL
if(h < A1) then
    rho = 1- (h/A1)

else
    rho = 0
end if
gamma = C0+ C1 * (1 - rho)

STABLE
rho = exp[-(h/A1) ^{alfa}]
gamma = C0+ C1 * (1 - rho)
$(0<alfa<2)$

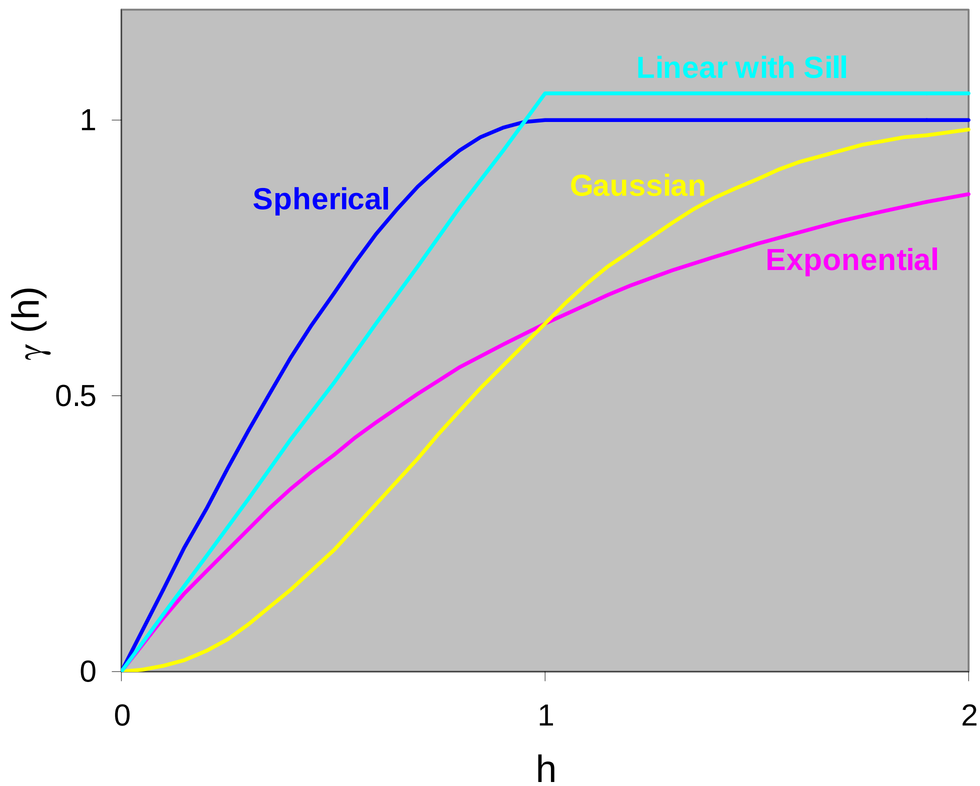
GENERALISED CAUCHY
rho = (1 + (h/A1)^{2})$^{-alfa}$
gamma = C0+ C1 * (1 - rho)
$(alfa>0)$

MATERN
rho = 1/[2 $^{(SMOOTH-1)}$ * Γ(SMOOTH)] * (h/A1) ^{SMOOTH} * $Bess_{SMOOTH}$(h/A1)
gamma= C0 + C1*(1 -rho)
where
  Γ (...) is Gamma function,
  $Bess_{SMOOTH}$(...) is the modified Bessel function of the third kind of order smooth.
$(0<SMOOTH<2)$
Matern is a general model that is flexible and can be used to approximate function behaving as exponential (smooth = 0.5), power, or Whittle (Bessel function) model (smooth = 1).

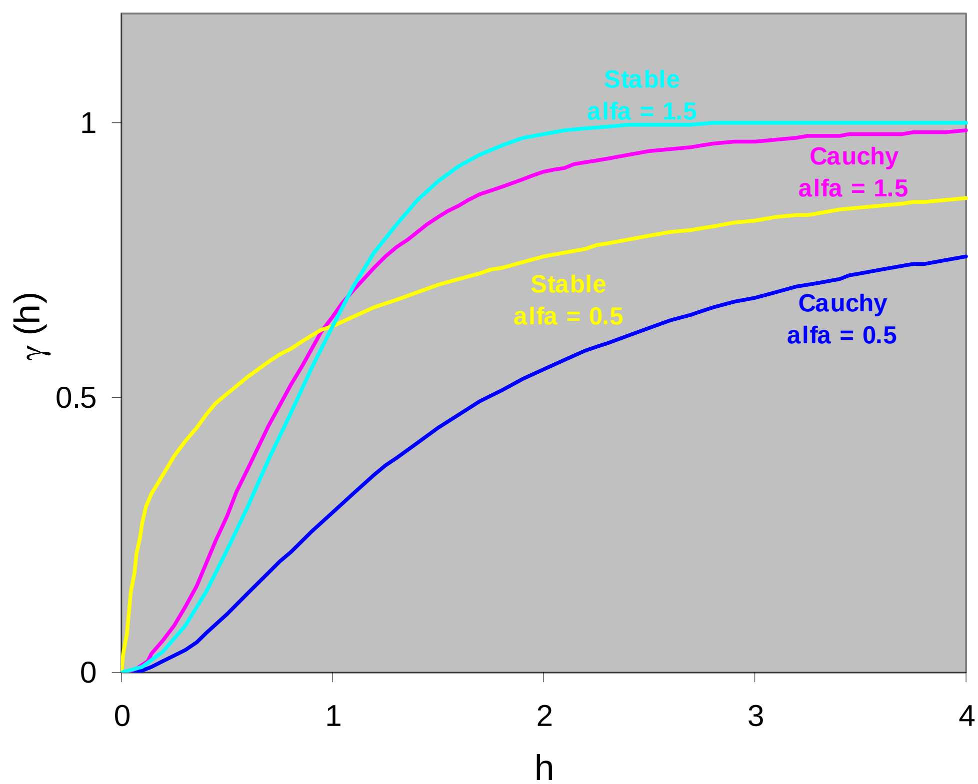
DOUBLE_SPHERICAL
if (h < A2) then
        rho1 = 1-1.5*h/A1+0.5*(h/A1)^{3}
        rho2 = 1-1.5*h/A2+0.5*(h/A2)^{3}
        if (h > A1) then
                rho1=0
        end if
else
        rho1 = 0
        rho2 = 0
end if
gamma = C0+C1*(1-rho1)+C2*(1-rho2)

DOUBLE_EXPONENTIAL
rho1 = exp(-h/A1)
rho2 = exp(-h/A2)
gamma = C0+C1*(1-rho1)+C2*(1-rho2)

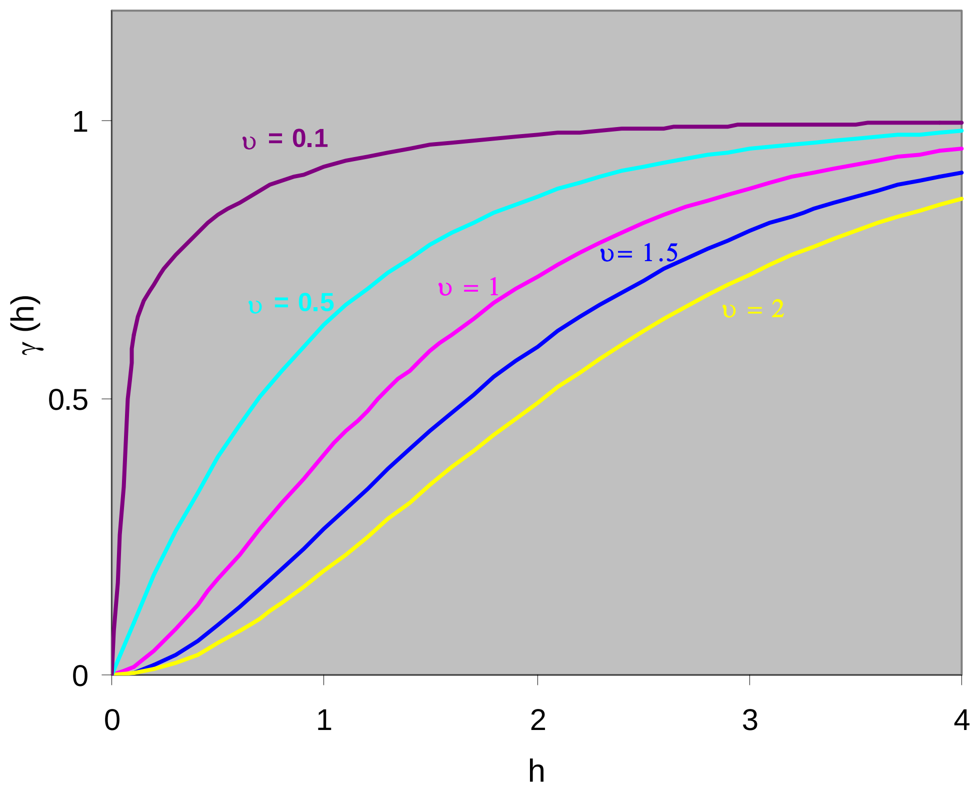
For local variogram, most crop yield data can be fitted with spherical and exponential model. The recommended model for local variogram is the exponential model, Gaussian model is not recommended as it can produce unstable kriging equation.



Spherical, exponential, Gaussian and linear model with C0=0, C1=1, and A1=1



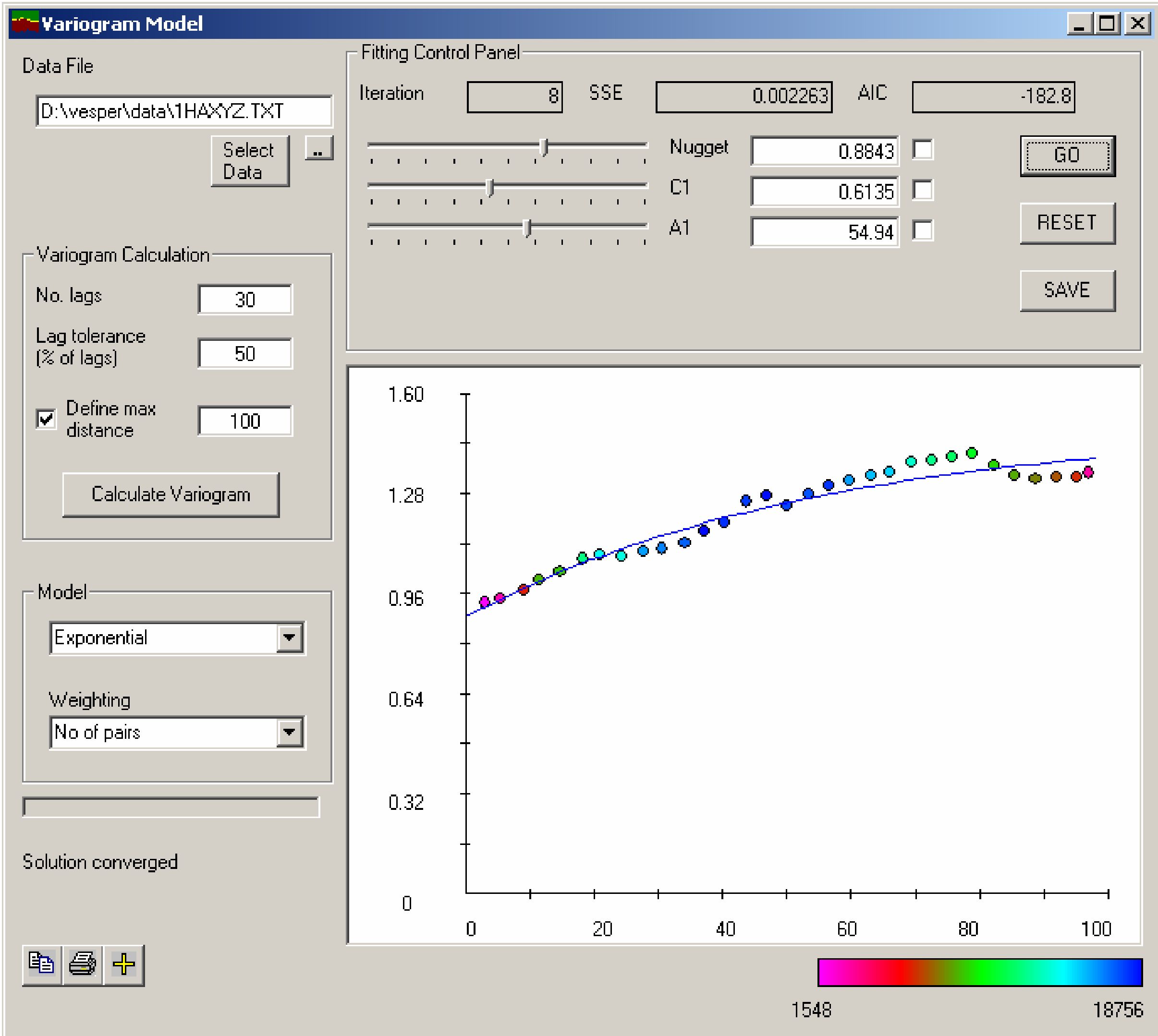
Generalised Cauchy and Stable model with C0=0, C1=1, and A1=1



Matern model with C0=0, C1=1, and A1=1 with various value for smooth (υ) parameter.

Calculating variogram & Fitting a model

To fit a global variogram, click "Fit Variogram" Button and the "Variogram model" window will appear:



Calculating the Variogram

The variogram (semivariance) is calculated from:

$$\hat{\gamma}(h) = \frac{1}{N(h)} \sum_{i=1}^{N(h)} \left[z(x_i) - z(x_i + h) \right]^2$$

Select the data-file or by clicking the  button, or you can select the data from different columns by clicking the “Select Data” button.

Specify "No. Lags" (number of lags) you wish to compute for the variogram and you can also define the maximum distance for the variogram.

e.g. if the no. of lags is 20 and maximum distance is 400 m, the variance will be calculated for every 20 m increments:

0 - 20, 21-40, ..., 381-400.

Lag tolerance is the tolerance value for particular distance to be put in a “lag”

For example 50% of lag tolerance means that a distance of 18 has a tolerance of 9 to 27 and will be put into lags of: 0-20 and 21-40.

Lag tolerance serve to smooth the variogram values, similar to a moving average.

Click "Calculate Variogram" to calculate the variogram.

The graph will show the calculated variogram. The dots are the calculated value, and the blue line is the current estimate of the model.
The colour represents the number of pairs for variance estimate at each lag.
The colour ranges from pink (smallest no. pairs) to blue (highest no. pairs) as indicated by the legend on the bottom right hand-side.

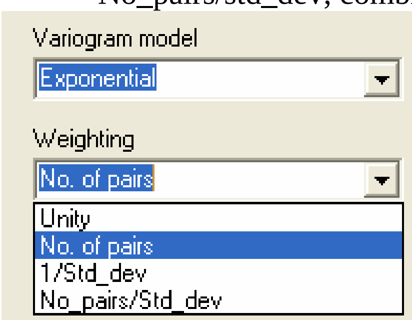
Weight for Fitting Variogram

Variogram model is fitted to the data by using weighted nonlinear least-squares method (Jian et al., 1996), minimising:

$$R = \sum_{i=1}^{n} w_i \left[\hat{\gamma}(h_i) - \hat{\gamma}^*(h_i) \right]^2$$

User can specify the type of weighting for *w*:

Unity (no weighting)
No. of pairs, no. of pairs calculated from semivariance $N(h)$
1/std.dev, the standard deviation of the average of semivariance for particular lag.
No_pairs/std_dev, combination of no. of pairs & std. deviation of the semivarainace estimate.



Fitting Variogram Model

The parameters of the model can be changed using the sliding bar next to each
Select the model you wish to fit.
Click the “GO” button to fit the model to the current variogram using non-linear least squares
The program will iterate to find the best parameters to fit the model to the data

The graph will show the calculated & fitted variogram.

The goodness of fit can be assessed by the SSE (sum of squared error) or AIC (Akaike Information Critereon). The lowest AIC pertains to the best model (Webster and McBratney, 1989).

AIC is defined as:

AIC = -2 ln(maximum likelihood) + 2 (number of parameters),

and is estimated by:

AIC = n ln (R) + 2 p

where R is the sum of squares of residuals, and p is the number of parameters.

The “Reset” Button redraws the variogram model with specified parameters.
Parameters can be locked or fixed by checking the square button next to the parameter's value
The “Save” button saves the variogram values and fitted parameters.

Running Vesper

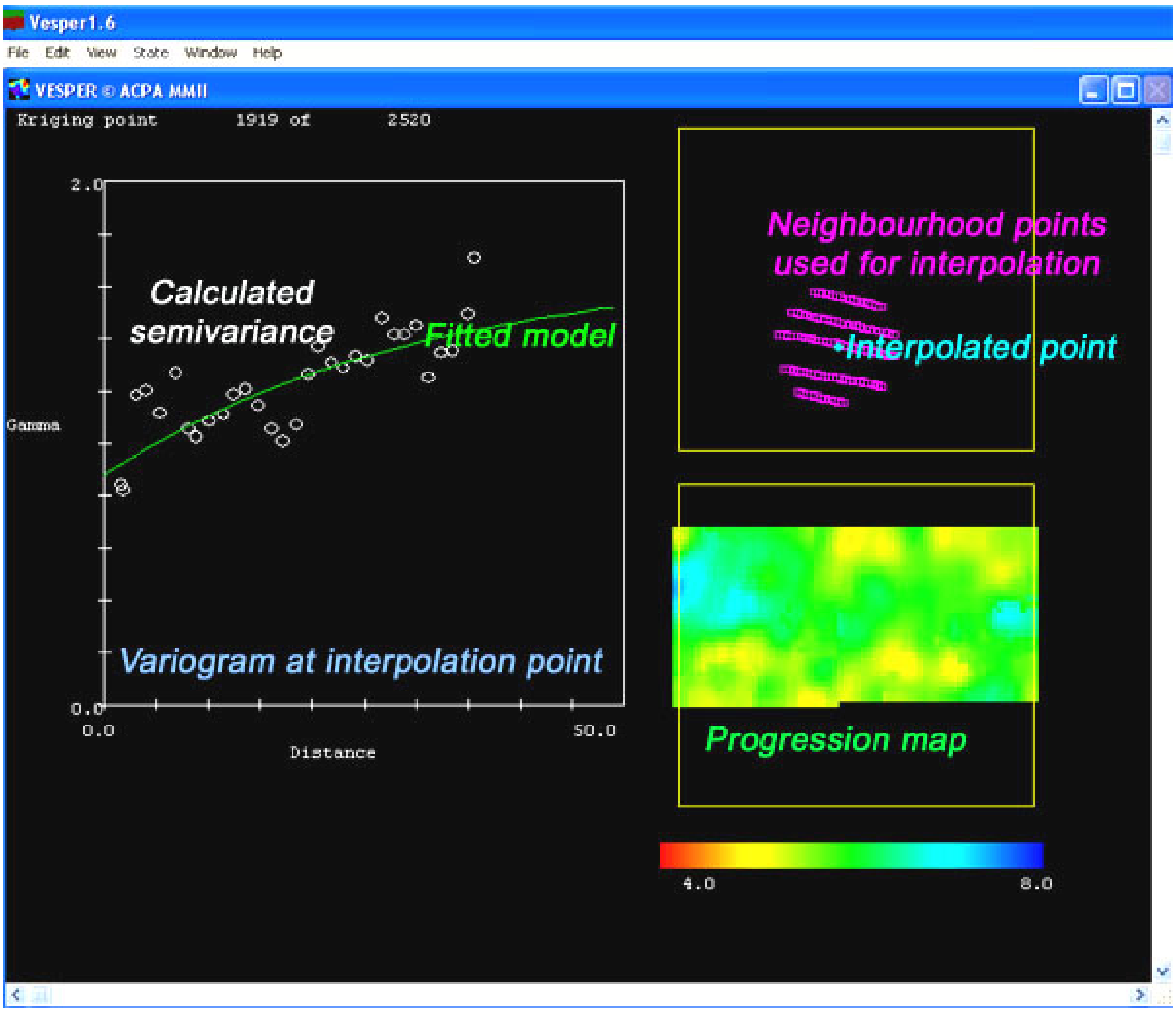
When the following parameters have been specified:

- Input/output files
- Interpolation grid
- Kriging parameters
- Variogram parameters

We can run the kriging program.

Click 

button.



When the program has finished, it will display map of the interpolation and also the uncertainty (standard error) of prediction.

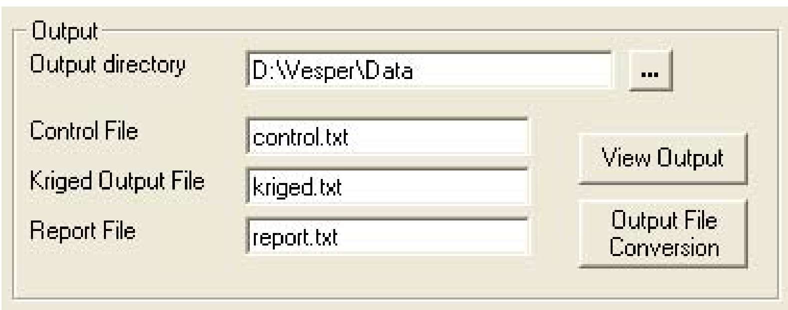
Understanding the Output

Vesper will produced a Kriged output file in the form of ASCII text:
The file consist of 5 columns, e.g:

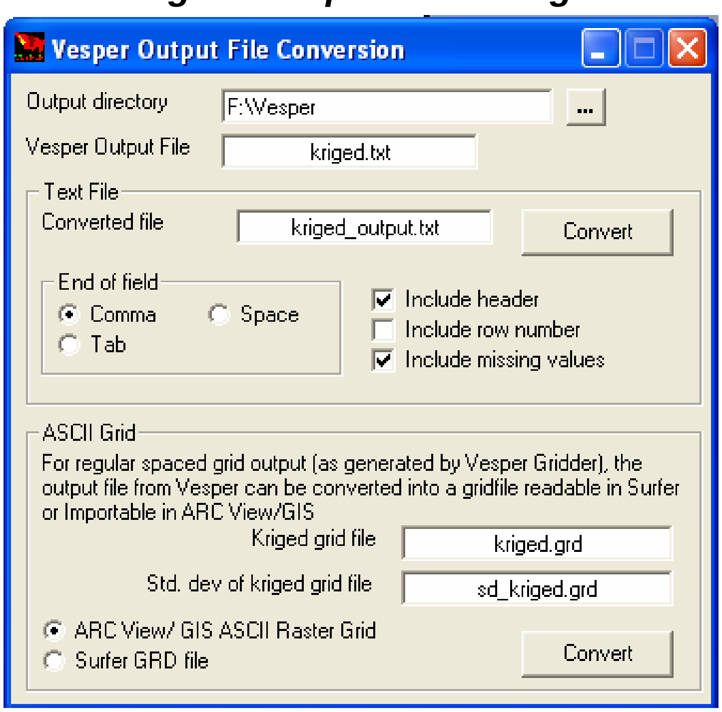
No.	X	Y	Predicted	sd_Pred
1	50.166	114.598	5.36046	0.21458
2	52.166	114.598	5.35444	0.16915
3	54.166	114.598	5.41664	0.16490

The first column is the number or order of the grid
x, and y is the coordinates, predicted and sd_Pred is the predicted and standard deviation of the predicted value.
When Vesper fail to interpolate a point, it will give a value of -9999.

The text file can be converted into other forms of text file or ASCII grid, by using the “Output File Conversion” tool:

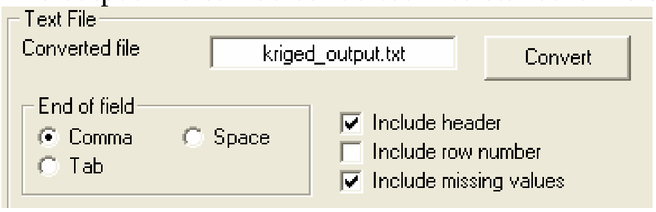


Converting the output to ASCII grid file

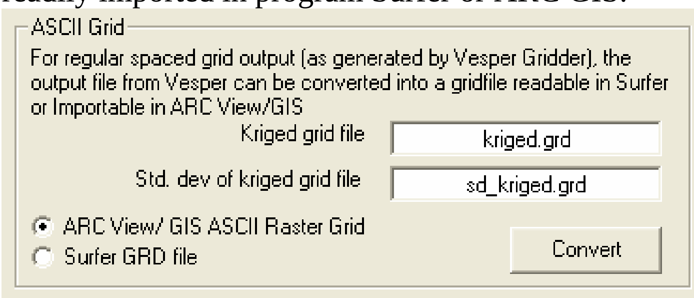


First, specify the output directory, and the name of the output file produced by Vesper.

The output file can be converted into standard ASCII file with comma, tab or space delimited.



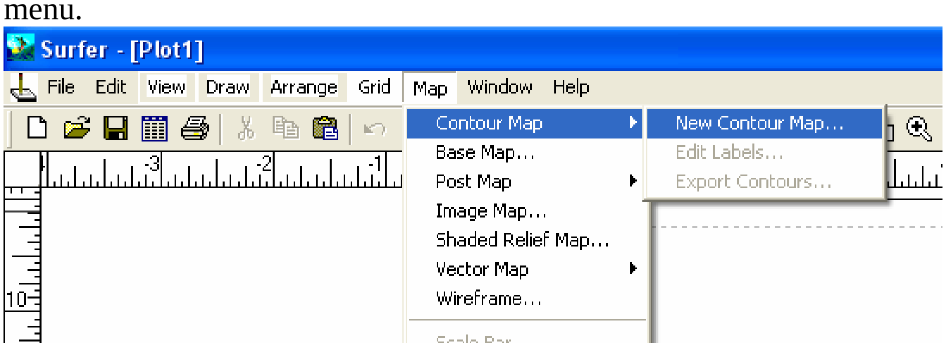
If the output is in a regular grid, the output file can be converted into ASCII raster grid file readily imported in program Surfer or ARC GIS.



Importing ASCII grid in Surfer

ASCII grid format for surfer contains the following header
DSAA
No_Colums No_Rows
XMIN XMAX
YMIN YMAX
ZMIN ZMAX
And followed by Data matrix

The grid file converted using Vesper can be plot directly in Surfer, by choosing the option in "Map" menu.



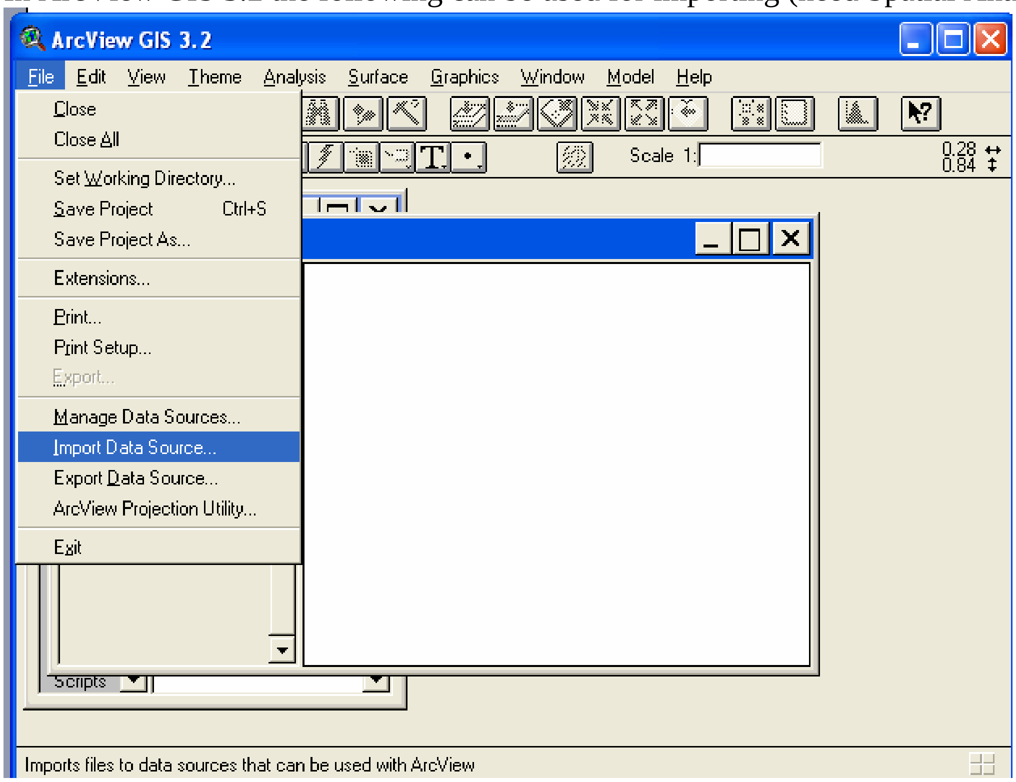
Importing ASCII grid in ARCView/ GIS

For Arc View/GIS, the ASCII grid file needs the following header, e.g.:
NCOLS   1000
NROWS 512

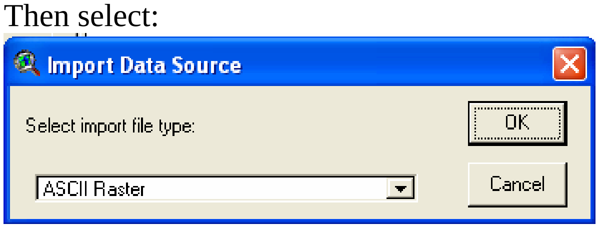
XLLCORNER 1
YLLCORNER 1
CELLSIZE 1
NODATA_VALUE -9999
This is followed by the data matrix.

The grid file from Vesper need to be converted to the binary format of ARC.

In ArcView GIS 3.2 the following can be used for importing (need Spatial Analyst extension) :



Then select:



For Arc GIS 8, use ArcToolbox and select “Import to Raster” and “ASCII to grid”

Specify the “Input ASCII file” (converted from Vesper) and the name of the “output grid” (in ARC format), select “float” for “Grid type”.

Advanced application

Understanding the control file:

A control file contains all the parameters needed to run Vesper, it is in a text file with the format as follows:

$vsl	tag, don't change
ivers= 161111	tag, don't change
title= 'Kriging analysis'	title of the analysis in single quotation mark ' '
datfil= 'D:\ vesper\data\1HAXYZ.TXT'	file containing the data
outdir= 'D:\ vesper\data'	output directory
repfil= 'report.txt'	name of report file
outfil= 'kriged.txt'	name of kriged file
parfil='parameter.txt'	name of parameter file
numcol= 3	number of columns in the input file
icol_x= 1	column no. containing x value in the input file
icol_y= 2	column no. containing y value in the input file
icol_z= 3	column no. containing z value in the input file
jordkrg= 1	ordinary kriging (leave as is)
jpntkrg= 1	1 = point kriging , 0 = block kriging
jlockrg= 0	1 = local variogram kriging , 0 = global variogram
nest= 10	no. of estimated grid for calculating block (leave as is)
dstinc= 10	distance between interpolation (for rectangular grid)
valmis=-9999	missing value
jsetint= 0	1 = set interpolation rectangle
xlint= 0	if jsetint=1, min x for interpolation
xhint= 0	if jsetint=1, max x for interpolation
ylint= 0	if jsetint=1, min y for interpolation
yhint= 0	if jsetint=1, min y for interpolation
jsetrad= 0	1 = set radius, 0 = calculate radius
radius= 100	search radius (when jsetrad=1)
minpts= 40	min. no. of points for interpolation
maxpts= 50	max. no. of points for interpolation
sigsqr= 0	sigma2
isomod= 1	isotropic model (leave as is)
modtyp= 2	variogram model no.
isearch= 0	isotropic search (leave as is)
igeos= 0	parameter for anisotropic search (leave as is)
icircs= 0	parameter for anisotropic search (leave as is)
phi= 0	parameter for anisotropic search (leave as is)
psin= 0	parameter for anisotropic search (leave as is)
pcos= 0	parameter for anisotropic search (leave as is)
jcomvar= 1	1=compute variogram, 0= define the variogram parameter
nlag= 30	no. of lags
hmax= 0	max distance, set to 0 if want to be determined automatically
tolag= 50	lag tolerance
iwei= 1	type of weighing for parameter estimation
jigraph= 1	1=show graph of variogram, otherwise 0
jimap= 1	1=show map of interpolation, otherwise 0
CO= 0	C0 value for variogram parameter
C1= 1	C1 value for variogram parameter
A1= 10	A1 value for variogram parameter
C2= 1	C2 value for variogram parameter
A2= 1	A0 value for variogram parameter
Alfa= 1	Alfa value for variogram parameter

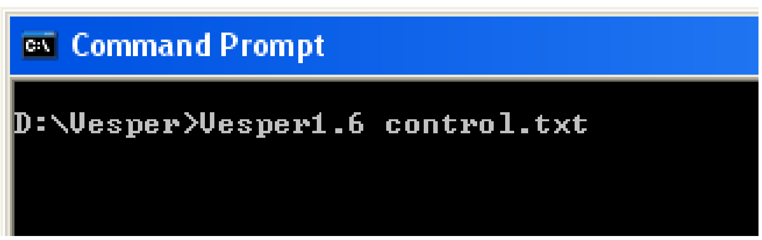
xside= 10	Block size (in x direction) for block kriging
yside= 10	Block size (in y direction) for block kriging
lognorm= 0	1=lognormal kriging, otherwise 0
itrend= 0	1=use quadratic detrending
iconvex= 0	1=non-negative weight
igrids= 0	1= specify a grid file
gridfile=''	name of the gridfile (when igrids=1)
$end	tag don't change

Note the parameter of the control file does not need to be in the above order.

Running batch mode

Vesper can be executed in batch mode, by typing dos command in the folder containing the Vesper application:

Vesper1.6 control_file_name



When multiple runs are needed, user can create different 'control' file and prepare a batch file.
For example:
We have created 4 control files and need to run it,
First create a text file and write:

```
vesper1.6 controla.txt
vesper1.6 controlb.txt
vesper1.6 controlc.txt
vesper1.6 controld.txt
```

Then save the file as "Vesper.bat" and run vesper.bat

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