Open Source Spatial Data Analytics in Python with GeostatsPy

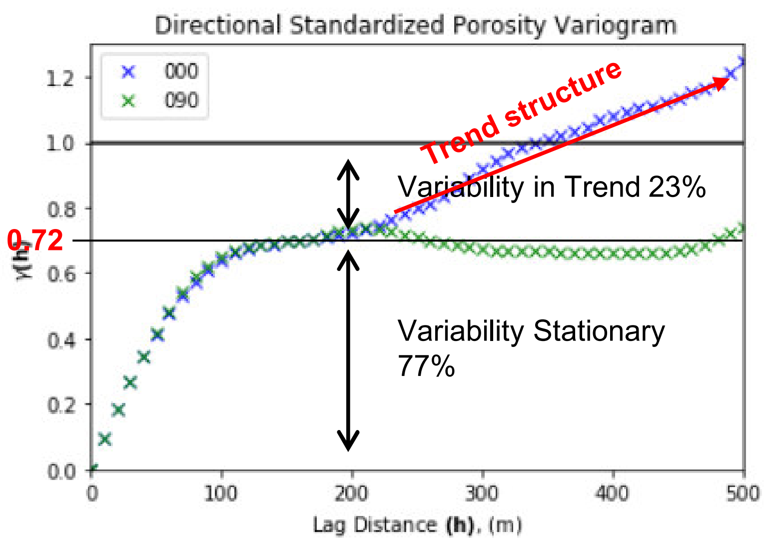
Introduction to GeostatsPy

Lecture outline . . .

- **Variogram Modeling**
- **Interactive Demo with GeostatsPy**
- **Workflow with GeostatsPy**

Motivation

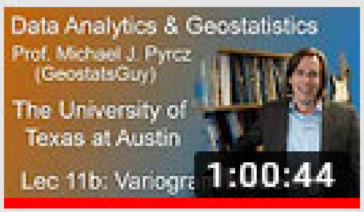
- After we calculate / quantify spatial continuity we need to model it for spatial prediction.



Recorded Lectures

11 Data Analytics: Variogram Interpretation

GeostatsGuy Lectures



11b Data Analytics: Variogram Modeling

GeostatsGuy Lectures

11c Python Data Analytics Reboot: Variogram Modeling

GeostatsGuy Lectures

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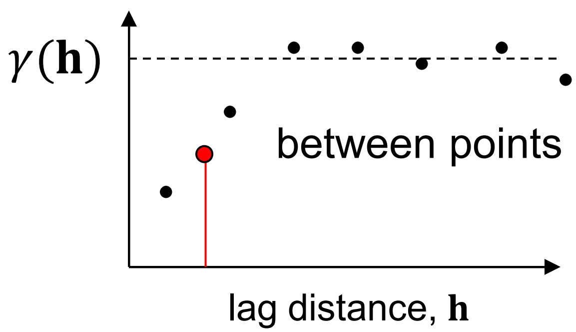
- **Variogram Modeling**

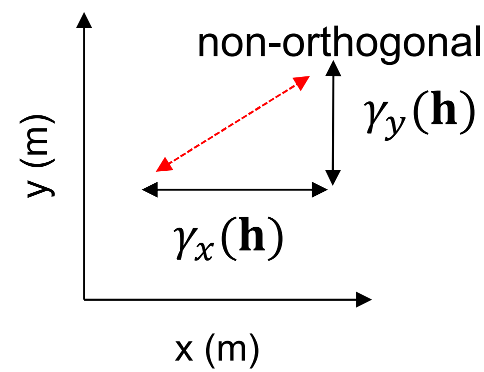
Reasons for Variogram Modeling

1. Need to know the variogram for all possible **h** lags, distances and directions – not just the ones calculated

All Distances



All Directions



a specific lag offset may not exist in our data!

2. Incorporate additional geological knowledge (such as analogue information or information on directions of continuity …)
3. The variogram model must be **positive definite** (a legitimate measure of distance), that is, the variance of any linear combination must be positive

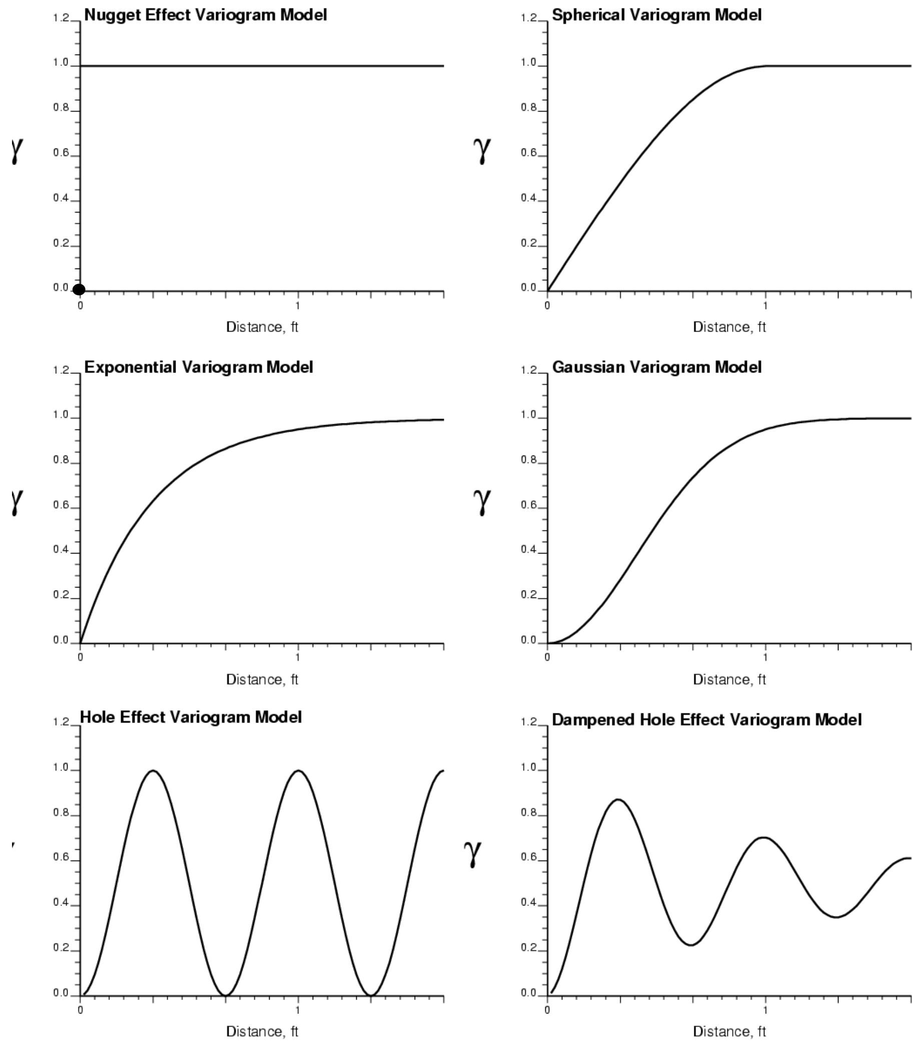
Common Variogram Models

No spatial correlation

Should be a small component of the overall variance

Similar to spherical but rises more steeply and reaches the sill asymptotically

For periodic variables



Commonly encountered variogram shape

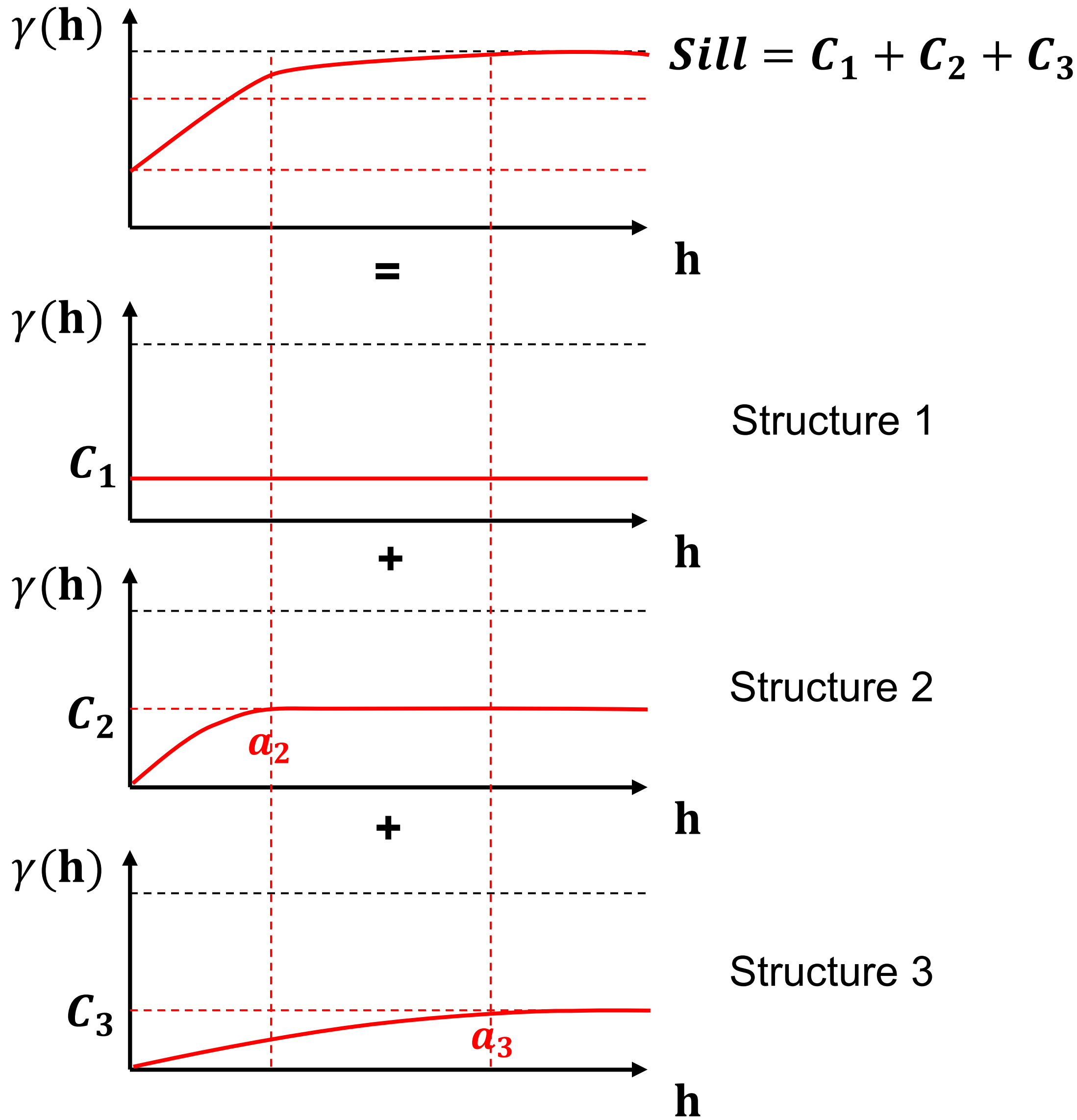
Implies short scale continuity; parabolic behavior at the origin, instead of linear

For periodic variables, when the period is not regular

Variogram examples from Pyrcz and Deutsch, 2014.

Variograms Models with Nested Structures

- The addition of positive definite variogram structures is positive definite.
- Each structure covers a proportion of the sill.
- For each structure we can change the:
  - *orientation*
  - range in major and minor
- We are explaining the spatial components of the variance!



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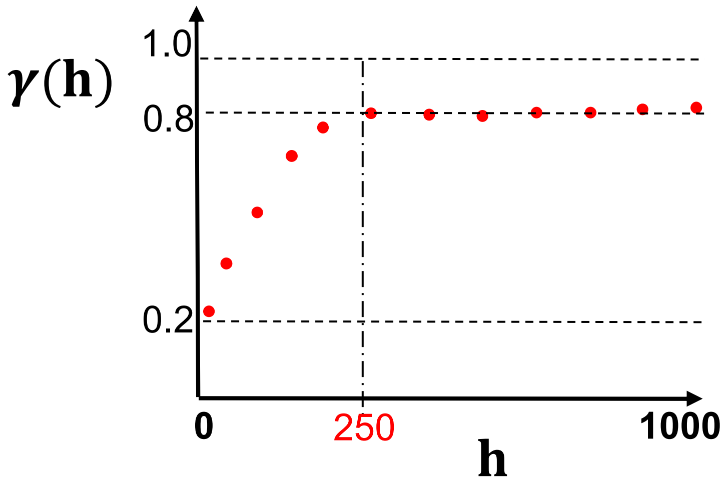
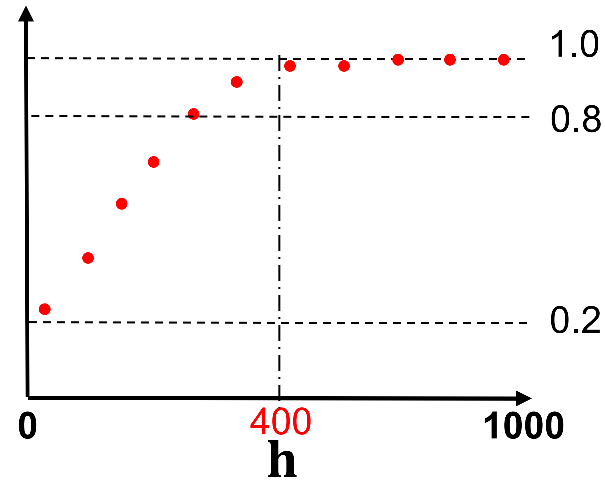
Variogram Modeling Example

Major Direction Azimuth 090



Minor Direction Azimuth 000



Structure	Type	c	a_{maj}	a_{min}
1	Nugget	0.2	-	-
2	Spherical	0.8	250	400
3	Spherical	0.2	9999	400
4				
5				

$$\gamma(h) = \mathbf{0.2} + 0.\mathbf{6} \cdot sph_{\substack{a_{maj}=250 \\ a_{min}=400}} + 0.\mathbf{2} \cdot sph_{\substack{a_{maj}=9999 \\ a_{min}=400}}$$

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Introduction to GeostatsPy

Lecture outline . . .

- **Interactive Demo with GeostatsPy**

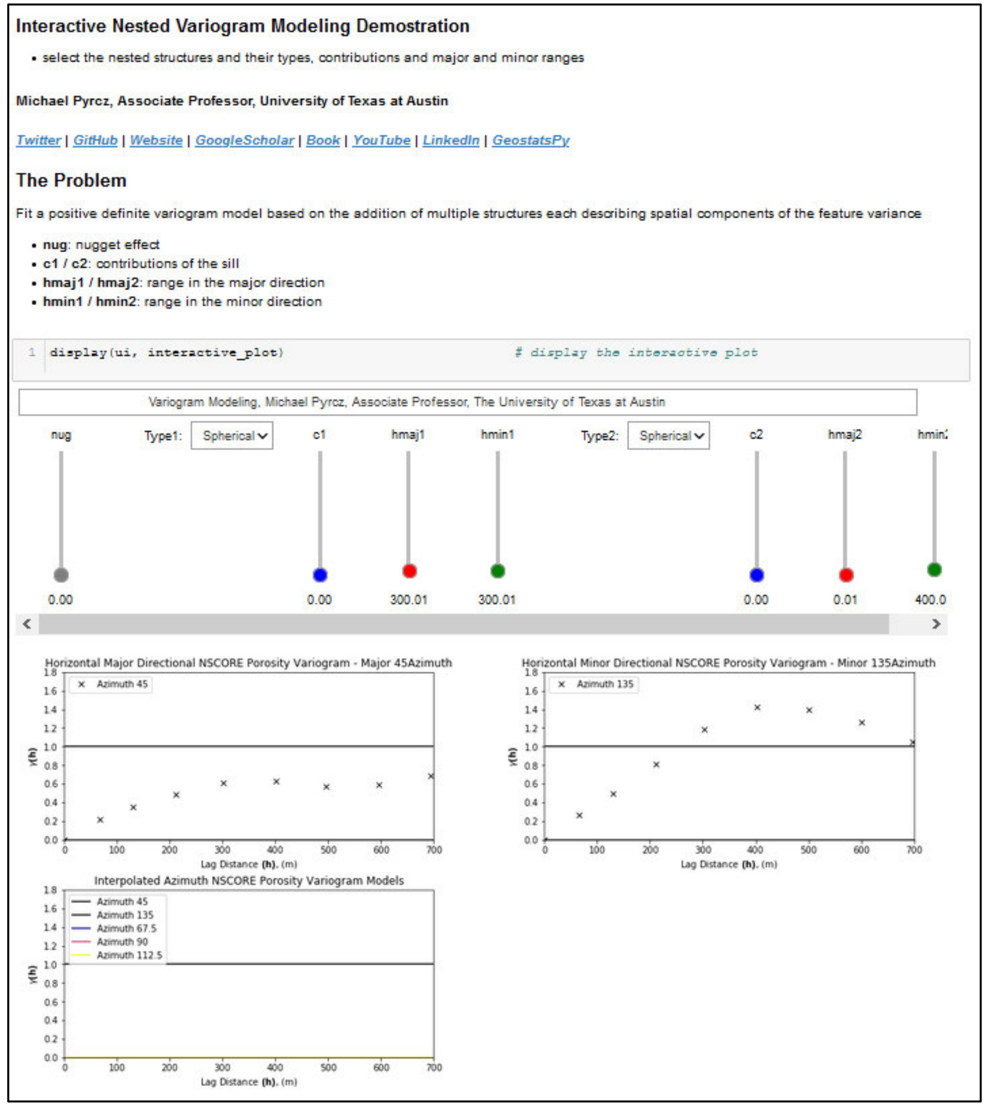
Interactive Variogram Calculation Demonstration with GeostatsPy

Let's model variograms:

- normal score transformed (standard Gaussian) porosity

Some Hints:

- don't change the variogram calculation
- find lowest common nugget effect
- add a structure to get to pseudo sill
- model remainder with very large range in major direction



Interactive Python Jupyter variogram modeling (Interactive_Variogram_Modeling.ipynb).

Introduction to GeostatsPy

Lecture outline . . .

- **Workflow with GeostatsPy**

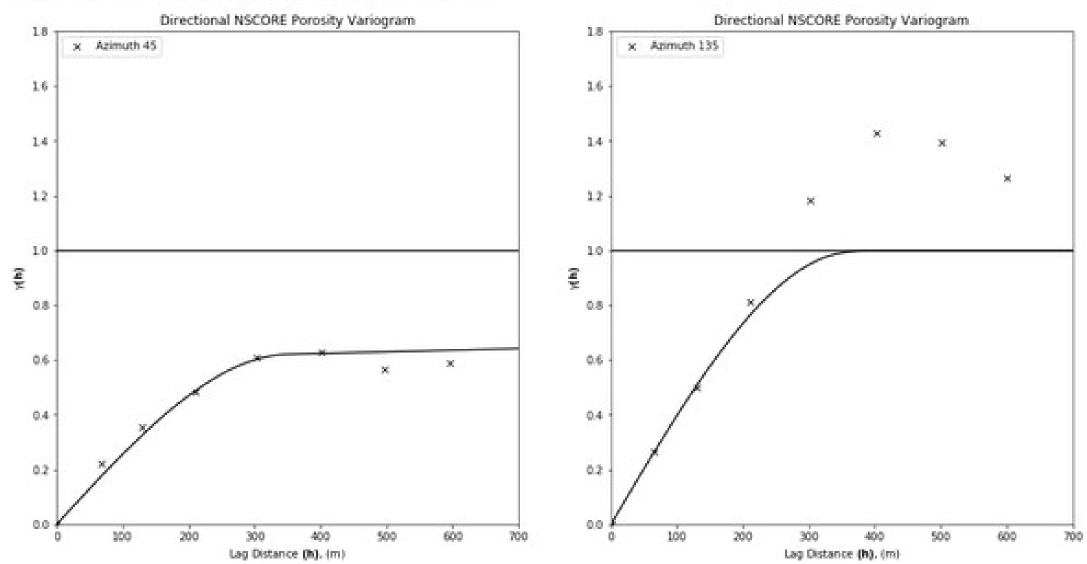
Variogram Modeling Workflow with GeostatsPy

Let's walkthrough a more thorough variogram-based spatial analysis workflow:

- calculate experimental variograms
- formulate variogram models

```
nug = 0.0; nst = 2                                             # 2 nest structure variogram model parameters
it1 = 1; cc1 = 0.6; azi1 = 45; hmaj1 = 350; hmin1 = 350
it2 = 1; cc2 = 0.4; azi2 = 45; hmaj2 = 9999.9; hmin2 = 400

vario = GSLIB.make_variogram(nug,nst,it1,cc1,azi1,hmaj1,hmin1,it2,cc2,azi2,hmaj2,hmin2) # make model object
nlag = 70; xlag = 10; azm = 45;                                # project the model in the 045 azimuth
index45,h45,gam45,cov45,ro45 = geostats.vmodel(nlag,xlag,azm,vario)
azm = 135                                                      # project the model in the 135 azimuth
index135,h135,gam135,cov135,ro135 = geostats.vmodel(nlag,xlag,azm,vario)

plt.subplot(1,2,1)
plt.plot(lag[2,:],gamma[2,:],'x',color = 'black',label = 'Azimuth ' +str(azi_mat[2]))
plt.plot([0,2000],[1.0,1.0],color = 'black')
plt.plot(h45,gam45,color = 'black')
plt.xlabel(r'Lag Distance $\bf(h)$, (m)')
plt.ylabel(r'$\gamma \bf(h)$')
plt.title('Directional NSCORE Porosity Variogram')
plt.xlim([0,700])
plt.ylim([0,1.8])
plt.legend(loc='upper left')

plt.subplot(1,2,2)
plt.plot(lag[6,:],gamma[6,:],'x',color = 'black',label = 'Azimuth ' +str(azi_mat[6]))
plt.plot([0,2000],[1.0,1.0],color = 'black')
plt.plot(h135,gam135,color = 'black')
plt.xlabel(r'Lag Distance $\bf(h)$, (m)')
plt.ylabel(r'$\gamma \bf(h)$')
plt.title('Directional NSCORE Porosity Variogram')
plt.xlim([0,700])
plt.ylim([0,1.8])
plt.legend(loc='upper left')

plt.subplots_adjust(left=0.0, bottom=0.0, right=2.2, top=1.6, wspace=0.2, hspace=0.3)
plt.show()
```

```
x,y,z offsets = 7.071067805519558,7.071067818211393
x,y,z offsets = 7.071067830903227,-7.071067792827723
```



Python Jupyter variogram calculation (GeostatsPy_variogram_modleing.ipynb).

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