National Geothermal Academy 2019
Geothermal Geostatistics Course Outline

GEOL 457/657 Module 1: Geothermal Geostatistics (2 credits)

Dates: June 10-14, 2019

Instructors: Dr. Cary Lindsey, Dr. Whitney Trainor-Guitton

Supported by the:

Location: University of Nevada, Reno

Course summary

This course aims to teach geoscience and engineering students and professionals how to perform exploratory statistical analysis on a variety of datasets relevant to geothermal exploration and production, as well as how to create 2D and 3D statistical models from these data. Participants will work in teams to complete exercises using various types of industry-relevant data from geothermal sites around the world such as thermal data, fluid chemistry and alteration mineralogy. In addition to exercises throughout the course, the participants will work in teams to create 2D and 3D temperature models using geostatistical methods as capstone projects. Participants will learn to design and carry out geo- and spatial statistics and visualizations in the R, ArcGIS, and SGeMS software environments. The course is intended for outstanding undergraduates, graduate students, and professionals with backgrounds in geoscience, math, and/or engineering. All classes will be held at the University of Nevada, Reno's Redfield campus in south Reno. International and USA applicants are welcome.

1. Introduction to Statistics & Geostatistics with R – Dr. Cary Lindsey

Outline:
- Introduction to R and R Studio
- Introduction to Descriptive Statistics
    - Exploring a data set with descriptive statistics
    - Mean, median, range, standard deviation, etc.
    - Using R Studio to calculate and plot descriptive statistics
- *Exercise*: Calculating and plotting descriptive statistics to better understand geothermal dataset, their uses and limitations.
- Predictive Statistics
    - Sample Distribution
    - Stating a hypothesis and null hypothesis
    - Errors
    - Correlation
    - Linear Regression

- *Exercise:* Given a data set, state a hypothesis and null hypothesis and test the hypotheses. Complete standard correlation tests and when appropriate, the degree of correlation. Build a linear model and test for significance.
- What are Spatial and Geo Statistics
- Variograms, Kriging, and Interpolation
- *Exercise:* using a sample dataset to calculate and plot a variogram to determine spatial correlation, and predict missing data via kriging. When predicting missing data, the more information we have, the better, and spatial correlation can help to refine our predictions.
- Other interpolation methods
  - Inverse Distance Weighting
    - Pros, cons, uses
- *Exercise*: determine the best alternate interpolation method to variograms and kriging, and create an interpolated surface of a geothermal dataset without the use of spatial correlation; test the results. Spatial correlation does not always exist or is difficult to define.

Learning outcomes:

At the end of this module, students will be able to:
- understand exploratory statistics and how to calculate them
- define sample distributions
- state a statistical hypothesis
- determine degree of correlation between variables
- understand the difference between spatial statistics and geostatistics and know when to apply each one
- determine the most appropriate interpolation method for a dataset
- produce an interpolated surface

2. Geostatistics in ArcGIS – Dr. Cary Lindsey

Outline:
- Importing data into ArcGIS and creating shapefiles
- Using Spatial Analyst tools
- Using Geostatistical Analyst tools
- *Exercise:* create multiple map layers in ArcGIS, identify training sites, and identify the lowest risk/highest potential locations for future exploration efforts (Play Fairway Analysis). The PFA approach integrates multiple data sets with the goal of reducing exploration risk.

Learning outcomes:

At the end of this module, students will be able to:
- upload a data set into ArcGIS and create a shapefile;
- use the various Spatial Analyst tools in ArcGIS for exploratory statistics and prediction, and

- use the various Geostatistical Analyst tools in ArcGIS for geostatistical analysis of geothermal data.
- create map layers that can be use in geothermal exploration.

3. 3D Geostatistical Modeling with SGeMS – Dr. Whitney Trainor-Guitton

Outline:
- Introduction to SGeMS (Stanford Geostatistical Modelling Software)
  - *Exercise:* Load temperature data and perform 3D variogram analysis
- 3D grids and kriging with SGeMS
  - *Exercise*: Build 3D grid and perform 3D kriging and sequential gaussian simulation (SGSIM) in SGeMS to generate deterministic and stochastic models of sub-surface temperature distribution, and evaluate model differences.
- Multiple Point Geostatistics
  - Building a training image
  - SNESIM program and algorithm
  - *Exercise*: Building SNESIM stochastic realizations to generate many models of potential fracture locations in a geothermal reservoir (capturing possible orientations, offsets and densities)
- Concept Check
  - Variogram vs TI
  - Kriging vs SGISM
- Data Integration Approach 1
  - Co-kriging
- Data Integration Approach 2
  - Bayles Law
- Project: *Exercise*: Co-kriging or SNESIM models with multiple data types (e.g. temperature and permeability) to demonstrate quantitative methods for integrating diverse data types into geothermal reservoir models

Learning outcomes:

At the end of this module, students will be able to:
- be able to build a geothermal reservoir model from available geologic, geothermal and engineering data
- define the difference between deterministic and stochastic reservoir models
- understand when to use advanced geostatistical techniques for combining data and treating it stochastically
- know the general concepts and equations behind geostatistics
- recognize the similarities and differences in variogram and training image methods
- apply relevant geostatistical algorithms to data sets from participants' projects