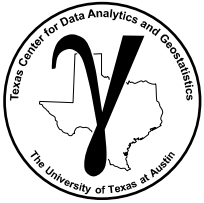


Open Source Spatial Data Analytics in Python with GeostatsPy II

Spatial Uncertainty Modeling with GeostatsPy

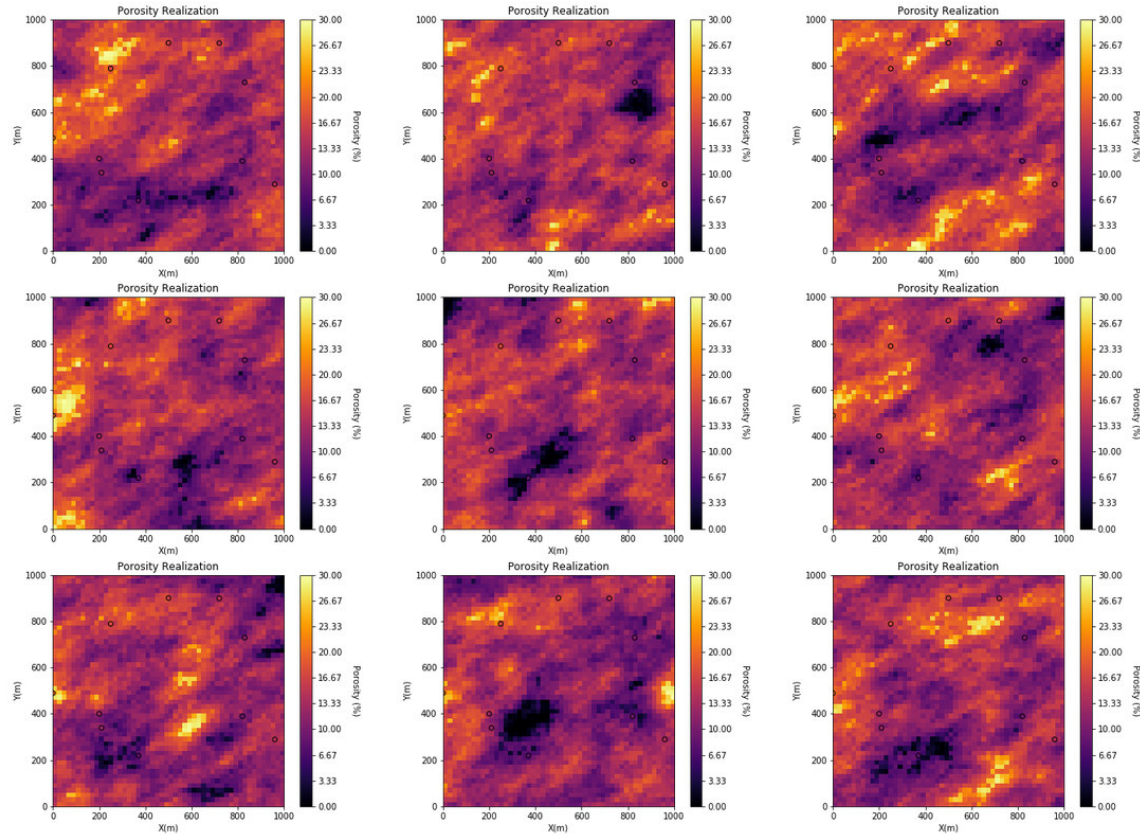
Lecture outline . . .

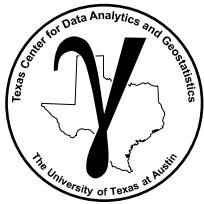
- **Spatial Simulation**
- **Interactive Demo with GeostatsPy**
- **Workflow with GeostatsPy**



Motivation

Spatial simulation to calculate an ensemble realizations is the building block for modeling spatial, subsurface uncertainty.





Recorded Lectures

GeostatsGuy Lectures

Sequential Gaussian Simulation Definition

- **Sequential** – sequential inclusion of simulated values to impose the correct spatial correlation between the simulated values.
- **Gaussian** – work in Gaussian space since the local conditional distribution shape is known and can be parameterized by mean (kriging estimate) and variance (estimation variance).
- **Simulation** – simulation through Monte Carlo simulation from the local distribution of uncertainty to add in the missing variance and construction of multiple, equiprobable realizations.

13 Data Analytics: Simulation

GeostatsGuy Lectures

PGE 337 Data Analytics and Geostatistics
Lecture 16b: Model Checking

Short Summary of:

- Model Checking
- Checking Reproduction of Model Inputs
- Cross Validation of Estimates
- Cross Validation of Uncertainty Models

Introduction
General Concepts
Univariate
Bivariate
Spatial
Calculation
Variogram Modeling

Professor Michael J. Pyrcz, Ph.D., P.Eng.
Associate Professor, The University of Texas at Austin
Advancing Spatial Data Analytics, Geostatistics and Machine Learning

H.B. Harkings, Jr. Professor of Petroleum Engineering
Hildebrand Department of Petroleum and Geosystems Engineering
Jackson School of Geosciences and Bureau of Economic Geology
Principal Investigator, Energy Analytics, College of Natural Sciences

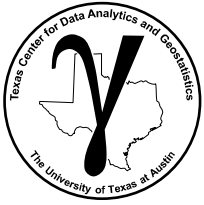
16b Data Analytics: Model Checking

GeostatsGuy Lectures

Cross Variogram and Cross Covariance

- Cross variogram starts at 0.0, $\gamma_{z,y}(0) = 0$, and then at the range reaches the correlation coefficient, $\gamma_{z,y}(h) \rightarrow \rho_{z,y}(0)$, as $h \rightarrow \text{range}$.
– if the correlation coefficient is less than zero, $\rho_{z,y}(0) < 0$, then the cross variogram is negative!
- Cross correlogram (equal to cross covariance if $\sigma_z = \sigma_y = 1$), starts at the correlation coefficient, $\rho_{z,y}(0) = 0$, and then at the range reaches the 0, $\rho_{z,y}(h) \rightarrow 0$, as $h \rightarrow \text{range}$.
– if the correlation coefficient is less than zero, $\rho_{z,y}(0) < 0$, then the cross correlogram is negative!

16 Data Analytics: Cosimulation

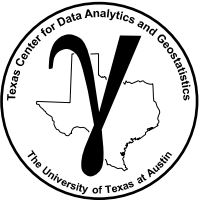


Open Source Spatial Data Analytics in Python with GeostatsPy II

Spatial Uncertainty Modeling with GeostatsPy

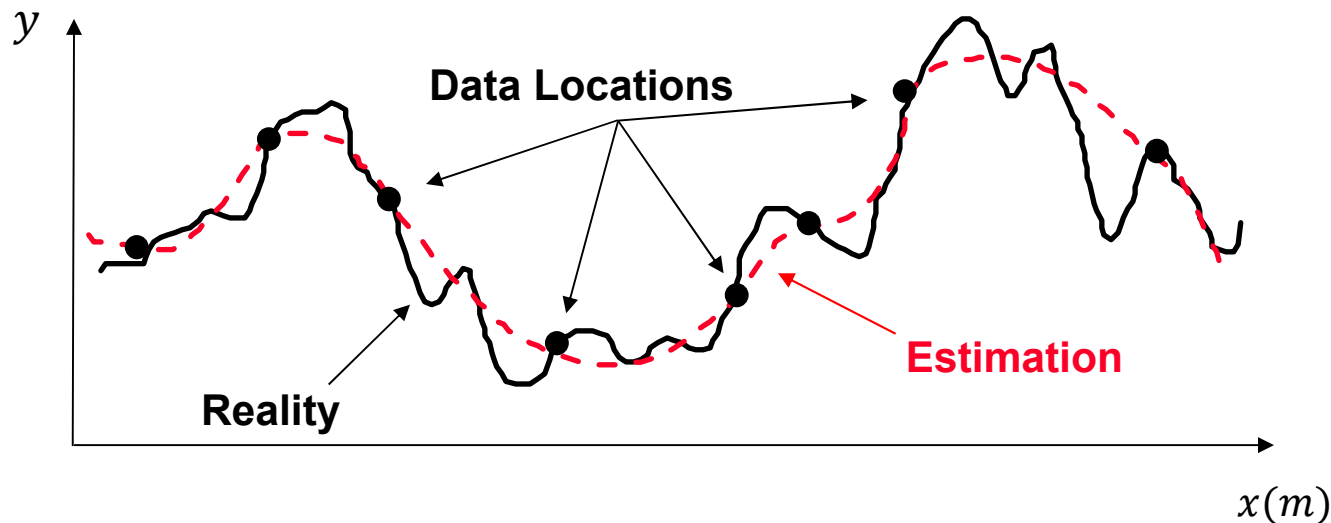
Lecture outline . . .

- Spatial Simulation

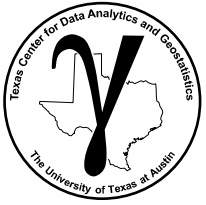


Motivation for Simulation

- Recall estimation: assign the most accurate value at each location.

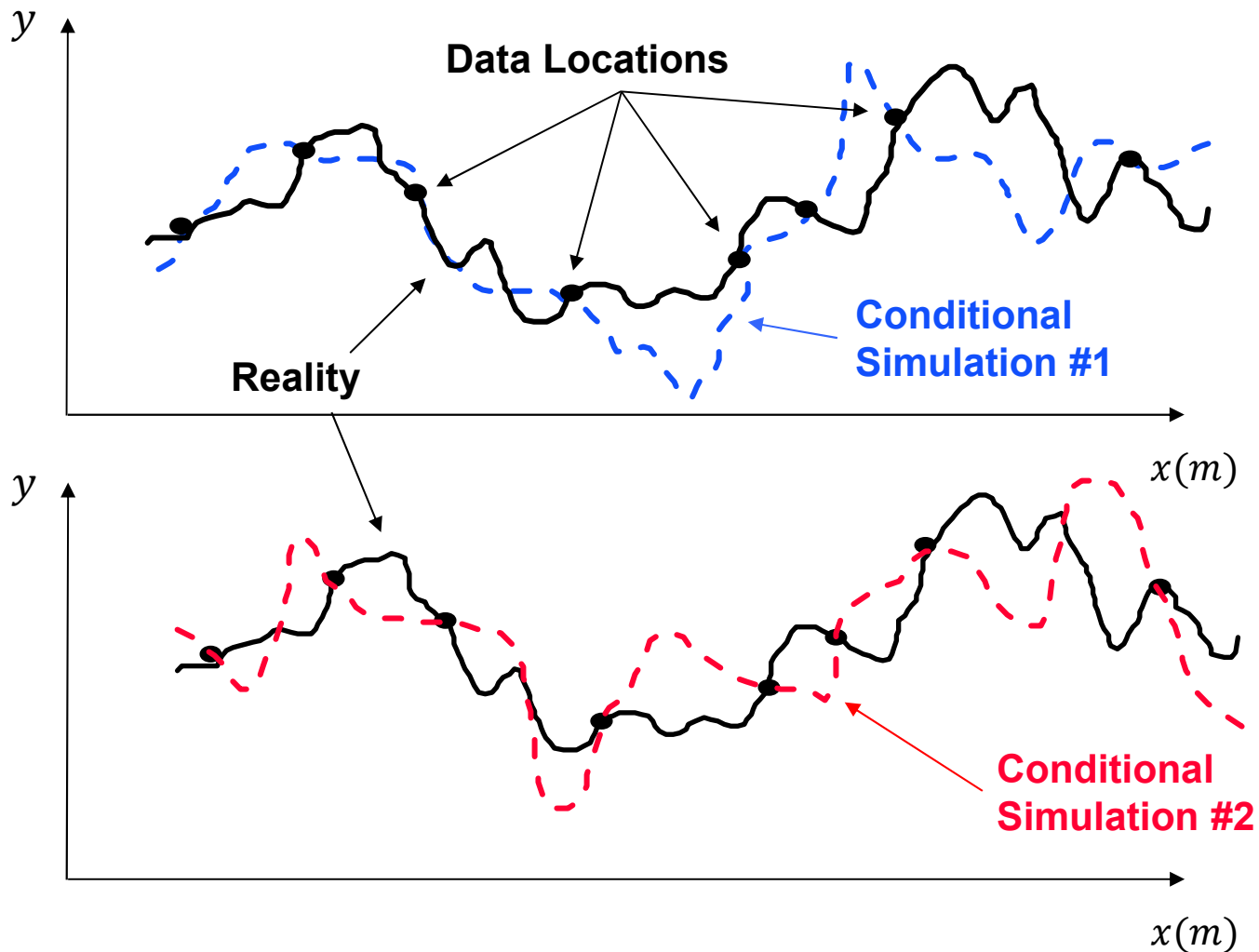


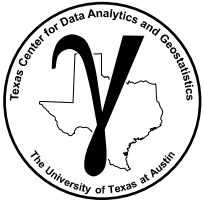
- This would not be appropriate for flow simulation!
 - Permeability variance is too low, Dykstra-Parsons is underestimated



Motivation for Simulation

- What do we accomplish with simulation?





Motivation for Simulation

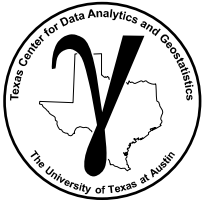
- What do we accomplish with simulation?



What does a simulated dill pickle potato chip taste like?

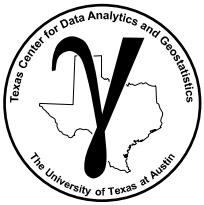
What does a simulated reservoir model look like?

What does a simulated reservoir flow like?



Estimation vs. Simulation

	Estimation	Simulation
Local Data Conditioning (Exactitude)	honors local data	honors local data
Local Accuracy (Best Value, Minimize Estimation Variance)	locally accurate, primary goal of estimation is 1 estimate!	sacrifices local accuracy, reproduces histogram
Spatial Continuity	too smooth, appropriate for visualizing trends	honors spatial variability, appropriate for flow simulation
Uncertainty Model	one model with local uncertainty, no assessment of global uncertainty	many models (realizations), assessment of global uncertainty



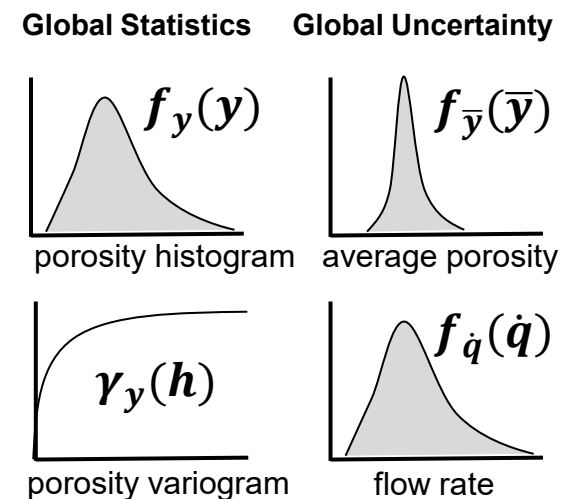
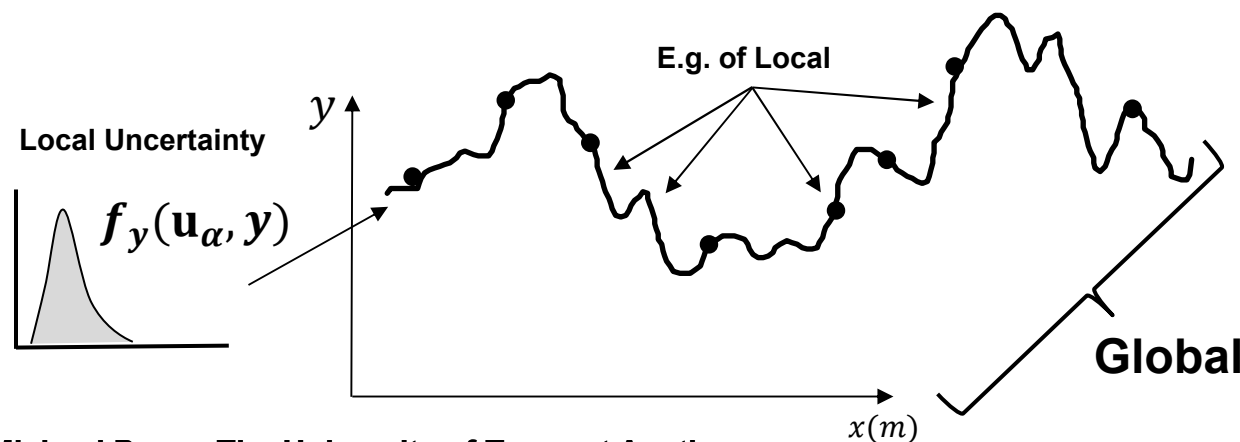
Global and Local Definition

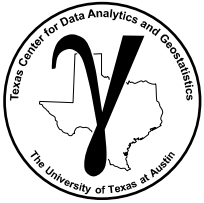
Global vs. Local Measures

- Local Measure – a feature value at a single location
- Global Measure – a statistical summary over the volume of interest

Global vs. Local Accuracy

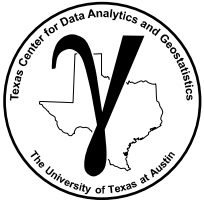
- Global Accuracy – we honor a statistic calculated over the volume of interest (variogram / distribution)
- Local Accuracy – we have an estimate the minimized the estimation variance / most likely value





Sequential Gaussian Simulation Definition

- **Sequential** – sequential inclusion of simulated values to impose the correct spatial correlation between the simulated values.
- **Gaussian** – work in Gaussian space since the local conditional distribution shape is known and can be parameterized by mean (kriging estimate) and variance (estimation variance). Due to the central limit theorem the global distribution is correct (Gaussian), so we can back transform after simulation original data space.
- **Simulation** – simulation through Monte Carlo simulation from the local distribution of uncertainty to add in the missing variance and construction of multiple, equiprobable realizations.

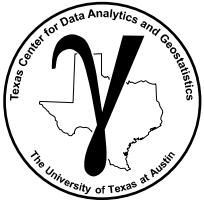


Open Source Spatial Data Analytics in Python with GeostatsPy II

Spatial Uncertainty Modeling with GeostatsPy

Lecture outline . . .

- Interactive Demo with GeostatsPy

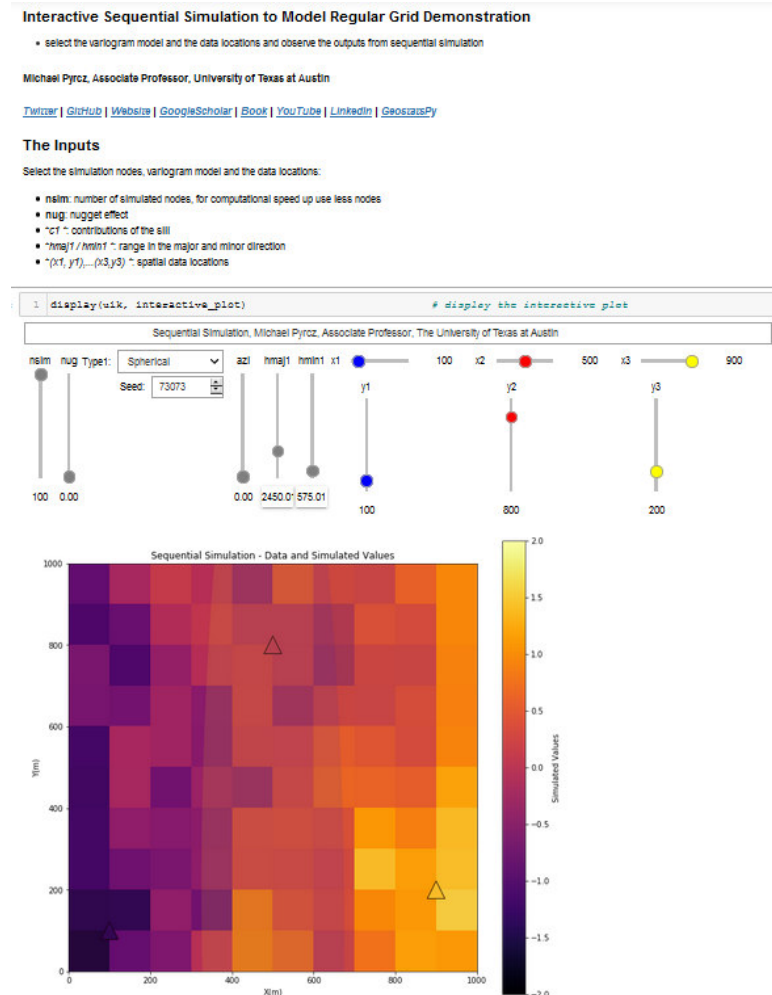


Interactive Spatial Simulation Demonstration with GeostatsPy

Let's calculate spatial simulations:

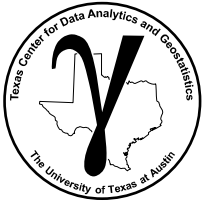
Some Hints:

- start with short range and few grid cells, nsim is small
- add anisotropy
- rotate the anisotropy
- increase the number of grid cells, WARNING: increase the number of grid cells



Interactive Python Jupyter simulation calculator
(Interactive_Simulation.ipynb).

Michael Pyrcz, The University of Texas at Austin

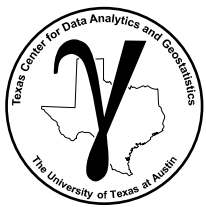


Open Source Spatial Data Analytics in Python with GeostatsPy II

Spatial Uncertainty Modeling with GeostatsPy

Lecture outline . . .

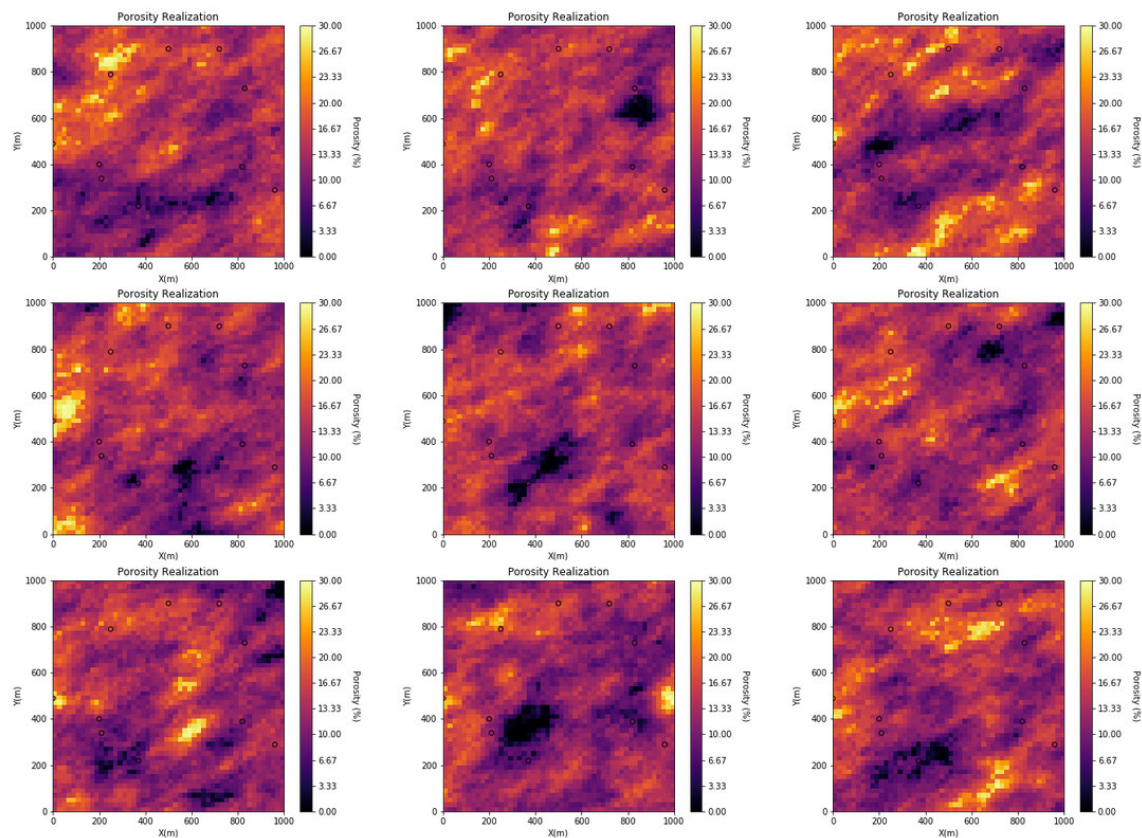
- Workflow with GeostatsPy



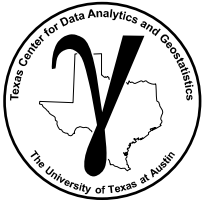
Spatial Simulation Workflow with GeostatsPy

Let's walkthrough a more thorough spatial simulation workflow:

- specify model parameters
- calculate and visualize realizations



Python Jupyter variogram calculation
(GeostatsPy_simulation_wPostSim.ipynb).



Open Source Spatial Data Analytics in Python with GeostatsPy II

Spatial Uncertainty Modeling with GeostatsPy

Lecture outline . . .

- Spatial Simulation
- Interactive Demo with GeostatsPy
- Workflow with GeostatsPy