

Geostatistics in the SPRING

Exercise 4

Course: Master of Science on Geospatial Technologies
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Contents

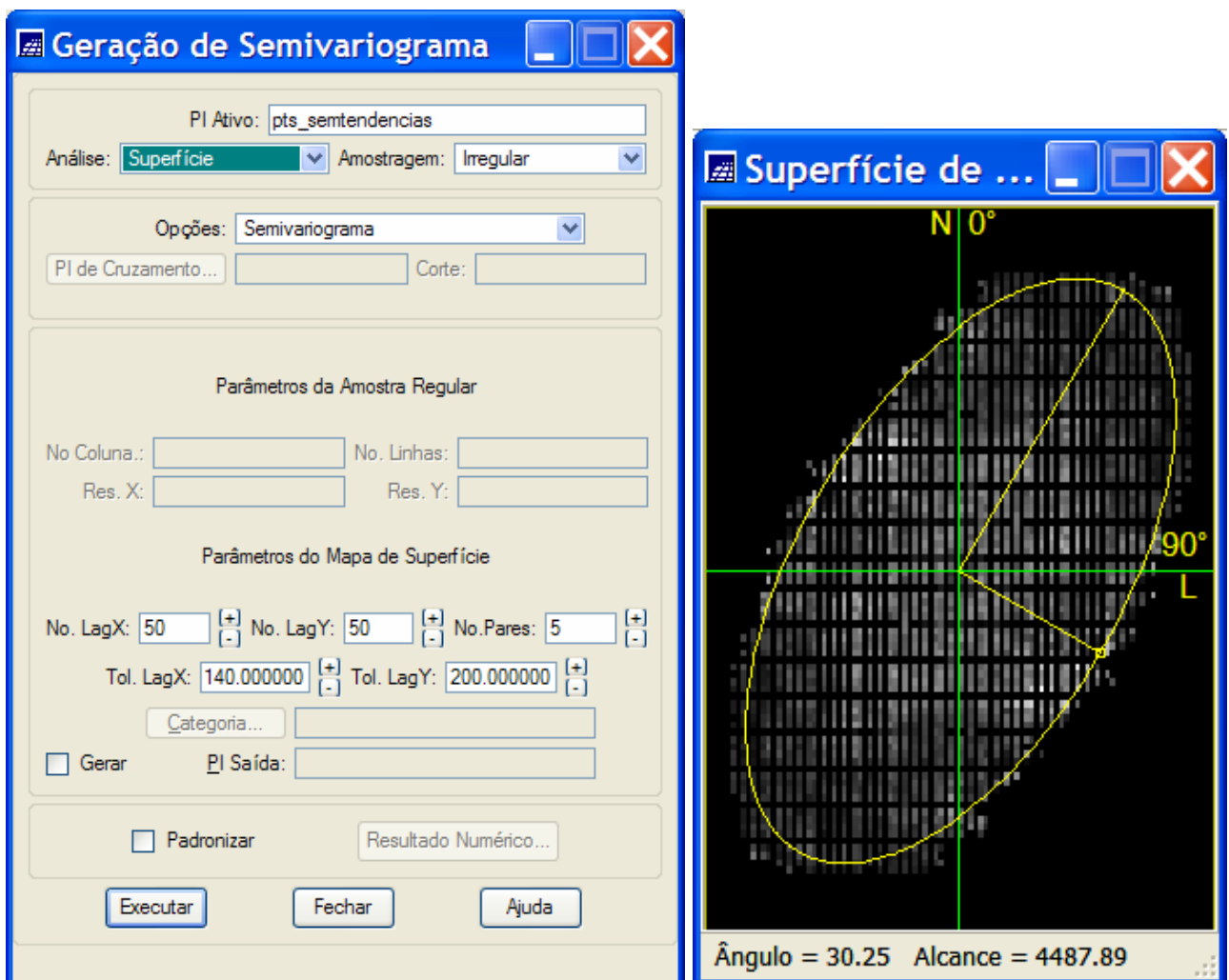
4. Modeling spatial variables considering anisotropic spatial variation

- 4.1 Verifying anisotropy with semivariogram surfaces
- 4.2 Generating experimental semivariograms (30⁰ direction)
- 4.3 Fitting theoretical semivariograms to the experimental (30⁰ direction)
- 4.4 Generating experimental semivariograms (120⁰ direction)
- 4.5 Fitting theoretical variogram to the experimental (120⁰ direction)
- 4.6 Defining structural parameters to the anisotropic variogram model
- 4.7 Performing the cross validation to the anisotropic model
- 4.8 Estimating numerical grids by Ordinary Kriging with anisotropic model
- 4.9 Visualizing the results in the SPRING graphical display
- 4.10 Comparative results between the isotropic and anisotropic modeling

4. Modeling spatial variables considering anisotropic spatial variation

4.1 Verifying anisotropy with variogram surfaces

- Select, in the Control Panel, the IL *pts_semtendencias* of the *Altimetria* category
- Select the option **Geostatistics** in the SPRING Analysis menu and then select the option **Semivariogram Generation...**
- Showing surface semivariograms for the *sem_tendencias* data
 - Select *Surface* as the Analysis option in the Semivariogram Generation window
 - Keep the default values and click on the Apply button of this window
 - Mark different locations in the Histogram Surface till find the better ellipse representing the distribution for the semivariogram values
 - Store the larger continuity angle defined by the large ellipse axes

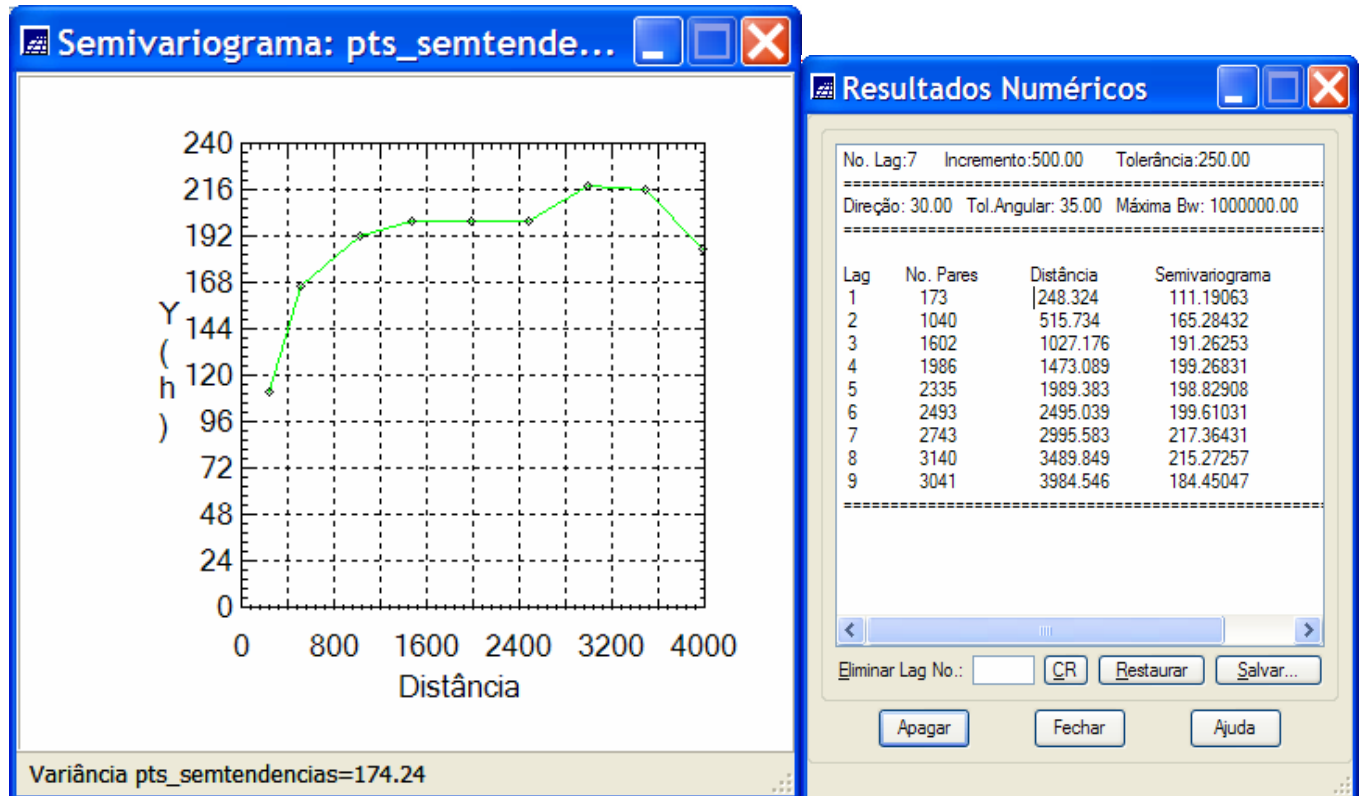


4.2 Generating experimental semivariograms (Direction 30°)

- Select, in the Control Panel, the IL *pts_semtendencias* of the *Altimetria* category
- In the **Analysis** menu of the SPRING, select the **Geostatistics** option and then select the **de Semivariogram Generation...** option
- Visualizing the Experimental Semivariograms of the sem tendências data.
 - Select the *Unidirectional* as the Analysis option in the Semivariogram Generation window
 - Generate the unidirectional semivariogram setting, as *Lag Parameters*, the following semivariogram parameter values: Number of lags (No.Lag) equal 7, Spatial Increment equal 500, Spatial Tolerance equal 250. Then mark number 2 as Direction Parameters and set the following values: Angular Direction (Dir2:) equal 30, Angular Tolerance (Tol2:) equal 35 degrees and BandWidth (Bw2:) equal *Max*.

The screenshot shows the 'Geração de Semivariograma' dialog box. The 'PI Ativo' field is set to 'pts_semtendencias'. The 'Análise' dropdown is set to 'Unidirecional' and 'Amostragem' is set to 'Irregular'. The 'Opções' dropdown is set to 'Semivariograma'. There are empty fields for 'PI de Cruzamento...' and 'Corte:'. The 'Parâmetros de Lag' section has 'No. Lag' set to 7, 'Incremento' set to 500.000000, and 'Tolerância' set to 250.000000. The 'Parâmetros de Direção' section has four rows, each with a checkbox, a direction value (Dir), a tolerance value (Tol), and a bandwidth value (Bw). Row 2 is selected (checkbox checked, highlighted in green): Dir2: 30.000000, Tol2: 35.000000, Bw2: MAX. Other rows have checkboxes unchecked and are highlighted in red (Dir1: 0.000000, Tol1: 90.000000, Bw1: MAX), blue (Dir3: 90.000000, Tol3: 35.000000, Bw3: MAX), and black (Dir4: 135.000000, Tol4: 35.000000, Bw4: MAX). At the bottom, there is a 'Padronizar' checkbox, a 'Resultado Numérico...' button, and three main buttons: 'Executar', 'Fechar', and 'Ajuda'.

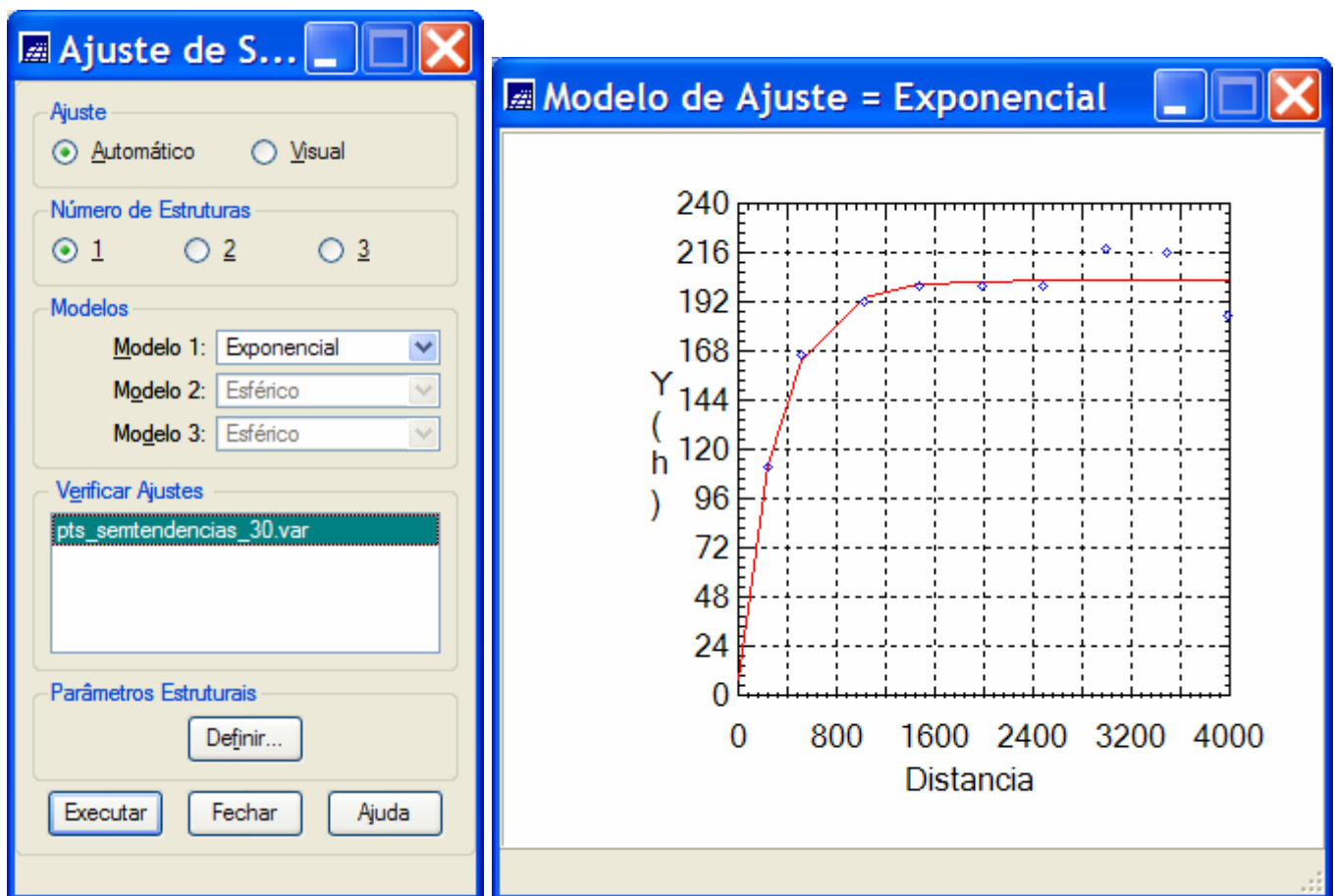
- Click on the Apply button to see the semivariogram graph generated with the given parameters. Change these values up till you find the better semivariogram using visual, qualitative, criteria.
- Observation: Click on the button Numeric Results to get a new window displaying a text report with the numerical values of the semivariogram. In this window make quantitative analysis to check the quality of the semivariogram. Pay special attention for the number of point pairs used to evaluate each the semivariogram value. The number of pairs should not be too small. Why?
- The figures bellow show the experimental semivariogram graph as well the numeric results obtained with the parameters supplied by the user.



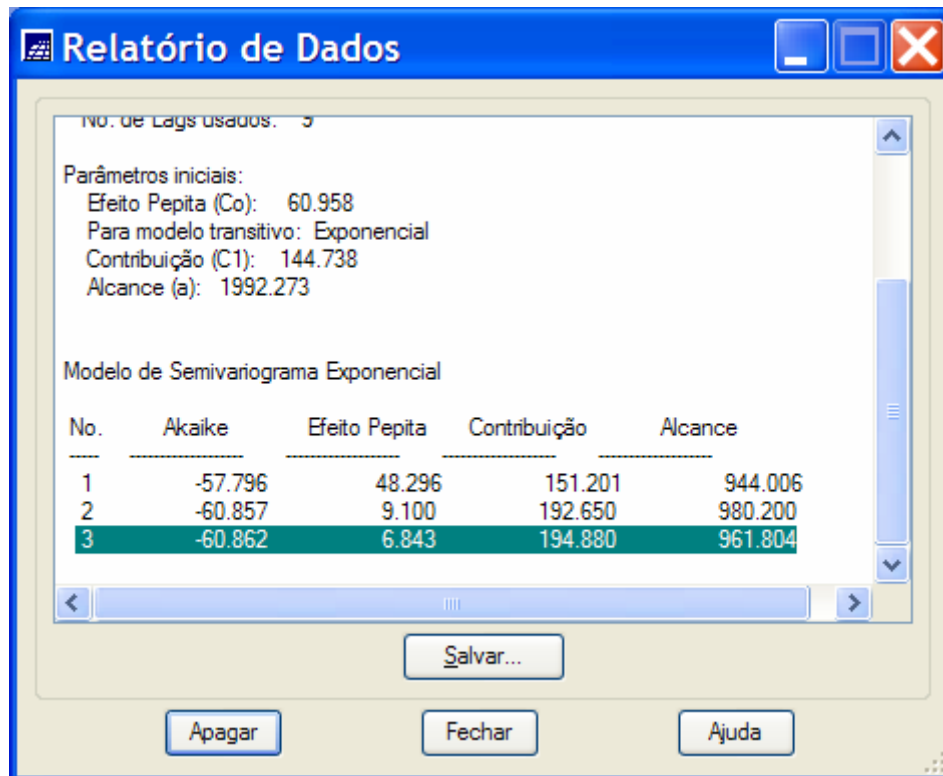
- Perform qualitative and quantitative analysis in the results above. What is the sill value of this semivariogram? Compare it with the global variance value of the samples. What about the nugget effect and the range values? Are they reasonable and/or acceptable?

4.3 Fitting theoretical variograms to the experimental (30° direction)

- Select, in the control panel, the IL *pts_semtendencias* from the *Altimetria* category
- In the **SPRING Analysis** menu, select **Geostatistics** option and then select **Semivariogram Generation...** option
- Visualizing Generated Semivariograms for the without tendency data.
 - Select Automatic as the Adjust option in the Semivariogram Modeling window
In this same window select **Number of Structures** equal 1 and *Exponential* for the **Model option**.
 - Click on the **button Apply**.
 - Click on the semivariogram name that appears in the Adjust Verification list to show the graph, and a data report, of the fitted semivariogram got with the defined model parameters.
 - Change the parameter values to obtain different theoretical semivariograms until you find a satisfactory result. Perform qualitative analysis (visual) and quantitative analysis using the data report presented along with the fitted semivariograma graph.



- The Nugget Effect, Contribution and Range parameters of the fitted semivariogram are presented in the last line (see the marked line below) of the Data Report window



- Save the parameter values for posterior manual evaluation of the final theoretical variogram. This will depend on the individual semivariogram models for the two directions of minimum and maximum continuity.

4.4 Generating experimental semivariograms (Direction 120°)

- Select, in the Control Panel, the InfoLayer *pts_semtendencias* of the *Altimetria* category.
- In the *Analysis menu* of the SPRING select the **option** *Geoestatistics* and, then, select the **option** *Semivariograma Generation...*
- Visualizing the experimental semivariogram taken from the original data.
 - In the window *Semivariogram Generation* select the **option** *Unidirectional* as the **Analysis**:
 - Select the option *Irregular* for the **Sample field**
 - Select the option *Semivariograma* for the **Options field**
 - Create the unidirectional semivariogram setting, in this window, the following distance and direction parameters: Number of lags (**No lags**) equal *8*, Spatial **Increment** equal *510*, Spatial **Tolerance** equal *255*, Angular Direction (**Dir3:**) equal *120* degrees, Angular Tolerance (**Tol3:**) equal *35* degrees and Bandwidth (**Bw3:**) equal *Max*.

PI Ativo: pts_semtendencias

Análise: Unidirecional Amostragem: Irregular

Opções: Semivariograma

PI de Cruzamento... Corte:

Parâmetros de Lag

No. Lag: 8 Incremento: 510.000000 Tolerância: 255.000000

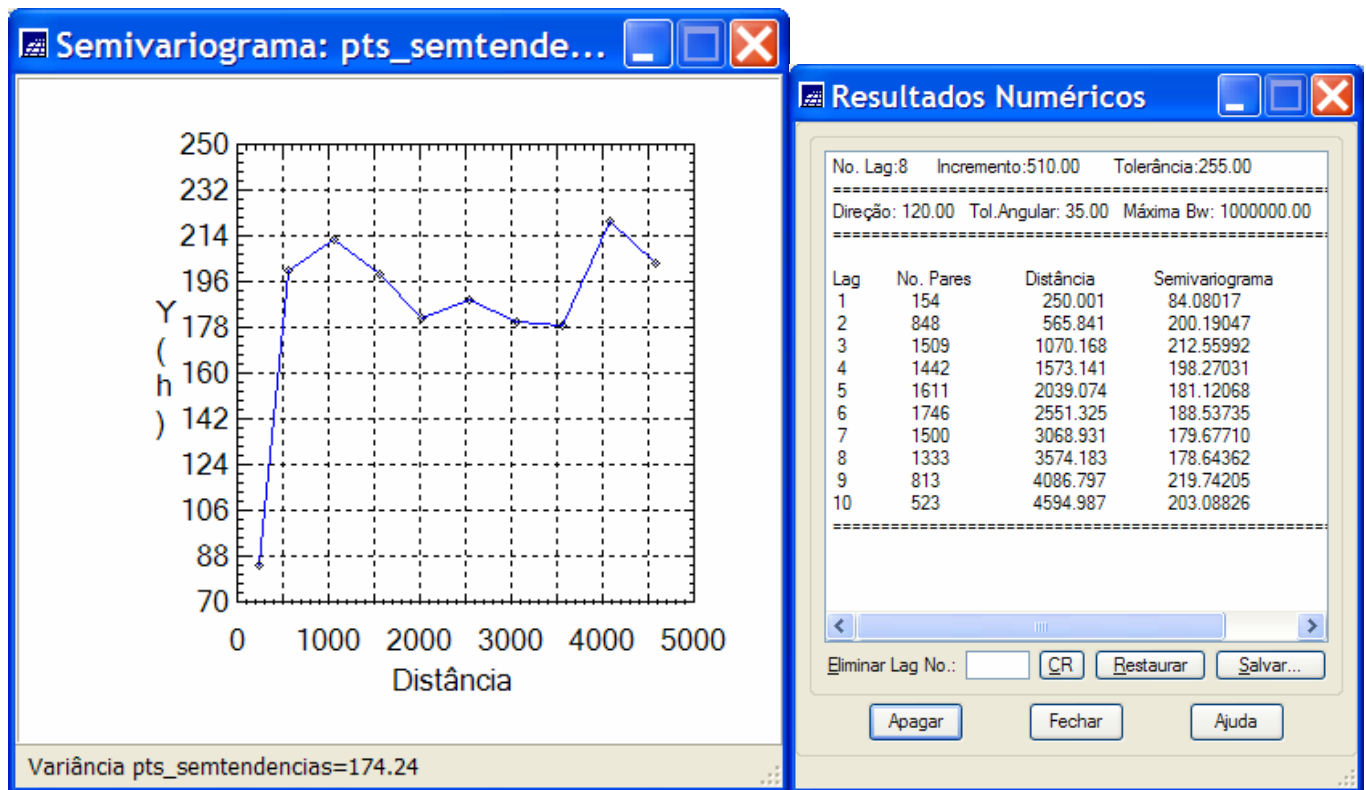
Parametros de Direção

Dir	Dir	Tol	Bw
<input type="checkbox"/>	Dir1: 0.00000	Tol1: 90.00000	Bw1: MAX
<input type="checkbox"/>	Dir2: 30.00000	Tol2: 35.00000	Bw2: MAX
<input checked="" type="checkbox"/>	Dir3: 120.00000	Tol3: 35.00000	Bw3: MAX
<input type="checkbox"/>	Dir4: 135.00000	Tol4: 35.00000	Bw4: MAX

Padronizar Resultado Numérico...

Executar Fechar Ajuda

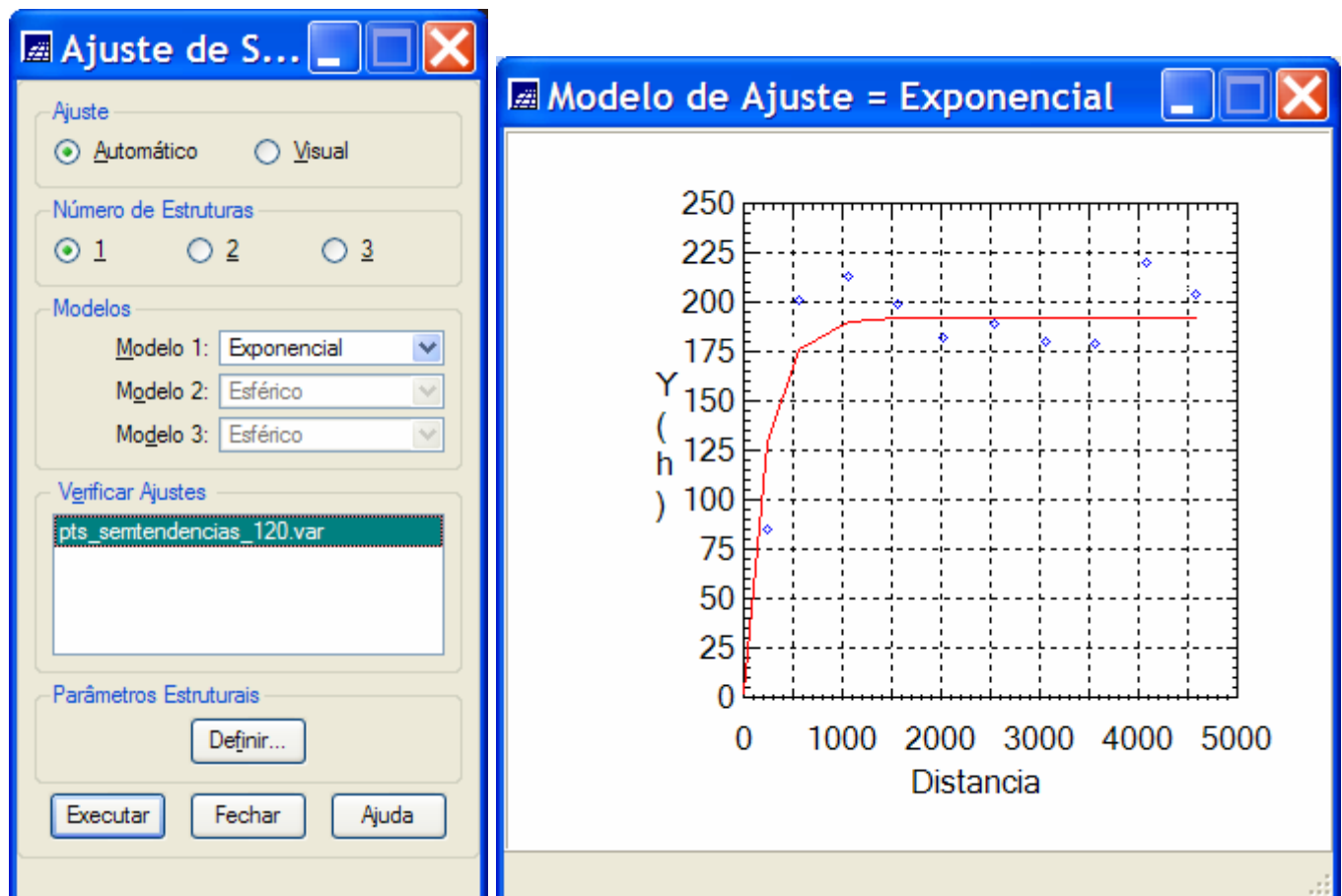
- Click on the **Apply** button to show the semivariogram graph generated from the given parameters. Change the current distance and directions parameters in order to create new semivariograms better than the already created. Use qualitative visual criteria to compare the variograms.
- Observation: Click on the **Numeric Result...** button to display a numeric report related to the experimental semivariogram values (*lag*, *No. pairs*, *distance* and $\gamma(h)$). In this window pay attention mainly to the $\gamma(h)$ values obtained with few pair of points.
- The figures below shows the semivariogram graph and numerical results created from the user defined parameters.



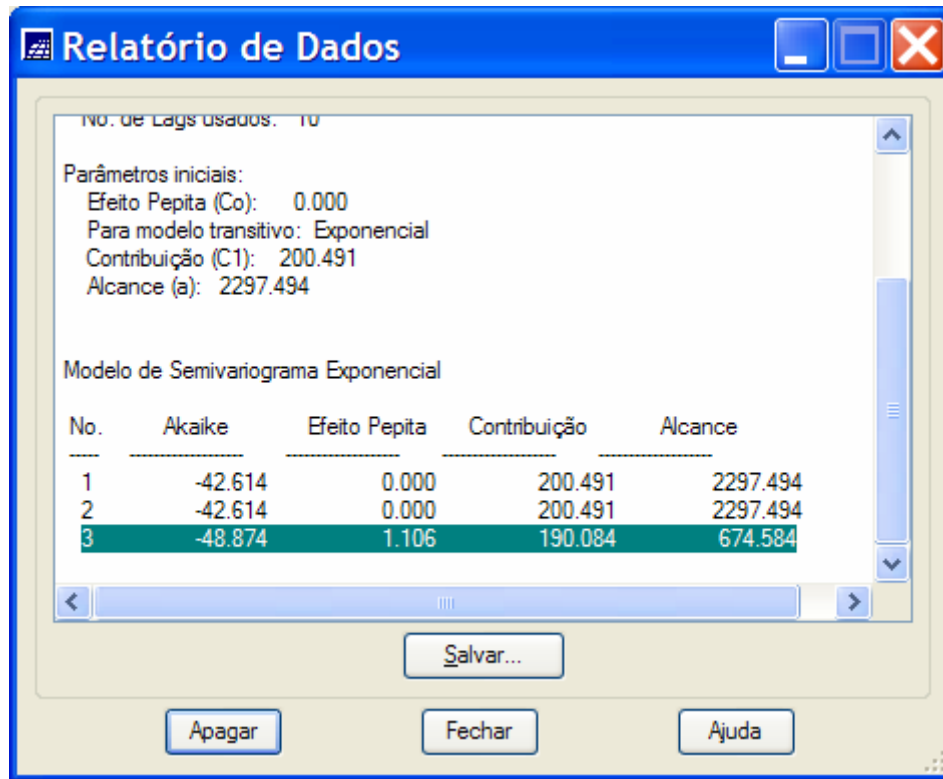
- **Important: Perform visual and quantitative analyses in the above semivariogram. What is approximately its sill value? Compare this sill value with the global variance value of the data. Observe the nugget and range values. Compare the value of the range with the length of the region we are studying (7km x 10km). What is your opinion about the range value of the above semivariogram?**

4.5 Fitting theoretical semivariograms to the experimental one (Direction 120°)

- Select, in the Control Panel, the IL *pts_semtendencias* of the category *Altimetria*.
- In the *Analysis menu* of the SPRING select the **option** *Geostatistics* and, then, select the **option** *Semivariogram Modeling*
- Visualizing Fitted Semivariogramas for the data of the *pts_semtendencias* Info Layer.
 - Select *Automatic* as the **Adjust option** in the Semivariogram Modeling window
 - In this same window select **Number of Structures** equal *1* and *Exponential* for the **Model option**.
 - Click on the **button** *Apply*.
 - Click on the semivariogram name that appears in the Adjust Verification list to show the graph of the fitted semivariogram got with the defined model parameters.
 - Change the parameter values to obtain different theoretical semivariogramas until you find a satisfactory result. Perform qualitative analysis (visual) and quantitative analysis using the data report presented along with the fitted semivariograma graph.



- The Nugget Effect, Contribution and Range parameters of the fitted semivariogram are presented in the last line (see the marked line below) of the Data Report window



- Save the parameter values for posterior manual evaluation of the final theoretical variogram. This will depend on the individual semivariogram models for the two directions of minimum and maximum continuity.

Important: From the two above semivariograms, 30° and 120° directions, a final variogram model has the following formulation (Important: Verify if this final model is right)

$$\gamma(\mathbf{h}) = 1.106 + 5.637 * \text{Exp}\left(\frac{h_{30}}{\varepsilon}, \frac{h_{120}}{674.548}\right) + 184.347 * \text{Exp}\left(\frac{h_{30}}{961.804}, \frac{h_{120}}{674.548}\right) + 10.533 * \text{Exp}\left(\frac{h_{30}}{961.804}, \frac{h_{120}}{\infty}\right)$$

4.6 Defining structural parameters to the anisotropic variogram model

- Click on the *Define...* button in the Semivariogram Modeling window to open a new window where the user must store the final parameters of the semivariogram model.
- Choose number of structures equal 3 and fill out the Nugget Effect field with the value 1.106 (the first structure is always a pure nugget effect)
- The parameters Structure Type, Contribution, Anisotropy Angle (greater continuity) and Minimum and Maximum Ranges must be filled, for the 3 structures, with the values presented in the figure below.

Parâmetros Estrut...

Parâmetros

Número de Estruturas: 1 2 3

Efeito Pepita: 1.106000

Primeira Estrutura

Tipo: Exponencial

Contribuição: 5.63700 Ângulo Anis.: 120.000

Alcance Máx.: 674.547 Alcance Min.: 0.00001

Segunda Estrutura

Tipo: Exponencial

Contribuição: 184.347 Ângulo Anis.: 30.000

Alcance Máx.: 961.804 Alcance Min.: 674.547

Terceira Estrutura

Tipo: Exponencial

Contribuição: 10.533 Ângulo Anis.: 120.000

Alcance Máx.: 100000 Alcance Min.: 961.804

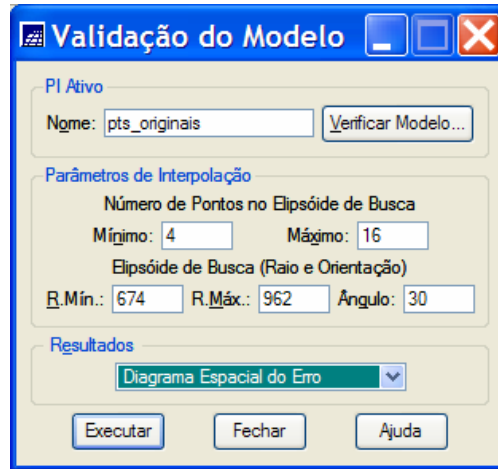
Executar Fechar Ajuda

- Click on the Apply button of the windows Structural Parameters in order to store the final anisotropic model in your computer.

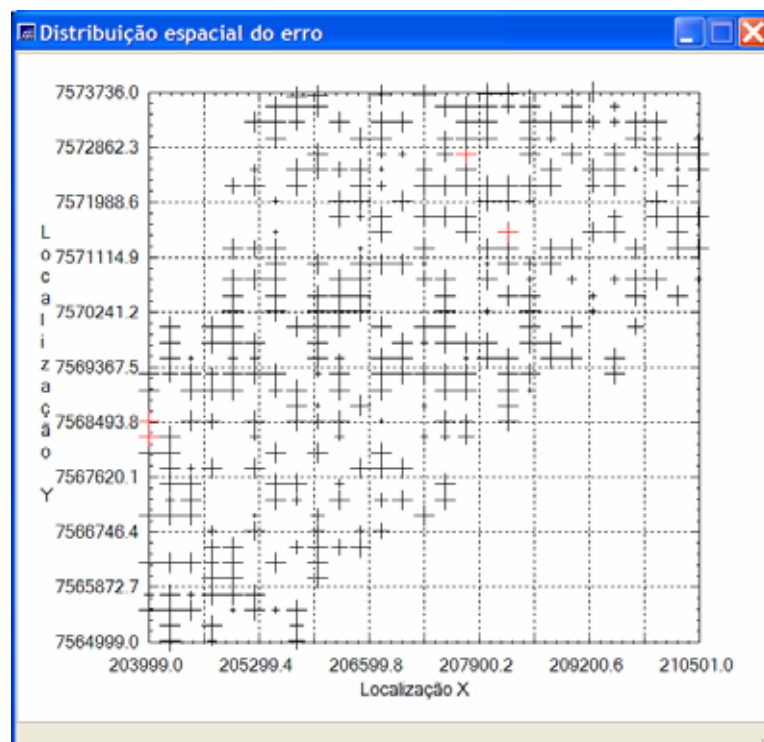
IMPORTANT: To define a semivariogram to the IL pts_originais repeat the sections 4.2 to 4.6 selecting the pts_originais in the Control Panel or you can use the same variogram model you got for the pts_semtendencia. If you are going to use the same variogram go to the next item (4.7)

4.7 Performing the cross validation for the anisotropic model

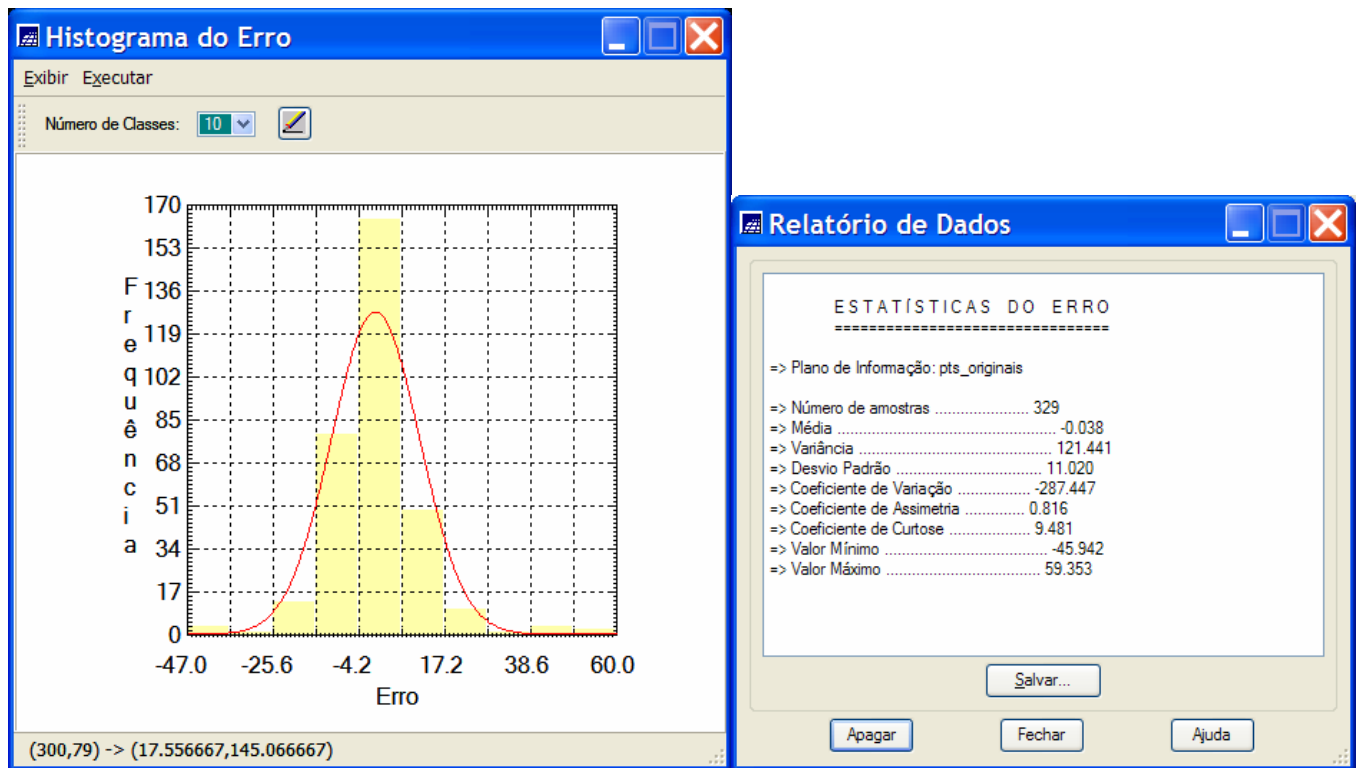
- Select, in the control panel, the *pts_originais* IL of the *Altimetria* category
- In the **Analysis** menu of the SPRING, select **Geostatistics option** and, then, select the **Model Validation ... option**.



- Clicking on the **button** Model Verification... it is possible to verify, to input or to change the values that will be used as parameters for the structural model of the semivariogram to be validated. If the structural parameter fields are empty, fill them out following the instructions of the item 4.6 above. Then press Apply to return to the Model Validation window..
- Define the Interpolation Parameters filling out the **fields Minimum** equal 4, **Maximum** equal 16, **R. Min** equal 674 and **R. Max** equal to 962 and **Angle** equal 30 (anisotropic)
- Click on the **button** Apply of this window and, then, select as **Results: Error Spatial Diagram**. The graph below will be presented.



- o Observe in this graph that the size of the + signals of the diagram are proportional to the estimated local error value related to the observed values. Click on any of this signal to get quantitative information about each individual error.
- o Select *Histogram of Error* as the **Results**, in the Model Validation window, in order to show the graph of the error distribution. The Number of Classes, used to define the intervals for the histogram display can be changed to a different value. To display the histogram after choosing different number of classes click on the **draw button**.
- o A numerical report displaying a summary of statistic of the errors can be obtained selecting the *Statistics of Error* in the **Results options** of the Model Validation window.
- o Observe, in the figures below, the shape of the probability distribution functions (simetric? Gaussian?), the mean value of the errors (closer to 0 indicate non bias), the standard deviation (measure of global error?) and other statistic information.



- o Select, in the Model Validation window, as an **option** of Results : Observed Diagram x Estimated, in order to display the scatter plot of the estimated values against the observed values of the IL *pts_originais*. Check the correlation between the two information and the presence of outliers in this graph.
- o Select the *Numerical option*, in the Results area of the Model Validation window, to get a numerical report showing the values used to plot the scatter plot above.
- o Click on the **Save... button**, of the Data Report window, if you want to save those information in a text file in your computer.

4.8 Estimating numerical grids by Ordinary Kriging with the anisotropic model

- Select, in the control panel, the IL *pts_originais* of *Altimetria* category.
- In the **Analysis menu** of SPRING, choose the **Geoestatistics option** and, then, select the **Kriging... option**
- In the Kriging window:
 - Click on the **button Model Verification** to check, or edit, the parameter values of the variogram model that was defined for the current sample set.
 - Select as a **Kriging type** the *Ordinary option*.
 - For the grid parameters keep the same **bounding box** of the project and the default values for resolutions X and Y (**ResX** and **RexY**). The default values will create a grid in the entire project area with 200 rows x 200 columns.
 - Fill out the **fields** related to the Interpolation Parameters as: **Minimum**: equal 4 and **Maximum** equal 16 (these parameters define the Minimum and Maximum number of the closest points that will be considered in the interpolation). **R. Min** equal to 674 and **R. Max** equal 962 (these parameters are related to the search ellipsoid that determine the influence area of each point to be interpolated. The values are different because the attribute variation in space is been modeled as anisotropic). The **Angle field** must be filled out with value 30 (angle of the greater continuity variation)
 - Choose the *Altimetria* category clicking on the **Category... button**.
 - Fill out the **InfoLayer field** with the name: *krig_ord_pts_origin_anis*
 - Click on the **Apply button** to finally run the ordinary kriging.

Krigagem

PI Ativo
Nome:

Krigagem
Tipo: Média:

Definição de Grade
Res. X: Res. Y:

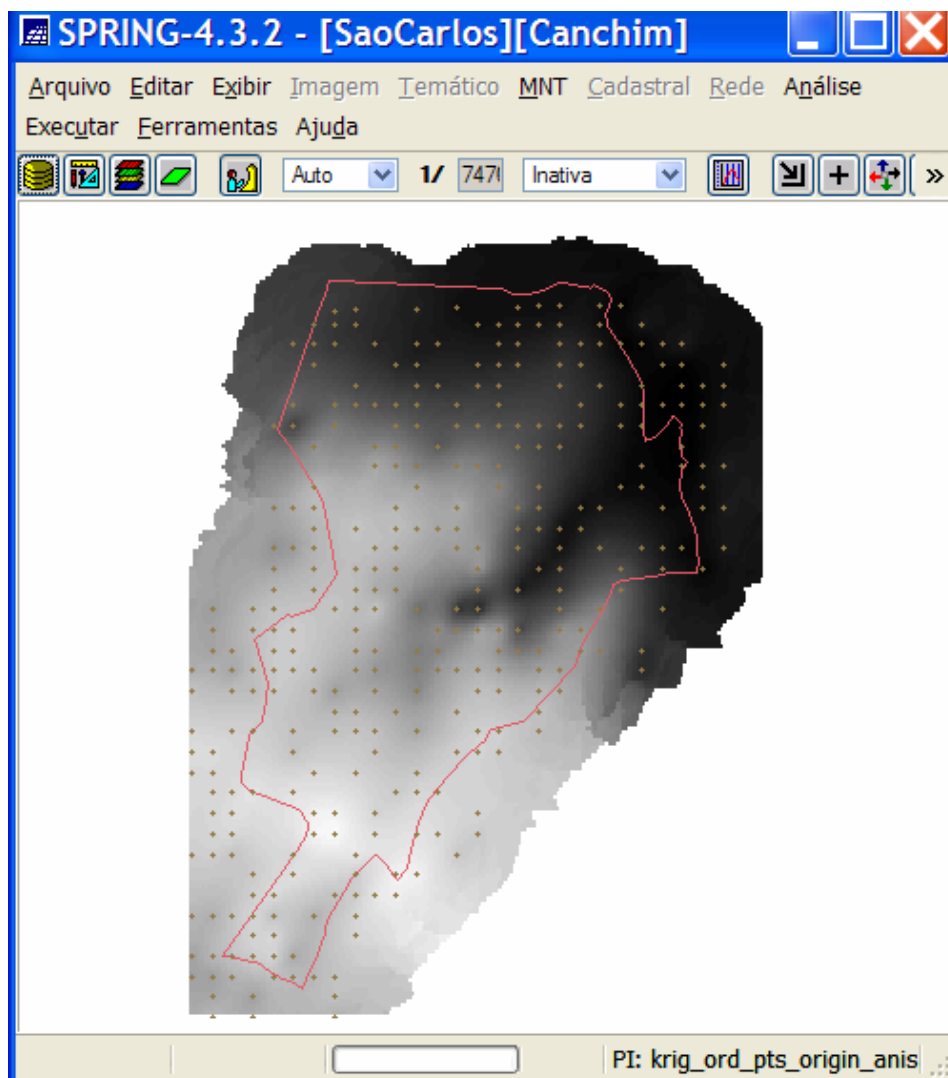
Parâmetros de Interpolação
Número de Pontos no Elipsóide de Busca
Mínimo: Máximo:
Elipsóide de Busca (Raio e Orientação)
R. Mín.: R. Máx.: Ângulo:


Saída

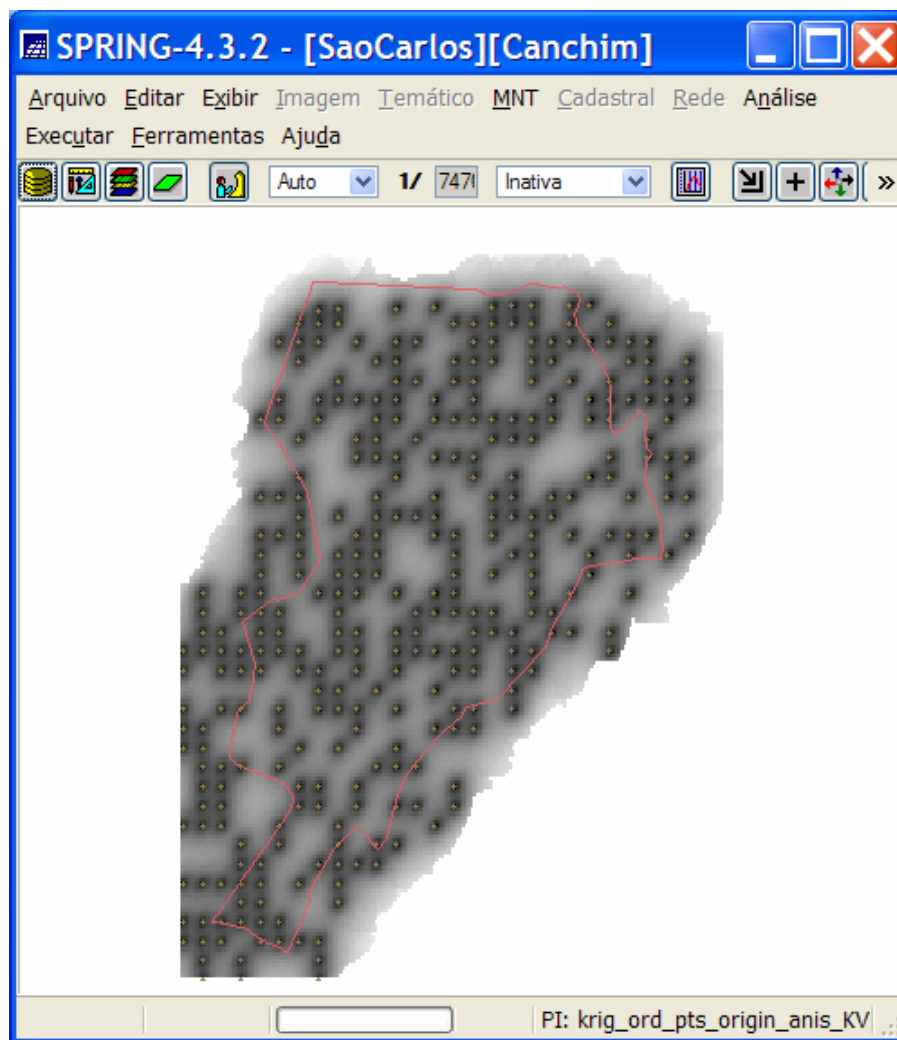
Plano de Informação:

4.9 Visualizing the results in the SPRING graphical display

- Displaying the map of estimates evaluated by ordinary kriging
- In the Control Panel
 - Enable the **Display 1**
 - Select in the list of **Categories**: *Altimetria*
 - Select in the list of **Infolayers** : *krig_ord_pts_origin_anis*
 - Select as representation: *Imagem*
 - Select also the *lines* of the Infolayer *recorte* of the *Limites* category
 - Select also the *samples* of the Infolayer *pts_originais* of the *Altimetria* category.
 - Click on **Draw button**.
- The figure below show the results of the display tasks suggested above. It can be seen the numerical grid evaluated by the ordinary kriging superposed by the elevation samples and the boundaries of the Canchim farm.



- Displaying the map of variance of the estimates evaluated by ordinary kriging
 - In the Control Panel
 - Enable and Show the **Display 2**
 - Select in the list of **Categories**: *Altimetria*
 - Select in the list of **Infolayers** : *krig_ord_pts_origin_anis_KV*
 - Select as representation: *Imagem*
 - Select also the *lines* of the Infolayer *recorte* of the *Limites* category
 - Select also the *samples* of the Infolayer *pts_originais* of the *Altimetria* category.
 - Click on the Draw **button** 
 - The figure below show the results of the display tasks suggested above. It can be seen the numerical grid of the variances evaluated by the ordinary kriging superposed by the elevation samples and the boundaries of the Canchim farm.



- Perform a visual analysis on the results obtained in the two maps above posted. Consider the quality of the estimator and the spatial distribution of the kriging variance. What is opinion about this distribution?

4.10 Comparative results between the isotropic and anisotropic modeling

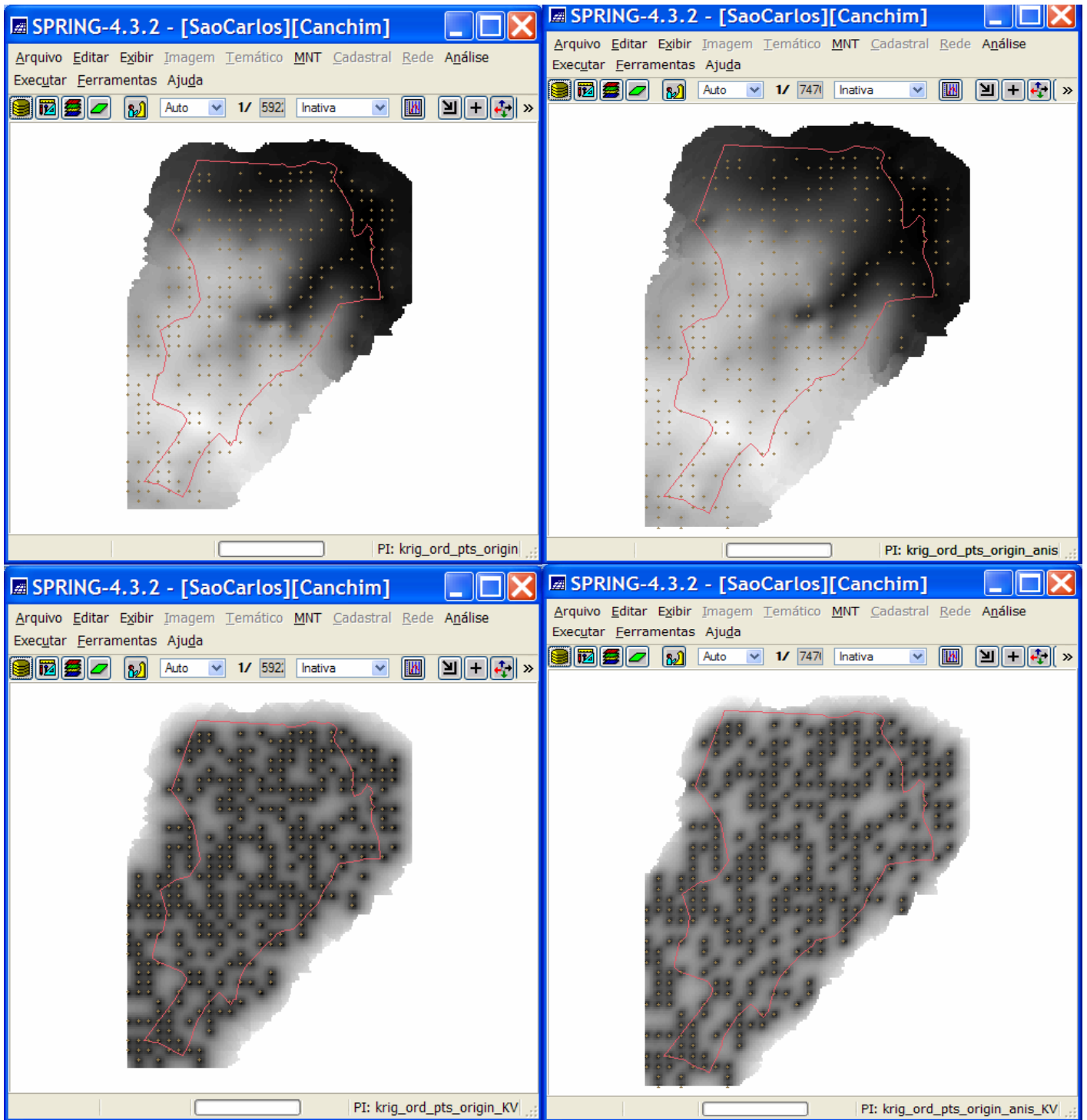


Figure: Maps of means (above maps) and variances (below maps) generated by modeling spatial data as isotropic (left maps) and anisotropic (right maps)