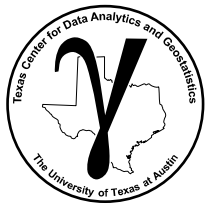




# Spatial Uncertainty Modeling with GeostatsPy

## Conclusions

- Concluding Remarks
- Plus / Delta Feedback

# Motivation

"Promote use of and contributions to the GeostatsPy open source package for enabling spatial data analytics and geostatistics in Python workflows."

"Support education, students, working professionals and potential students"

"Expand the use of spatial data analytics and machine learning in the subsurface."

"Make spatial data analytics and machine learning workflows accessible to all scientists and engineers."

# Spatial Uncertainty Modeling with GeostatsPy

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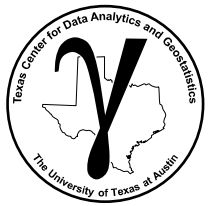
Michael Pyrcz, The University of Texas at Austin




# GeostatsPy Contributors

*Appreciations to the contributors!*

Honggeun Jo – initial 3D routines for variogram calculation and modeling

Anton Kupenko – bug fixes, Docstrings, code conformance to PEP8, removed duplicate functions

Wendi Liu – 3D gamma bar routine

Alex Gigliotti – initial unit tests for Travis continuous integration

Michael Pyrcz – GSLIB and geostats modules

And others!

*I would love to see this expand*

# Current State of GeostatsPy

*What is good?*

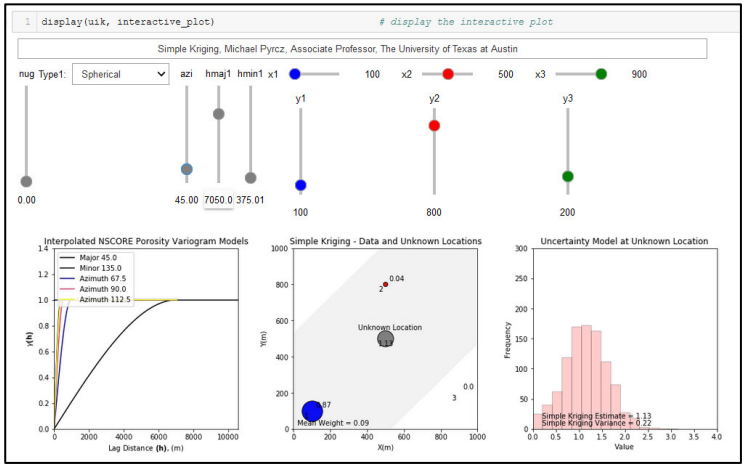
docs passing

## GeostatsPy Package

The GeostatsPy Package brings GSLIB: Geostatistical Library (Deutsch and Journel, 1998) functions to Python. GSLIB is a practical and extremely robust set of code for building spatial modeling workflows.

I created the GeostatsPy Package to support my students in my **Data Analytics**, **Geostatistics** and **Machine Learning** courses. I find my students benefit from hands-on opportunities, in fact it is hard to imagine teaching these topics without providing the opportunity to handle the numerical methods and build workflows. Last year, I tried to have them use the original FORTRAN executables and even with support and worked out examples, it was an uphill battle. In addition, all my students and I are now working in Python for our research. Thus, having access to geostatistical methods in Python directly impacts and facilitates the research of my group.

GeostatsPy GitHub repository and docs.




Interactive demonstrations for teaching tools.

**Michael Pyrcz, The University of Texas at Austin**


GeostatsPy available on PyPI

| | | |
|---|---|---|
| GeostatsPy_Confidence_Hypothesis.ip... | Confidence Intervals and Hypothesis Testing with GeostatsPy | 16 months ago |
| GeostatsPy_Monte_Carlo_simulation.i... | Monte Carlo simulation with GeostatsPy | 16 months ago |
| GeostatsPy_bootstrap.ipynb | Bootstrap for Uncertainty with GeostatsPy | 15 months ago |
| GeostatsPy_datadistributions.ipynb | Univariate Summary Statistics and Distributions with GeostatsPy | 16 months ago |
| GeostatsPy_declustering.ipynb | Add files via upload | 2 months ago |
| GeostatsPy_indicator_kriging.ipynb | Indicator Kriging in GeostatsPy | 15 months ago |
| GeostatsPy_inv_distance.ipynb | Add files via upload | last month |
| GeostatsPy_kriging.ipynb | Kriging with GeostatsPy | 15 months ago |
| GeostatsPy_multivariate.ipynb | Multivariate Analysis with GeostatsPy | 16 months ago |
| GeostatsPy_overfit.ipynb | Trend Model Overfit Demonstration | 16 months ago |
| GeostatsPy_plottingdata.ipynb | Plotting Data Demo with GeostatsPy | 16 months ago |
| GeostatsPy_simulation.ipynb | Bug fix | 14 months ago |
| GeostatsPy_simulation_postsim.ipynb | Add files via upload | 13 months ago |
| GeostatsPy_sisim.ipynb | SISIM in Python with GeostatsPy | 13 months ago |
| GeostatsPy_spatial_continuity_directio... | Add files via upload | 15 months ago |
| GeostatsPy_spatial_updating.ipynb | Spatial Bayesian Updateding with GeostatsPy | 16 months ago |
| GeostatsPy_synthetic_well_maker.ipynb | Add files via upload | 4 months ago |
| GeostatsPy_transformations.ipynb | Univariate Distribution Transformations in GeostatsPy | 16 months ago |
| GeostatsPy_trends.ipynb | Spatial Trend Modeling with GeostatsPy | 16 months ago |
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| GeostatsPy_variable_ranking.ipynb | Multivariate Feature Ranking with GeostatsPy | 15 months ago |
| GeostatsPy_variogram_calculation.ipynb | Experimental Variogram Calculation with GeostatsPy | 16 months ago |
| GeostatsPy_variogram_modeling.ipynb | Add files via upload | last month |
| GeostatsPy_volume_variance.ipynb | Volume-variance with GeostatsPy | 14 months ago |

Many well-documented demonstrations for common subsurface data analytics and geostatistics workflows.

# Current State of GeostatsPy

*What needs work?*

```
def sisim(df,xcol,ycol,vcol,ivtype,koption,ncut,thresh,gcdf,trend,tmin,tmax,zmin,zmax,ltail,ltpar,middle,mpar,utail,utpar,nx,xmn,xs
          ndmax,nodmax,mults,nmult,noct,radius,ktype,vario):

    """A 2D version of GSLIB's SISIM Indicator Simulation program (Deutsch and Journel, 1998) converted from the
    original Fortran to Python by Michael Pyrcz, the University of Texas at
    Austin (March, 2019). WARNING: only tested for cateogrical ktype 0, 1 and 2 (locally variable proportion).
    :param df: pandas DataFrame with the spatial data
    :param xcol: name of the x coordinate column
    :param ycol: name of the y coordinate column
    :param vcol: name of the property column (cateogorical or continuous - note continuous is untested)
    :param ivtype: variable type, 0 - categorical, 1 - continuous
    :param koption: kriging option, 0 - estimation, 1 - cross validation (under construction)
    :param ncut: number of categories or continuous thresholds
    :param thresh: an ndarray with the category labels or continuous thresholds
    :param gcdf: global CDF, not used if trend is present
    :param trend: an ndarray [ny,ny,ncut] with the local trend proportions or cumulative CDF values
    :param tmin: property trimming limit
    :param tmax: property trimming limit
    :param nx: definition of the grid system (x axis)
    :param xmn: definition of the grid system (x axis)
    :param xsiz: definition of the grid system (x axis)
    :param ny: definition of the grid system (y axis)
    :param ymn: definition of the grid system (y axis)
    :param ysiz: definition of the grid system (y axis)
    :param nxdis: number of discretization points for a block
    :param nydis: number of discretization points for a block
    :param ndmin: minimum number of data points to use for kriging a block
    :param ndmax: maximum number of data points to use for kriging a block
    :param radius: maximum isotropic search radius
    :param ktype: kriging type, 0 - simple kriging and 1 - ordinary kriging
    :param vario: list with all of the indicator variograms (sill of 1.0) in consistent order with above parameters
    :return:
    """
```

Docstrings, documentation.

```
@jit(nopython=True)
def setup_rotmat(c0, nst, it, cc, ang, pmx):
    """Setup rotation matrix.
    :param c0: nugget constant (isotropic)
    :param nst: number of nested structures (max. 4)
    :param it: TODO
    :param cc: multiplicative factor of each nested structure
    :param ang: TODO
    :param pmx: TODO
    :return: TODO
    """
    PI = 3.141_592_65
    DTOR = PI / 180.0

    # The first time around, re-initialize the cosine matrix for the variogram
    # structures
    rotmat = np.zeros((4, nst))
    maxcov = c0
    for js in range(0, nst):
        azmuth = (90.0 - ang[js]) * DTOR
        rotmat[0, js] = math.cos(azmuth)
        rotmat[1, js] = math.sin(azmuth)
        rotmat[2, js] = -1 * math.sin(azmuth)
        rotmat[3, js] = math.cos(azmuth)
        if it[js] == 4:
            maxcov = maxcov + pmx
        else:
            maxcov = maxcov + cc[js]
    return rotmat, maxcov
```

Efficiency, optimization.

```
def semipartial_corr(C): # Michael Pyrcz modified the function above by Fabian Pedregosa-Izquierdo, f@bianp.net for semipartial cor
    C = np.asarray(C)
    p = C.shape[1]
    P_corr = np.zeros((p, p), dtype=np.float)
    for i in range(p):
        P_corr[i, i] = 1
        for j in range(i+1, p):
            idx = np.ones(p, dtype=np.bool)
            idx[i] = False
            idx[j] = False
            beta_i = linalg.lstsq(C[:, idx], C[:, j])[0]
            res_j = C[:, j] - C[:, idx].dot( beta_i)
            res_i = C[:, i] # just use the value, not a residual
            corr = stats.pearsonr(res_i, res_j)[0]
            P_corr[i, j] = corr
```

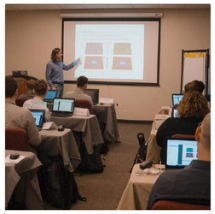
Expanded spatial data analytics, spatial statistics.

```
def sqdist3(x1,y1,z1,x2,y2,z2,ind,rotmat):
    """Squared Anisotropic Distance Calculation Given Matrix Indicator - 3D

    This routine calculates the anisotropic distance between two points
    given the coordinates of each point and a definition of the
    anisotropy.

    Converted from original fortran GSLIB (Deutsch and Journel, 1998) to Python by Wendi Liu, University of Texas at Austin
```

Support for 3D workflows.

**Michael Pyrcz, The University of Texas at Austin**

# More Resources on Subsurface Data Analytics and Machine Learning



Always Happily Coding, Researching or Teaching

**Michael Pyrcz**
GeostatsGuy

Edit profile

Associate Professor at the University of Texas at Austin Data Analytics, Geostatistics and Machine Learning

Overview | Repositories 32 | Projects 0 | Packages 0 | Stars 1 | Followers 676 | Following 8

Popular repositories — Customize your pins

**GeostatsPy**
Reimplementation of GSLIB, Spatial Data Analytics and Geostatistics in a Python package.
Jupyter Notebook ★ 123 ⑂ 79

**PythonNumericalDemos**
A collection of Python demos for geostatistical methods.
Jupyter Notebook ★ 93 ⑂ 78

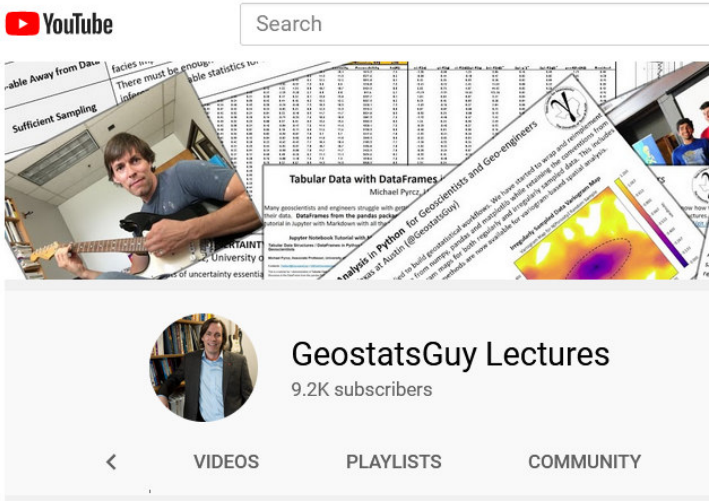
**2DayCourse**
2 day short course.
★ 42 ⑂ 20

**Resources**
★ 33 ⑂ 7

**ExcelNumericalDemos**
A set of numerical demonstrations in Excel to assist with teaching / learning concepts in statistics and geostatistics.
★ 26 ⑂ 13

**PGE383_SubsurfaceModeling**
Graduate course on subsurface modeling
Jupyter Notebook ★ 25 ⑂ 7

For a lot of content, demonstrations in Python, R and Excel, follow on GitHub.

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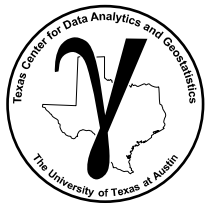
## Ask Me About:

**DIRECT Consortium** for Subsurface Data Analytics and Machine Learning

**daytum** for Energy Data Science education for working professionals.

**Michael Pyrcz, The University of Texas at Austin**




# Open Source Spatial Data Analytics in Python with GeostatsPy II

## Spatial Uncertainty Modeling with GeostatsPy

### Conclusions

- **Plus / Delta Feedback**

**Michael Pyrcz, The University of Texas at Austin**

# Plus / Delta Feedback

| Plus | Delta |
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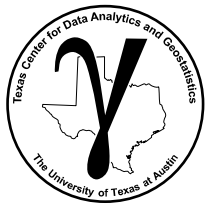
**Michael Pyrcz, The University of Texas at Austin**




# Open Source Spatial Data Analytics in Python with GeostatsPy II

## Spatial Uncertainty Modeling with GeostatsPy

### Conclusions

- Some Comments
- Plus / Delta Feedback

Michael Pyrcz, The University of Texas at Austin