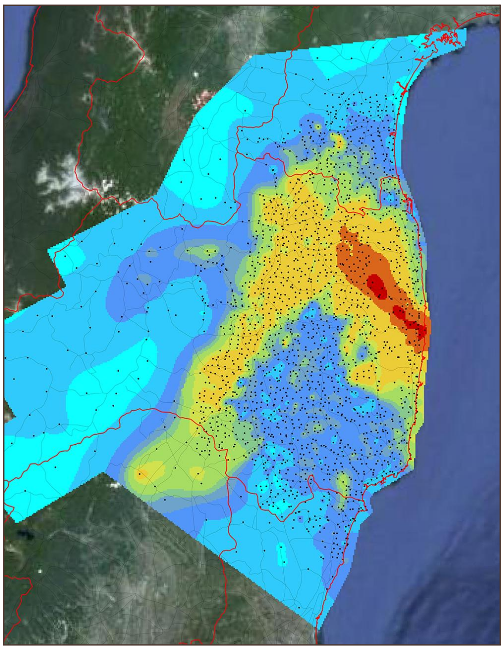
Geovariances

Where no one has gone before

White paper



Dose rate mapping

Are you using the right interpolation method?

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Apply an interpolation method that gives you keys to evaluate the reliability of your maps.

The objective of any serious mapping is to obtain a realistic and reliable image of the studied phenomenon. Concerning dose rate, maps are often derived from punctual measurements interpolated using deterministic methods. Sometimes, the choice of the *inverse distance squared weighted* (IDW2) interpolation is wrongly justified by the fact that the dose rate issued from a punctual source is theoretically inversely proportional to the squared distance between the source and the measurement point.

This white paper shows you why this *inverse distance squared weighted* interpolation is not the appropriate method for dose rate mapping and why the geostatistical approach by kriging is the solution for a quality and reliable mapping.

Geovariances has been applying this geostatistical approach for more than fifteen years in the framework of characterization and remediation projects of sites contaminated with radionuclides (for CEA, Andra, etc.).

Dose rate measurements around a punctual source

Are you confident with the quality of your maps?

With a punctual source, the dose rate decrease is theoretically inversely proportional to the square of the distance to the source. This formula allows estimating the dose rate at a point from a measurement achieved at a given distance from the source. That results from the fact that the global flow is identical over all the spheres (surface proportional to d^2) having their centers at the emission source.

In a working area, a sampling network according to a regular grid (every two meters) allows measuring the dose rate from the punctual source (in the center of the area).

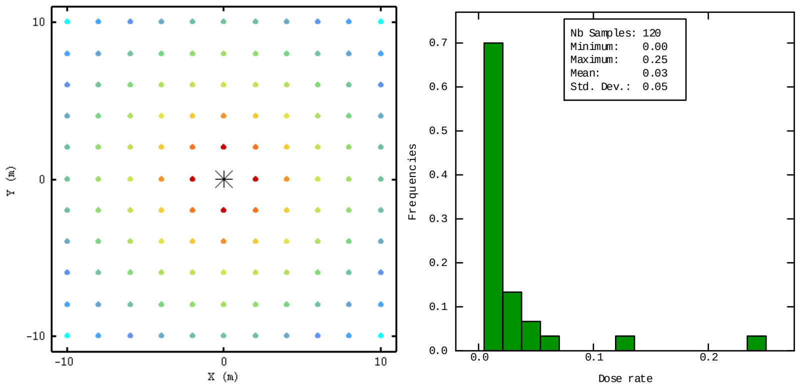

Fig.1 : Regular sampling network around the punctual source and histogram of the measured dose rate

Methodology: taking into account the spatial structure of the measured phenomenon

From this regular measurement network, the objective is to map the entire zone. Two interpolation methods are used:

Does your map give a relevant image of the reality?

- The ***inverse distance squared weighted interpolation***, which aims at calculating the interpolated value as the weighted average of the surrounding information. Weights are calculated as the inverse of the squared distance between the data points and the target point. This deterministic method does not take into account the spatial structure of the phenomenon.
- The ***geostatistical approach***. The variogram model fits the spatial structure of the studied phenomenon observed at measuring points. The estimation is achieved by kriging of the Gaussian-transformed variable (also known as multi-gaussian kriging or conditional expectation), which allows quantifying the estimation uncertainty as a confidence interval at 95%.

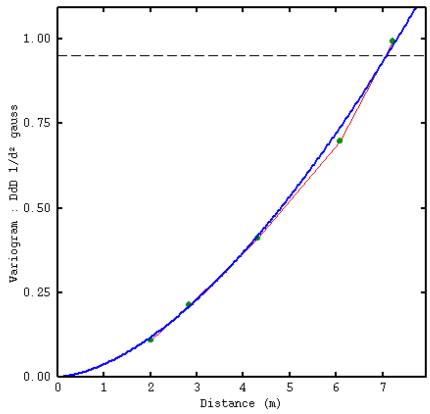

Fig. 2 : Variogram model fitted on the gaussian transform of the dose rate

Benefits of geostatistics

The estimation results are illustrated along a profile around the source (the origin) to a distance of 10 m on both sides of the source (located at X=0).

The data points are distributed every 2 meters along the regular grid.

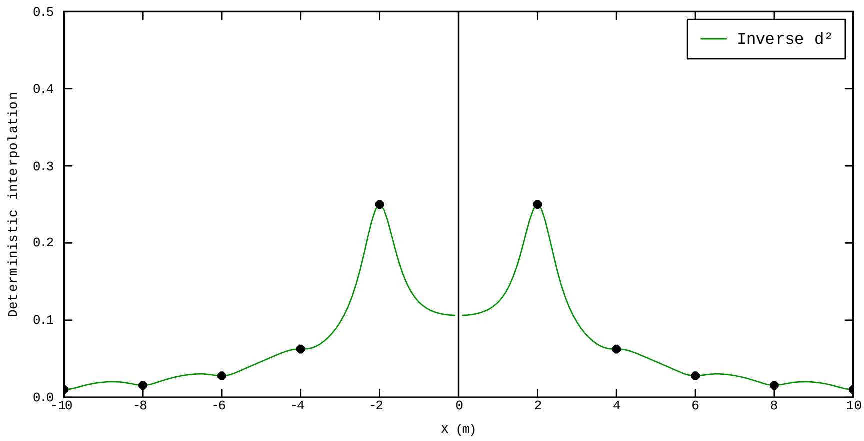

Fig 3 : Dose rate interpolation by inverse distance squared

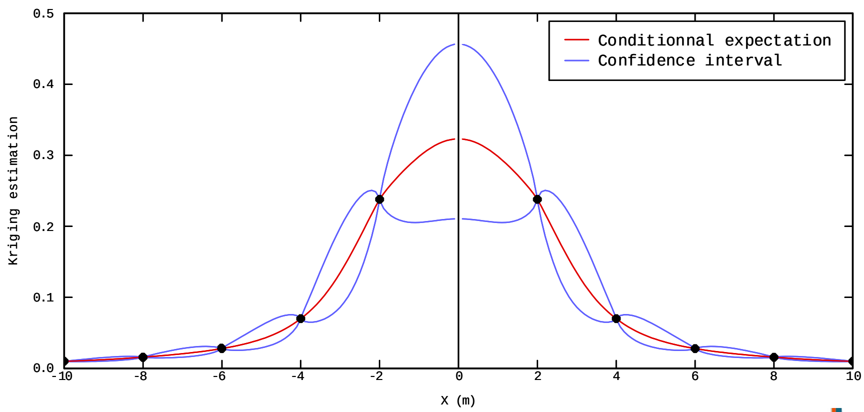

Fig. 4 : Dose rate interpolation by kriging

References

- E. Aubonnet (Geovariances), D. Dubot (CEA): Radiological characterization for decommissioning – methodology, approach and example of a nuclear facility – SFEN 2013
- Y. Desnoyers (Geovariances), D. Dubot (CEA): Geostatistical Methodology for Waste Optimization of Contaminated Premises – ICEM 2011
- J. Attiogbe (Geovariances), D. Dubot (CEA DSV), N. Jeannée (Geovariances), Y. Desnoyers (Geovariances): Isatis and Kartotrak, an efficient combination for the characterization of radiological contaminations - StatGis 2009

Success Story

Since 2012, the French Institute for Radiological Protection and Nuclear Safety IRSN has been applying the geostatistical approach to map the dose rate in the framework of the French territory monitoring. The same methodology has been used in post-accidental situation at Fukushima.

For more information: link.geovariances.com/irsn-success-story.

Kriging provides a confidence interval at each point of the interpolated map.

Kriging allows a more realistic mapping.

The comparison between deterministic interpolation and geostatistical estimation allows highlighting large differences between the interpolation results.

- The ***inverse distance squared weighted interpolation*** shows artificial variations of the estimated values, the interpolator being attracted by the average data trend between the data points. Between 0 and 2 meters, a strong underestimation of the dose rate can be noticed, as well as a slight overestimation between 6 and 8 meters, or between 8 and 10 meters.

- The ***geostatistical estimation*** shows a more consistent and realistic behaviour as it takes into account the spatial structure of the phenomenon. The method even provides estimation values higher than the ones measured on the area close to the source (between -2 and +2 m) because of the good spatial continuity of the phenomenon and of the histogram fitting (gaussian anamorphosis).

  In the present case, the kriging is performed on a gaussian transform of the variable, which provides more advanced estimation results: in addition to the interpolated value, an interval can be calculated for a given confidence level (here equal to 95%). It is obviously more important between the data points and, in particular, for the high values (especially between 0 and 2 m, on both sides of the source).

At data points (every two meters on the abscissa axis), the different interpolators naturally estimate the measured value (unbiased property).

As for mapping results, deterministic interpolation artificially creates several and small hot spots around the real one which is not identified. On the contrary, geostatistics reproduce correctly radiation distribution with a unique and central source as expected.

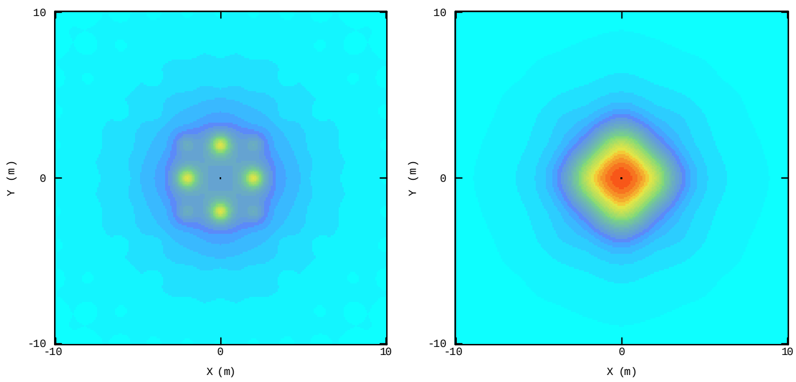

Fig 5 : Dose rate mapping by inverse distance squared interpolation (on the left) and by geostatistical interpolation (on the right)

Geovariances
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Who is Geovariances?

Geovariances is specialist geostatistical software, consulting and training company. We have over 45 staff, including environmental consultants and statisticians.

Geovariances develops and sells two software solutions:

- **Kartotrak** is an integrated software solution dedicated to the characterization of sites contaminated with chemical or radioactive substances.
- **Isatis** is the accomplishment of +25 years of dedicated experience in geostatistics. It is the global software solution for all geostatistical questions.

Unique expertise

Geovariances is a world leader in developing and applying new and practical geostatistical solutions to the environmental industry. We have strong experience in site characterization and have gained trust from the leading environmental and consulting companies.

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Conclusion

It is necessary to distinguish the physical equation of the phenomenon and the mathematical formulas used by the interpolator.

The variogram highlights and models the spatial structure of the phenomenon. Furthermore, the estimation by conditional expectation allows the quantification of the estimation uncertainty, for example through a confidence interval.

For a contaminated area with one or more punctual sources, the inverse distance squared interpolation is not relevant and it is highly recommended to use geostatistical methods. In the same way, geostatistics must be used to process data in the case of large sources, in 2D or in 3D.

Our expertise

Kartotrak is the first all-in-one software solution for contaminated site characterization and is born out from a +10 years partnership between the French Alternative Energies and Atomic Energy Commission CEA and Geovariances. Easy to use, the software offers an integrated workflow which guides the user through each step of his project, from data loading and contamination mapping to contaminated soil volume estimation and uncertainty quantification.

Geovariances offers a unique expertise based on more than fifteen years of experience in applying geostatistics for site remediation projects issues. Most projects have been conducted for the CEA, IRSN, AREVA or ANDRA, the major actors of the French nuclear industry.

For more information

Let us help you understand the geostatistics added-value for your remediation projects or your contamination mapping.

Contact our consultants: consult-env@geovariances.com.