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Standard Guide for
Analysis of Spatial Variation in Geostatistical Site Investigations[1]

This standard is issued under the fixed designation D 5922; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—Paragraph 1.5 was added editorially October 1998.

INTRODUCTION

Geostatistics is a framework for data analysis, estimation, and simulation in media whose measurable attributes show erratic spatial variability yet also possess a degree of spatial continuity imparted by the natural and anthropogenic processes operating therein. The soil, rock, and contained fluids encountered in environmental or geotechnical site investigations present such features, and their sampled attributes are therefore amenable to geostatistical treatment. This guide is concerned with the analysis, interpretation, and modeling of spatial variation. The purpose of this guide is to offer guidance based on a consensus of views but not to establish a standard practice to follow in all cases.

1. Scope

1.1 This guide covers recommendations for analyzing, interpreting, and modeling spatial variation of regionalized variables in geotechnical and environmental site investigations.

1.2 The measures of spatial variation discussed in this guide include variograms and correlograms; these are fully described in **(1)**, **(2)**, **(3)**, and **(4)**.[2]

1.3 This guide is intended to assist those who are already familiar with the geostatistical tools discussed herein and does not provide introductory information on the analysis, interpretation, and modeling of spatial variation.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 5549 Guide for Reporting Geostatistical Site Investigations[3]

D 5923 Guide for Selection of Kriging Methods in Geostatistical Site Investigations[4]

D 5924 Guide for the Selection of Simulation Approaches in Geostatistical Site Investigations[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *anisotropy, n—in geostatistics*, a property of the variogram or covariance stating that different spatial variation structures are observed in different directions.

3.1.1.1 *geometric anisotropy, n*—a form of anisotropy in which the variogram range changes with direction while the sill remains constant.

3.1.1.2 *zonal anisotropy, n*—a form of anisotropy in which the variogram sill changes with direction.

3.1.2 *correlogram, n*—a measure of spatial variation expressing the coefficient of correlation between two variables as a function of the lag separating their locations.

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[1] This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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[2] The boldface numbers in parentheses refer to a list of references at the end of the text.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 04.09.

3.1.3 *drift, n—in geostatistics*, a systematic spatial variation of the local mean of a variable, usually expressed as a polynomial function of location coordinates.

3.1.4 *estimation, n*—a procedure by which the value of a variable at an unsampled location is predicted using a weighted average of sample values from the neighborhood of that location.

3.1.5 *lag, n—in geostatistics*, the vector separating the locations of two variables, as used in measures of spatial variation.

3.1.6 *nugget effect, n*—the component of spatial variance unresolved by the sample spacing including the variance due to measurement error.

3.1.7 *range, n—in geostatistics,* the maximum distance over which a variable exhibits spatial correlation in a given direction.

3.1.8 *regionalized variable, n*—a measured quantity or a numerical attribute characterizing a spatially variable phenomenon at a location in the field.

3.1.9 *sill, n—in geostatistics*, a stable level of spatial variation observed for lags greater than the range.

3.1.10 *simulation, n—in geostatistics*, a Monte-Carlo procedure for generating realizations of fields based on the random function model chosen to represent a regionalized variable. In addition to honoring a random function model, the realizations may also be constrained to honor data values observed at sampled locations.

3.1.11 *structure, n—in geostatistics*, a source of spatial variability with a characteristic length scale.

3.1.12 *variogram, n*—a measure of spatial variation defined as one half the variance of the difference between two variables and expressed as a function of the lag; it is also sometimes referred to as the semi-variogram.

3.1.12.1 *experimental variogram, n*—an experimental measure of spatial variation usually calculated as one half the average squared difference between all pairs of data values within the same lag.

3.2 For definitions of other terms used in this guide, refer to Terminology D 653 and Guides D 5549, D 5923, and D 5924. A complete glossary of geostatistical terminology is given in Ref **(5)**.

4. Summary of Guide

4.1 This guide presents advice on three separate but related components of the study of spatial variation: the analytical tools that are used; the interpretation of the results; and the development of an appropriate mathematical model.

4.2 For the analysis of spatial variation, this guide emphasizes the use of variograms and correlograms on both transformed and untransformed variables since these are the most common and successful analytical tools in most practical situations. Other methods exist and may enhance the development of an appropriate model of spatial variation.

4.3 For the interpretation of spatial variation, this guide emphasizes the importance of site-specific quantitative and qualitative information. Quantitative information includes the number and configuration of the available data, their precision, and their univariate statistics; qualitative information includes items such as local geology and geomorphology, site usage, and history. All of these are necessary for a sound interpretation of spatial variation.

4.4 For the modeling of spatial variation, this guide recommends attention to the short-scale behavior of the mathematical model of spatial variation and to its anisotropy as reflected in the directional changes in the range.

5. Significance and Use

5.1 This guide is intended to encourage consistency in the analysis, interpretation, and modeling of spatial variation.

5.2 This guide should be used in conjunction with Guides D 5549, D 5923, and D 5924.

6. Analysis of Spatial Variation

6.1 The principal tools for analyzing spatial variation are the variogram and the correlogram; whenever possible, both should be used.

NOTE 1—Features that appear on both the variogram and correlogram are usually worthy of interpretation and should be reflected in the mathematical model for spatial variation. Features that appear on one but not the other may reflect artifacts of the calculation or peculiarities of the available data and their configuration; such features require further investigation before a decision can be made on whether they should be reflected in the mathematical model for spatial variation.

6.2 If univariate data analysis has revealed that the data have a skewed distribution or if study objectives require that the data be transformed, then the analysis of spatial variation should be performed on an appropriate transform of the data.

NOTE 2—One of the most important aspects of a mathematical model of spatial variation is the direction and degree of anisotropy. This is often much better revealed by variograms and correlograms of transformed data values, such as logarithms or normal scores. Even if the study ultimately makes use of the original data values in estimation or simulation, the analysis of spatial variation on transformed data values often leads to the development of a more appropriate model of spatial variation.

6.3 The choice of lag spacing and tolerance should take into account the data configuration, particularly the minimum spacing between the available data and the average spacing between the available data. Whenever possible, the choices of lag spacing and tolerance should ensure that at least 20 paired data values will be available for each lag.

NOTE 3—With data configurations that are pseudo-regular, it is common to use the spacing between the columns and rows of the sampling grid as the lag spacing and to use half of this distance as the lag tolerance. If the data configuration is irregular, then the lag spacing and tolerance may also need to be irregular (see Refs **(3)**, and **(6)**).

6.4 Spatial variation should be analyzed in different directions; the choice of directions and directional tolerances should reflect the configuration of the available data and should also take into account qualitative information about the physical and chemical characteristics of the regionalized variable being studied.

NOTE 4—Omni-directional variograms or correlograms often are appropriate for refining decisions on lag spacing and lag tolerance; they also provide preliminary insight into the range of correlation and the short-scale variability of the data. However, omni-directional calculations of spatial variation do not constitute a thorough analysis of spatial variation since they offer no insight into directional anisotropies that commonly occur in geologic data. For two-dimensional (2D) problems, contour maps