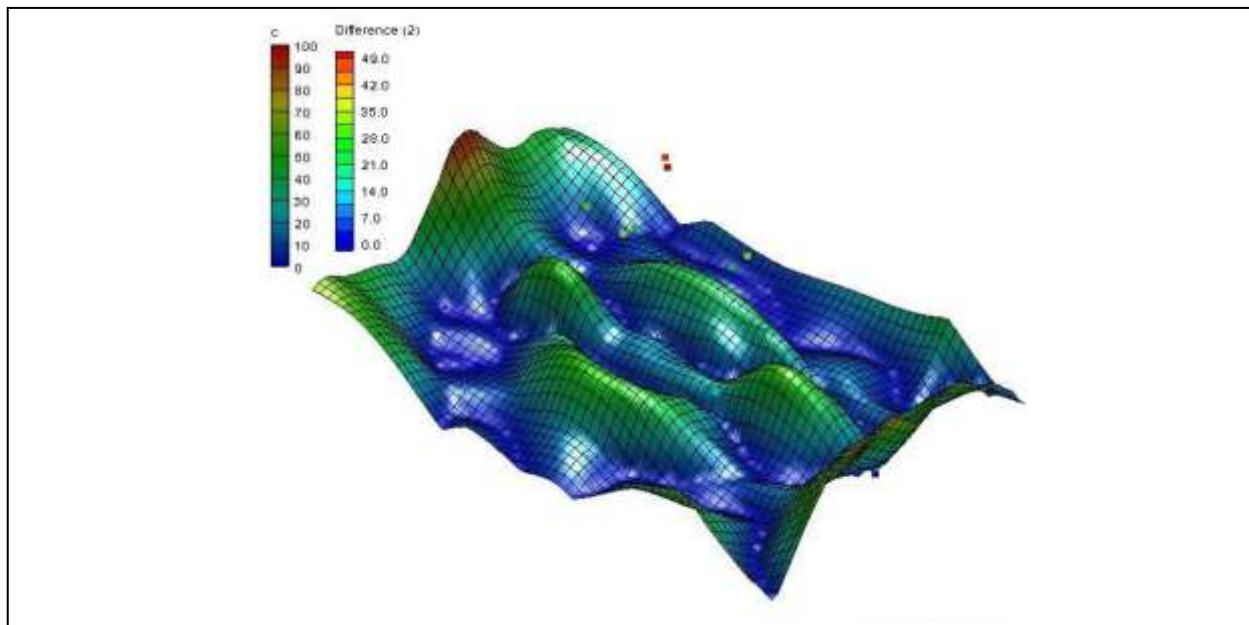


## GMS 10.0 Tutorial

### Geostatistics – 2D

Learn the various 2D interpolation methods available in GMS



### Objectives

Learn to create scatter point sets from scratch and how to import scatter sets from a file. Investigate the various 2D interpolation methods available in GMS, including linear, inverse distance weighted (IDW), and kriging.

### Prerequisite Tutorials

- None

### Required Components

- Grid Module
- Geostatistics

### Time

- 30-45 minutes



<b>1</b>	<b>Introduction .....</b>	<b>2</b>
1.1	Outline.....	2
<b>2</b>	<b>Getting Started .....</b>	<b>3</b>
<b>3</b>	<b>Creating a Scatter Point Set .....</b>	<b>3</b>
<b>4</b>	<b>Importing a Scatter Point Set.....</b>	<b>4</b>
4.1	Open the File .....	4
4.2	Import Wizard—Step 1 .....	4
4.3	Import Wizard—Step 2 .....	5
<b>5</b>	<b>Changing the Display Options .....</b>	<b>6</b>
<b>6</b>	<b>Creating a Bounding Grid .....</b>	<b>7</b>
<b>7</b>	<b>Selecting an Interpolation Scheme.....</b>	<b>7</b>
<b>8</b>	<b>Linear Interpolation.....</b>	<b>7</b>
<b>9</b>	<b>Viewing the Results .....</b>	<b>8</b>
<b>10</b>	<b>Viewing the Elliptical Control Function .....</b>	<b>9</b>
<b>11</b>	<b>Simple IDW Interpolation .....</b>	<b>10</b>
<b>12</b>	<b>IDW Interpolation with Gradient Planes.....</b>	<b>11</b>
<b>13</b>	<b>Using the Horizontal Anisotropy Option .....</b>	<b>12</b>
<b>14</b>	<b>IDW Interpolation with Quadratic Nodal Functions.....</b>	<b>13</b>
<b>15</b>	<b>Truncation .....</b>	<b>14</b>
<b>16</b>	<b>Kriging .....</b>	<b>15</b>
16.1	Creating the Experimental Variogram.....	15
16.2	Creating the Model Variogram.....	16
16.3	Interpolating to the Grid .....	16
<b>17</b>	<b>Switching Datasets .....</b>	<b>17</b>
<b>18</b>	<b>Using the Data Calculator .....</b>	<b>17</b>
<b>19</b>	<b>Conclusion.....</b>	<b>18</b>

## 1 Introduction

---

Two-dimensional geostatistics (interpolation) can be performed in GMS using the 2D Scatter Point module. The module is used to interpolate from sets of 2D scatter points to any of the other object types (meshes, grids, TINs). Several interpolation schemes are supported, including kriging. Geostatistics are useful for setting up input data for analysis codes or for site characterization.

The tools for manipulating scatter point sets and the interpolation schemes supported in GMS are described in this tutorial. The interpolation schemes presented in this tutorial will be easier to understand if the user has read the *Interpolation* section of the *GMS Online Help*. The “Geostatistics – 2D” tutorial should be completed before attempting the “Geostatistics – 3D” tutorial.

### 1.1 Outline

---

Here are the steps of this tutorial:

1. Create a scatter point set from scratch.
2. Import scatter points from a file.
3. Create a bounding grid.

4. Interpolate the scatter points using various interpolation methods.
5. Use the data calculator to compare interpolations.

## 2 Getting Started

---


Do the following to get started:


1. If necessary, launch GMS.
2. If GMS is already running, select the *File* / **New** command to ensure that the program settings are restored to their default state.

## 3 Creating a Scatter Point Set

---

Interpolation in GMS is performed using scatter points. A set of 2D scatter points is defined by a set of xy coordinates. A group of scatter points is called a scatter point set. Each scatter point set may also have a dataset associated with it. Datasets are scalar or vector values—one value at each scatter point. The scatter points represent the geometric objects while the datasets represent the data values at the points. The datasets may represent anything—elevation, heat measurements, concentration of a chemical, etc. The datasets can be interpolated to a TIN, mesh, or grid.

2D scatter point sets can be created inside GMS using the **Create Scatter Points**  tool.

1. In the Project Explorer, right-click on the empty space, and then, from the pop-up menu, select the *New* / **2D Scatter Point Set** menu command.
2. Select the **Create Scatter Points**  tool.
3. Click on the screen a few times in different places.

This is how scatter points are created. When creating each point, GMS automatically assigns a dataset value at the point. The user can change it so that GMS prompts the user for the dataset values.

4. Select the *Scatter Points* / **Scatter Point Settings** menu command.
5. In the dialog, turn on the *Confirm dataset value* option, and click **OK**.
6. Click on the screen.

The *Scatter Point Dataset Value* dialog will appear. Now the user will be prompted to enter a dataset value every time he or she creates a new point.

7. Click **OK** to exit the *Scatter Point Dataset Value* dialog.

This is the only way to enter steady state data. To create a scatter point set with transient data, the user would need to import it from a file. That's what the next step will be.



## 4 Importing a Scatter Point Set

---

Scatter point sets can be imported from an existing file using the *Import Wizard*. The *Import Wizard* allows users to import data into GMS from text files that are in columnar format. The file to be imported here was generated as an Excel spreadsheet and exported from Excel as tab-delimited text. The file contains scatter points which represent locations where the concentration of a contaminant has been estimated using a soil gas survey. The goal is to generate a map of the contaminant plume.

### 4.1 Open the File

---

1. Select the **New**  button, and select **No** when prompted to save changes.
2. Select the **Open**  button.
3. At the bottom of the *Open* dialog, change the *Files of type* filter to “Text Files (\*.txt,\*.csv).”
4. Locate and open the directory entitled *Tutorials\Geostatistics\geos2d*.
5. Select the file named “plumedat.txt.”
6. Click on the **Open** button.

The *Import Wizard* should appear. The first step of the *Import Wizard* allows users to specify how the data is delineated and where in the file the data should begin. For this file, the first row contains column headings. The first column contains the point labels, the second column contains the X values of the points, the third column contains the Y values, and the fourth column contains the dataset values for the points.

### 4.2 Import Wizard—Step 1

---

1. Turn on the *Heading row* option as shown in Figure 1 below.

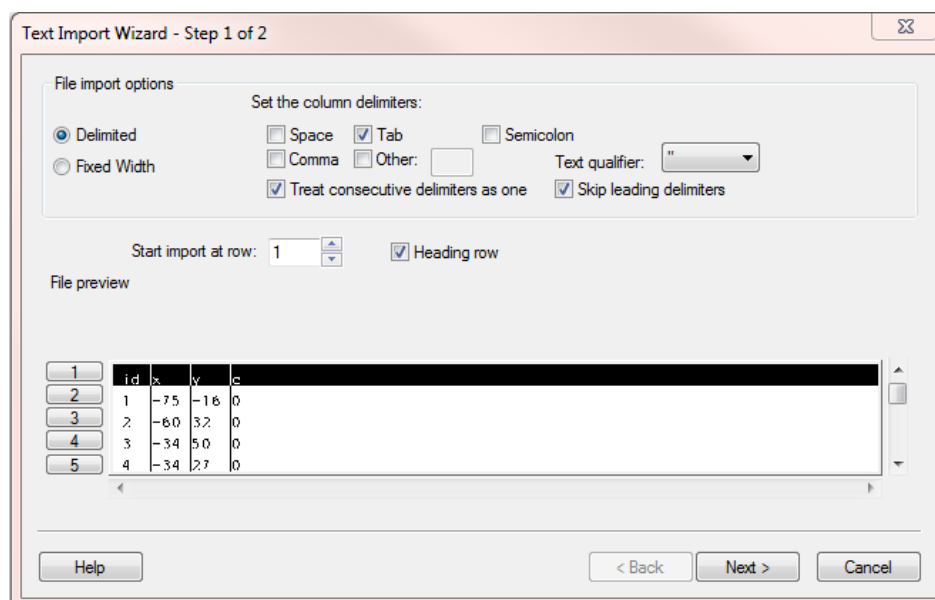


Figure 1 Text Import Wizard, Step 1

2. Select the **Next** button.

### 4.3 Import Wizard—Step 2

Step 2 of the *Import Wizard* allows users to specify what the data in the file means.

1. Select “2D Scatter Points” as the *GMS data type*.

The data associated with 2D scatter points is now displayed in the *Mapping options* section. The next step is to tell GMS what each column in the file means. This is done by selecting the correct data type in the *Type* row of the spreadsheet for each column in the file. The *Type* row is the first row in the spreadsheet. The options in the combo box change depending on the GMS data type selected in the top of the dialog. Since the user specified the use of a heading row in the first step, GMS looked at the headings and automatically found and mapped the X and Y columns by selecting the X and Y selection in the *Type* row of the spreadsheet.

2. Locate the *Type* row, the first row in the spreadsheet. The first column contains IDs for each point.
3. In the *Type* row for the first column, select the “Label” option in the pull-down menu.
4. For the column with heading “c,” make sure the type is set to “Dataset.”

The dataset in this file represents concentrations of a contaminant. The *No data* option can be used to specify a key value in the file used to indicate a lack of information. For example, if no measurement was taken at one of the points, the user might enter “-999” or some other key value for the concentration and specify “-999” as the *No data* value in the *Import Wizard*. GMS will then know to ignore these points when doing the

interpolation later. The key value should be a value that would not normally be encountered in the dataset. In this case, the user doesn't need to use this option.

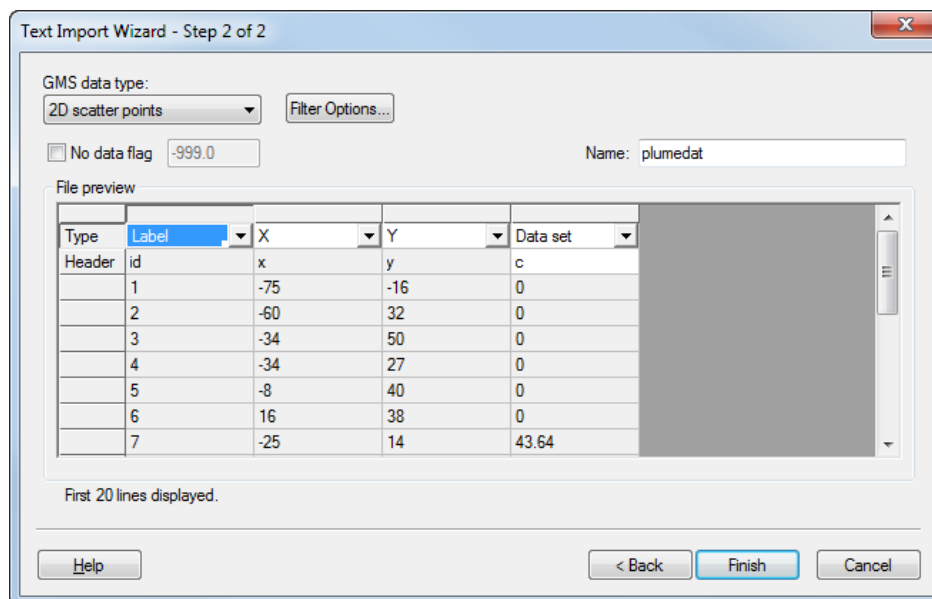




Figure 2 Text Import Wizard, Step 2

- Make sure the dialog looks like Figure 2, and click the **Finish** button.


A set of points should appear on the screen.

## 5 Changing the Display Options

Users can change the appearance of the scatter points using the *Display Options* dialog:

- Select the **Display Options**  button.
- In the *Display Options* dialog, select the *2D Scatter Data*  item from the list on the left.
- Select the *Scatter point symbols* option and the *Contours* option.
- Select the **OK** button to exit the *Display Options* dialog.

Each of the points should now be displayed with a colored square. The color of the symbol represents the relative concentration of the contaminant at the point. When displaying colored symbols, it is useful to also display a color legend.

- Select the *Display Options*  button.
- Select the **Options** button next to the *Contours* option.
- In the *Dataset Contour Options* dialog, turn on the *Legend* option.


8. Select the **OK** button to exit the *Dataset Contour Options* dialog.
9. Select the **OK** button to exit the *Display Options* dialog.

Notice that the concentrations vary from 0.0 to about 100.0.


## 6 Creating a Bounding Grid

---

The goal of this tutorial is to generate a series of contour plots illustrating the plume. To do this, it is first necessary to create a grid that bounds the scatter point set and then it will be possible to interpolate the concentrations from the scatter points to the grid nodes. The grid will then be contoured.

1. In the Project Explorer, right-click on the “plumedat”  scatter point set and select the **Bounding 2D Grid** menu command.

In the *Bounding 2D Grid* dialog, notice that the x and y dimensions of the grid are already defined. The default values shown in the dialog cause the grid to extend beyond the scatter points by 10% on each side.

2. In the *X-Dimension* section, enter “60” for the *Number of cells*.
3. In the *Y-Dimension* section, enter “40” for the *Number of cells*.
4. Select the **OK** button.
5. Select the **Frame**  button.

A grid should appear on the screen that encompasses only the scatter point set.

## 7 Selecting an Interpolation Scheme

---

The next step is to select an interpolation scheme. Several interpolation schemes are supported in GMS because no particular interpolation scheme is superior in all situations. Typically, the best approach is to try several schemes and then determine which scheme is giving the most reasonable results. GMS has been structured in such a way that several different schemes can be tested quickly and easily.

## 8 Linear Interpolation

---

Do the following to try simple linear interpolation:

1. Select the *Interpolation* | **Interpolation Options** menu command.
2. In the *2D Interpolation Options* dialog, select the *Linear* option under *Interpolation method*.

3. Select the **OK** button.

To interpolate to the grid, do the following:

4. Select the *Interpolation* / **Interpolate** → **2D Grid** menu command.
5. When the *Interpolate* → *Object* dialog appears, click **OK**.



## 9 Viewing the Results

---

A set of contours should now be displayed. The concentrations have been interpolated to the grid.

1. Select the **Oblique View**  button.

Notice that the grid has been deformed to match the contours. Color shading the entire surface can provide an even more effective display of the grid.

2. Select the **Display Options**  button.
3. Select the *2D Grid Data*  item from the list on the left.
4. Make sure the *Contours* option is checked.
5. Then select the **Options** button to the right of the *Contours* option.
6. The *Dataset Contour Options* dialog will appear.
7. For the *Contour method*, select “Color Fill.”
8. Select the **OK** button to exit this dialog.
9. Select the **OK** button to exit the *Display Options* dialog.

The resulting image should look like Figure 3.



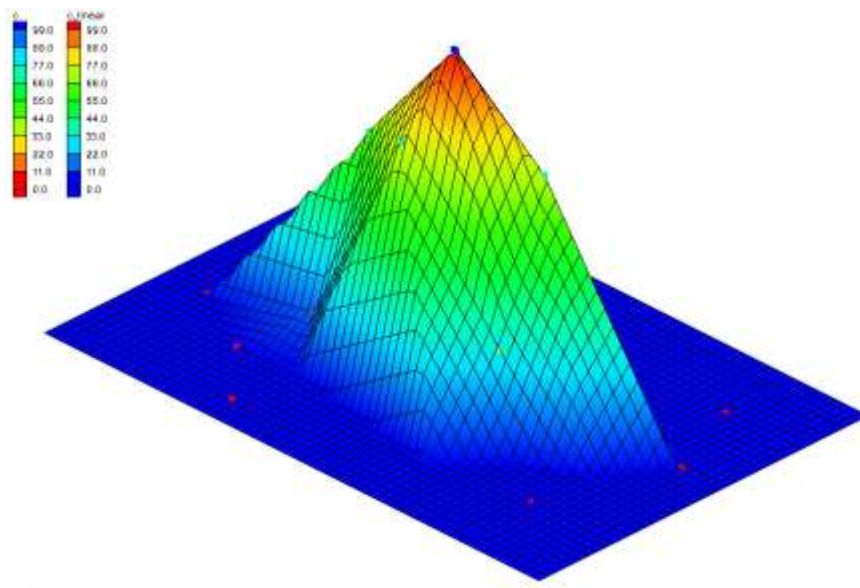



Figure 3 Linear interpolation with color fill

Notice that the outer part of the grid still has a concentration value equal to zero. When linear interpolation is performed, the scatter points are triangulated to form a temporary TIN. A plane equation is computed for each triangle in the TIN and the coefficients of the plane equation are used to interpolate to points inside the triangle. Therefore, linear interpolation cannot be performed for grid nodes outside the convex hull of the TIN (the boundary of the TIN). As a result, these nodes are assigned a value of zero. However, for this application, a value of zero is appropriate since the concentrations of the scatter points on the perimeter of the scatter point set are zero.

## 10 Viewing the Elliptical Control Function

The scatter points were generated from an elliptical control function. It's interesting to see how the different interpolation schemes compare to the original control function. To view the original control function:

1. Right-click on the “grid”  item in the Project Explorer and select the **Import Dataset...** option.
2. In the *Dataset Filename* dialog, choose “All Files (\*.\*)” for *Files of Type*.
3. Open the directory entitled *Tutorials\Geostatistics\geos2d*.
4. Select the file named “ellipse2g.dat,” and click *Open*.
5. Select the “control\_function” dataset in the Project Explorer to make it active.

The result should resemble Figure 4.

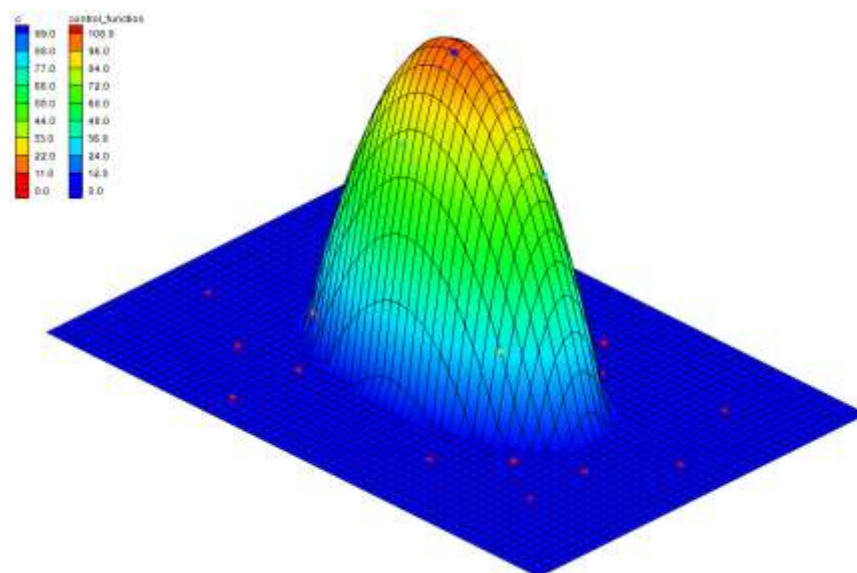



Figure 4 Interpolation scheme with original control function

## 11 Simple IDW Interpolation

The next scheme to try is a simple form of inverse distance weighted (IDW) interpolation.

1. Click on the “2D Scatter Data”  folder in the *Project Explorer*.
2. Select the *Interpolation* | **Interpolation Options** menu command.
3. In the *2D Interpolation Options* dialog, select the *Inverse distance weighted* option in the *Interpolation method* section.
4. Select the **Options** button to the right of the *Inverse distance weighted* option.
5. The *2D IDW Interpolation Options* dialog will appear.
6. In the *Nodal function* section at the top of the dialog, select the *Constant (Shepard’s method)* option.
7. Select the **OK** button to exit the *2D IDW Interpolation Options* dialog.
8. Select the **OK** button to exit the *2D Interpolation Options* dialog.

To interpolate to the grid, do the following:

9. Select the *Interpolation* | **Interpolate → 2D Grid** menu command.
10. When the *Interpolate → Object* dialog appears, select the **OK** button.

The result should resemble Figure 5.

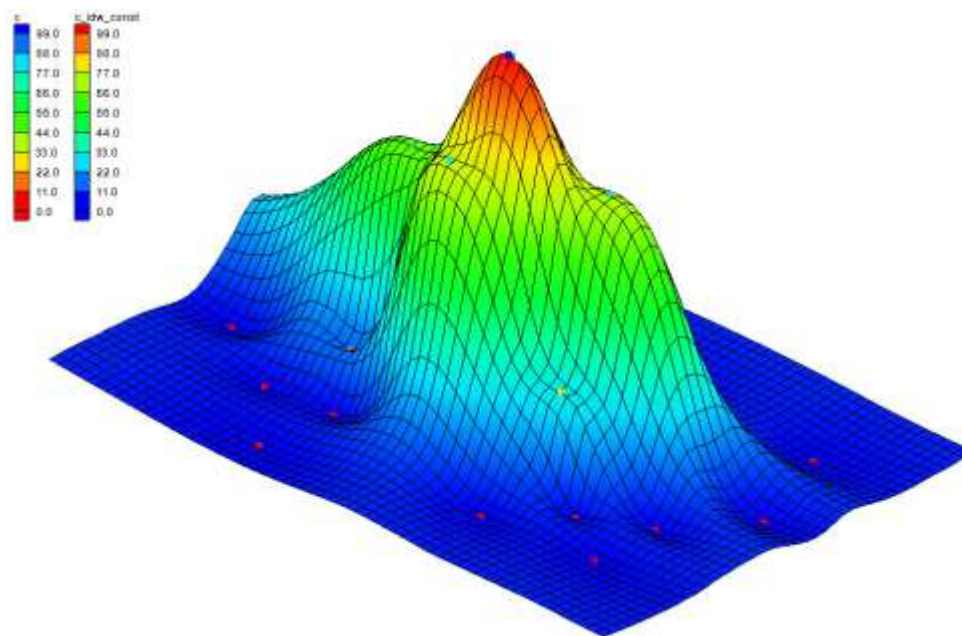


Figure 5 Inverse distance weighted (IDW) interpolation

The *IDW* scheme is a simple moving weighted averages scheme. To interpolate a value at a point, a weighted average of the nearby scatter points is used. The weights are an inverse function of distance. The closer a scatter point is to the interpolation point, the greater the weight given to the scatter point.

## 12 IDW Interpolation with Gradient Planes

One of the problems with simple *IDW* interpolation is that the interpolated dataset always tends toward the mean of the dataset in the voids between scatter points. As a result, local minima or maxima in the voids in the scatter point set are not properly inferred. To overcome this problem, a “nodal function” can be computed at each scatter point.

A “nodal function” is a plane or quadratic function that is forced to pass through the scatter point and approximate the nearby scatter points in a least squares sense. When the interpolation is performed, rather than computing an average of the dataset values at the scatter point locations, an average is computed of the nodal functions of the nearby scatter point evaluated at the interpolation point. This approach allows local trends to be inferred and often results in a more accurate interpolation.

The next scheme to try is *IDW* interpolation with planar nodal functions.

1. Select the *Interpolation* | **Interpolation Options** menu command.
2. In the *2D Interpolation Options* dialog, select the **Options** button to the right of the *Inverse distance weighted* option.

3. In the *2D IDW Interpolation Options* dialog, find the *Nodal function* section at the top of the dialog.
4. Then select the *Gradient plane* option.
5. Select the **OK** button to exit the *2D IDW Interpolation Options* dialog.
6. Select the **OK** button to exit the *2D Interpolation Options* dialog.

Do the following to interpolate to the grid:

7. Select the *Interpolation / Interpolate → 2D Grid* menu command.
8. When the *Interpolate → Object* dialog appears, select the **OK** button.

See Figure 6 for the results.

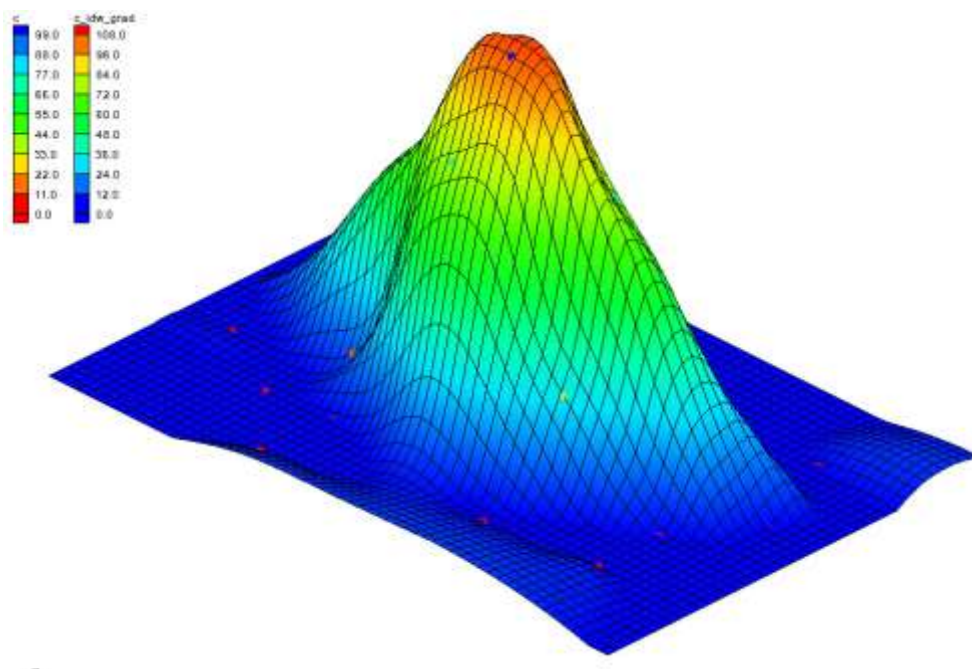


Figure 6 IDW interpolation with planar nodal functions

## 13 Using the Horizontal Anisotropy Option

The interpolation can be “stretched” in a horizontal direction by using the horizontal anisotropy option in conjunction with a specified azimuth. This option might be used if, for example, the user knows that a contaminant plume is elongated in a particular direction due to groundwater flow.

Do the following to change the horizontal anisotropy:

1. Select the **Plan View**  button.

2. Select the *Interpolation* | **Interpolation Options** menu command.
3. In the *2D Interpolation Options* dialog, change the *Horizontal anisotropy* value to “2.0.”
4. Change the *Azimuth* value to “90.0.”
5. Select the **OK** button.
6. Select the *Interpolation* / **Interpolate** → **2D Grid** menu command.
7. In the *Interpolate* → *Object* dialog, enter “c\_idw\_grad\_h2” for the *Interpolated dataset name*.
8. Select the **OK** button.

As can be seen in Figure 7, the data has been stretched in the horizontal direction. The user might want to experiment with different values for the horizontal anisotropy.

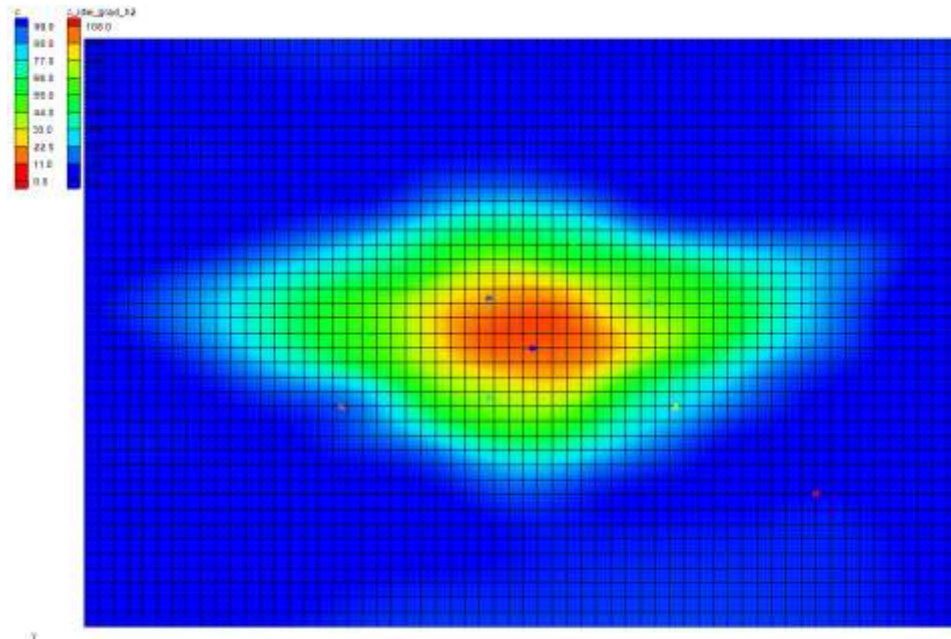


Figure 7 Horizontal anisotropy

## 14 IDW Interpolation with Quadratic Nodal Functions

The nodal functions used in IDW interpolation can also be quadratic functions which are constrained to pass through the scatter point and approximate the neighboring scatter points in a least-squares fashion. The averaging or blending of the quadratic functions during the interpolation stage often results in a very smooth surface.

1. Select the **Oblique View**  button.



2. Select the *Interpolation* | **Interpolation Options** menu command.
3. In the *2D Interpolation Options* dialog, select the **Options** button to the right of the *Inverse distance weighted* option.
4. In the *2D IDW Interpolation Options* dialog, find the *Nodal function* section at the top of the dialog.
5. Select the *Quadratic* option.
6. Select the **OK** button to exit the *2D IDW Interpolation Options* dialog.
7. Select the **OK** button to exit the *2D Interpolation Options* dialog.

To interpolate to the grid, do the following:

8. Select the *Interpolation* / **Interpolate → 2D Grid** menu command.
9. In the *Interpolate → Object* dialog, select the **OK** button.

Refer to Figure 8 for the resulting image.

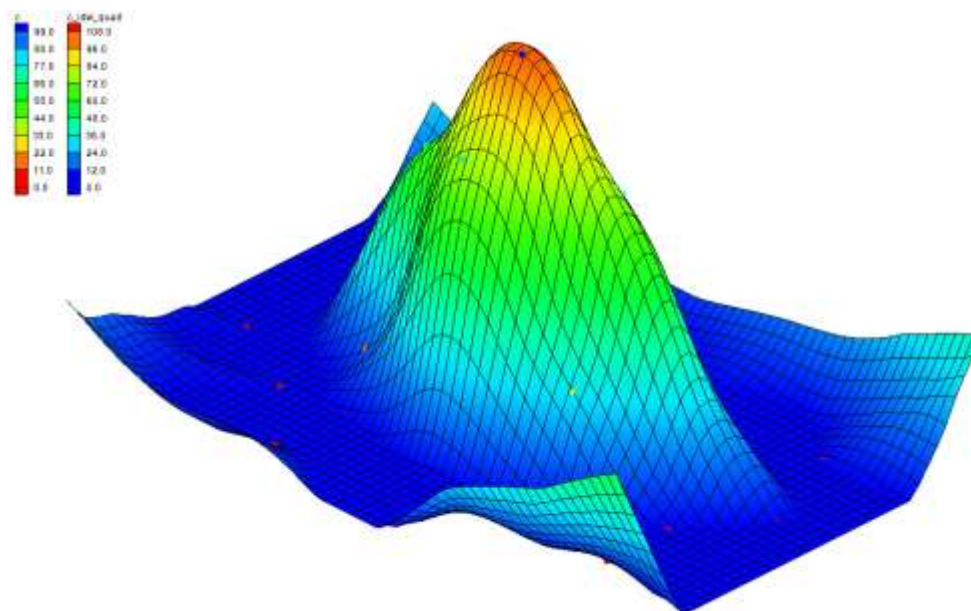


Figure 8 Quadratic nodal functions

## 15 Truncation

Notice that the minimum value listed in the color legend is a negative number. Of course, this is impossible since there is no such thing as a negative concentration. By inferring trends, the nodal functions can sometimes project the plume values beyond zero and into the negative range. This type of error can be easily fixed using truncation.

1. Select the *Interpolation* | **Interpolation Options** menu command.
2. In the *2D Interpolation Options* dialog, turn on the *Truncate values* option in the lower right-hand side of the dialog.
3. Beneath that option, select the *Truncate to specified range* option.
4. Enter “0.0” for the *Min* value, and enter “150.0” for the *Max* value.

The concentrations should not go below zero, but it is okay to allow the interpolation scheme to infer a maximum concentration greater than the maximum measured value.

5. Select the **OK** button.
6. Select the *Interpolation* | **Interpolate → 2D Grid** menu command.
7. In the *Interpolate → Object* dialog, enter “c\_idw\_quad\_trunc” for the *Interpolated dataset name*.
8. Select the **OK** button.

Notice that the concentrations are now mostly zero around the perimeter of the map.

## 16 Kriging

---

The last interpolation scheme to test is kriging. Kriging is based on the assumption that points that are near each other have a certain degree of spatial correlation, but that points that are widely separated are statistically independent. Kriging is a set of linear regression routines that minimizes estimation variance from a predefined covariance model.

1. Select the *Interpolation* | **Interpolation Options** menu command.
2. In the *2D Interpolation Options* dialog, select the *Kriging* option under the *Interpolation method* section.
3. Select the **Options** button to the right of the *Kriging* option.
4. This brings up the *Kriging Options* dialog.

### 16.1 Creating the Experimental Variogram

---

There are a large number of options to be specified in the *Kriging Options* dialog. Fortunately, the defaults shown are adequate in most cases. However, a variogram must always be defined.

1. In the *Kriging Options* dialog, select the **Edit Variograms** button to bring up the *Variogram Editor*.

2. Select the **New** button in the section entitled *Experimental variogram*.
3. In the *Experimental Variogram* dialog, select the **OK** button to accept the defaults.

A curve should appear in the upper window of the *Variogram Editor*. This curve is called an experimental variogram. The experimental variogram is found by calculating the variance in dataset values of each scatter point in the set with respect to each of the other points and plotting the variances versus the distance between the points.

As can be seen in the plot of the experimental variogram, the shape of the variogram indicates that, at small separation distances, the variance is small. In other words, points that are close together have similar data values. With many datasets, after a certain level of separation, the variance in the data values becomes somewhat random and the variogram oscillates around a value corresponding to the average variance. However, with concentration data, many of the points have zero values and this tends to pull the experimental variogram back down.

## 16.2 Creating the Model Variogram

---

Once the experimental variogram is computed, the next step is to define a model variogram. A model variogram is a simple mathematical function that models the trend in the experimental variogram. The model variogram is used in the kriging computations.

1. While still in the *Variogram Editor* dialog, select the **New** button in the section entitled *Nested structure*.
2. For the *Model function*, select the “Gaussian” option.
3. Enter a value of “25.0” for the *Nugget*, “1965.0” for the *Contribution*, and “63.0” for the *Range*.

At this point, a reasonable fit should exist between the model and the first part of the experimental variogram. The second part is difficult to fit in this case because of the zero values described above.

4. Select the **OK** button to exit the *Variogram Editor*.
5. Select the **OK** button to exit the *Kriging Options* dialog.
6. Select the **OK** button to exit the *2D Interpolation Options* dialog.

## 16.3 Interpolating to the Grid

---

To interpolate to the grid:

1. Select the *Interpolation / Interpolate → 2D Grid* menu command.
2. In the *Interpolate → Object* dialog, select the **OK** button.



As seen in Figure 9, notice that this interpolation scheme results in an upward curvature towards the outside edges of the grid. If users wanted to correct this, they could add more scatter points with a concentration of 0.0 in these outlying areas.

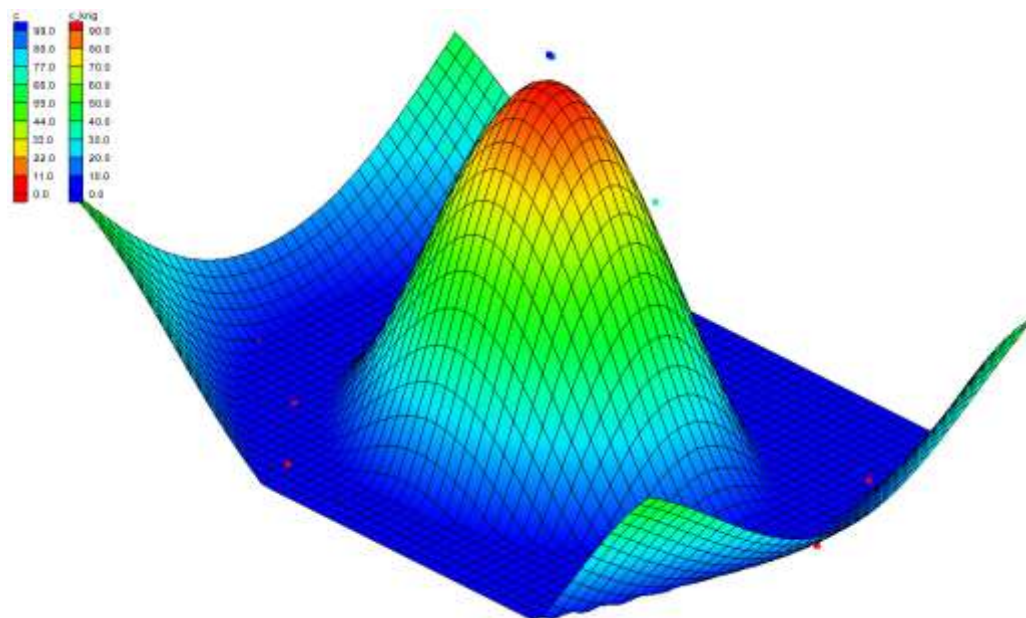





Figure 9 Model variogram

## 17 Switching Datasets

Now that the user has interpolated to the grid using several different interpolation schemes, he or she may wish to review the results by replotting some of the interpolated datasets. To do this, the user can switch back to one of the previous datasets using the Project Explorer.

1. Select the **Plan View**  button.
2. In the Project Explorer, select the “c\_linear” dataset under the “grid”  item in the “2D Grid Data”  folder.
3. Use the up and down keys to switch between the datasets and watch the contours change.

## 18 Using the Data Calculator

Occasionally, it is useful to use the *Data Calculator* to compare two datasets generated by interpolation. As an example, this tutorial will use the *Data Calculator* to compute the difference between the kriging and IDW quadratic datasets.

1. Select the *Data Calculator*  tool.


The currently available datasets are listed in the top of the dialog. Each dataset is numbered from “d1” to “d10”. Datasets are referenced in the mathematical expression using the “d” numbers. The “c\_krig” dataset should be numbered “d10” and the “c\_idw\_quad” dataset should be labeled “d7.”

2. In the *Expression* field, enter “abs(d7-d10).”
3. In the *Result* field, enter “Difference.”
4. Select the **Compute** button.

This will compute the difference between the two datasets. Now that the user has computed the difference between two datasets, it is helpful to view some basic statistics related to the new dataset.

5. Select the **Dataset Info** button.

The resulting *Dataset Info* dialog displays basic statistics related to the active dataset such as minimum, maximum, and mean data values.

6. Select the **OK** button to exit the *Dataset Info* dialog.
7. Select the **Done** button to exit the *Data Calculator* dialog.
8. Select the **Frame**  button.

The contour plot now displayed represents the dataset that was just computed. Any new dataset computed using the *Data Calculator* is automatically designated the active dataset.

## 19 Conclusion

---

This concludes the tutorial. Here are some of the key concepts in this tutorial:

- Users can interpolate from a sparse set of points to a different set of points (usually more dense and surface-defining points) by using 2D scatter points.
- 2D scatter points can be created by hand or imported from a file.
- Several interpolation algorithms are available in GMS.
- Linear algorithms do not interpolate beyond the convex hull of the scatter points.
- Anisotropy and truncation can be used to help control the interpolation process.