Evaluating the Accuracy of Linear and Geostatistical Interpolation Methods in Subsurface Mappping

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Abstract

The methods by which we model the Earth's subsurface will always necessitate some form of interpolation; however the way in which we estimate these unknowns and the accuracy with which we can make these predictions has been improved. Further, inaccurate interpolation of subsurface geology can lead to wasted money and resources. This study seeks to compare the results of both linear and geostatistical interpolation methods utilizing a large sampling of boreholes drilled for a subsurface rock investigation at our study site in coastal Central America.

One way to determine the accuracy of an interpolated surface is to compare the values from the surface to additional values collected in the field. In this study, we divide a total population of nearly 500 borings into two parts; a random sampling of 75% of the borings are used as an input to each of the interpolated surfaces, and the remaining 25% are used to assess the surface's accuracy. The linear interpolation method takes the larger 75% sampling of points, generates a triangulated irregular network (TIN), and converts the TIN to a raster. The same 75% sampling are also used to develop a surface through kriging interpolation, a geostatistical method. We then compare each interpolated surface to the values from the remaining 25% sample not used to generate the surface.

The accuracy of each surface will be determined through the use of a three-dimensional root mean square error (RMSE) method. This workflow is used to create multiple iterations of each surface using a different random sampling every time and allowing summary statistics to be evaluated rigorously and consistently across the study.

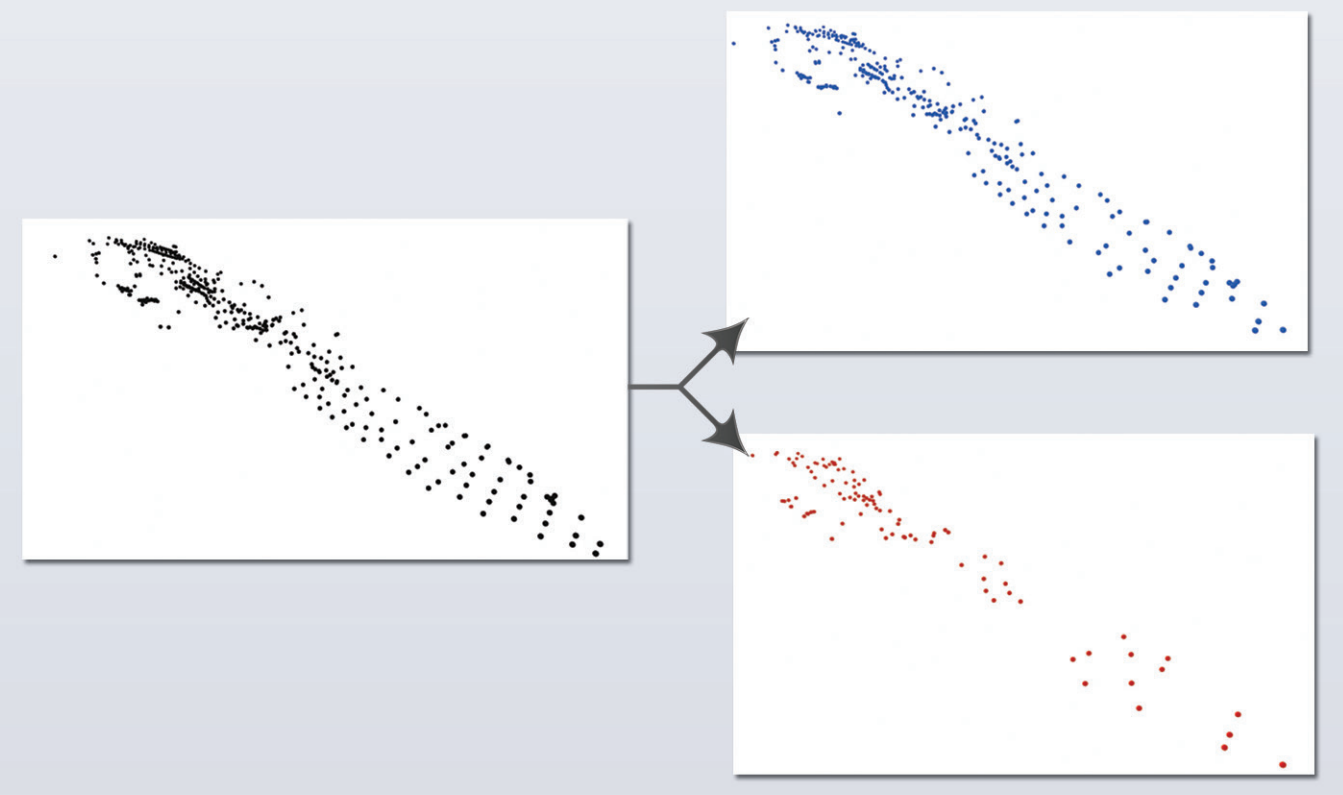
Introduction

The utilization of spatial statistics and modern day computing in subsurface mapping has introduced advancements in the way we analyze, explore and ultimately interpolate a surface. Traditional linear interpolation methods have been used for decades and will always have a practical application in subsurface mapping. They are exact interpolators, easily understood and have an application to a wide variety of industries and use cases. In recent decades, however, geostatistical interpolations have found their way into modern geographic information systems (GIS) and statistical software packages. These alternate interpolations methods are not without challenge and their implementation requires a thorough understanding of the spatial distribution of one's data. Our study aims to show that geostatistical methods are a viable alternative to traditional linear interpolation methods by quantitatively comparing interpolated and actual values of a subsurface geologic layer.

Methodology

A methodology consisting of two nearly identical workflows was developed using the Python programming language and the Esri ArcGIS Geostatistcal Analyst Extension. These iterative methodologies were used to evaluate the accuracy of both the geostatistical and linear interpolation methods.

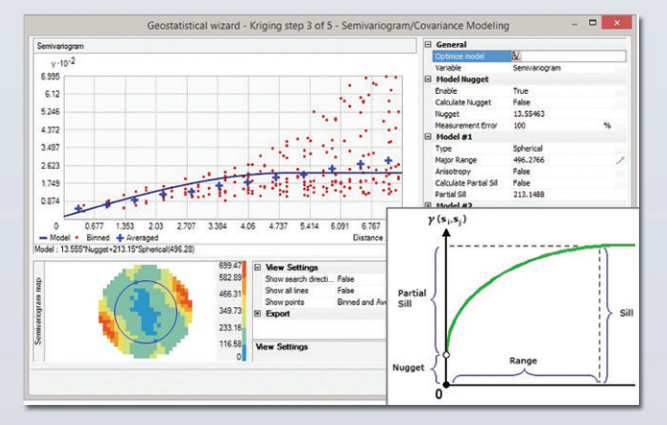
1. Subset

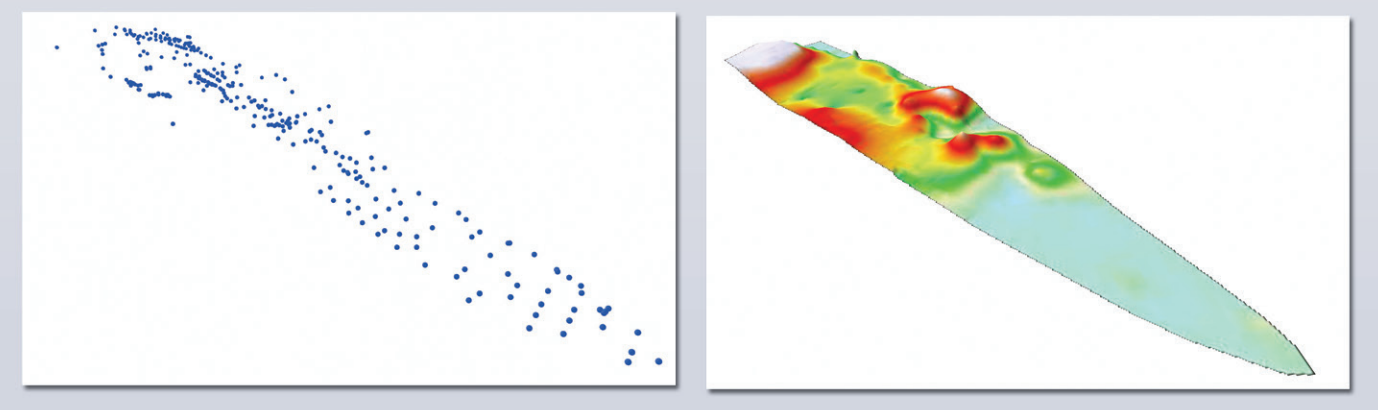


A random selection process divided the total population of 500 borings into two parts; 75% were utilized as input points to each of the interpolation surfaces with the remaining 25% set aside and used as assessment points to evaluate the accuracy of the interpolation.

2a. Interpolate

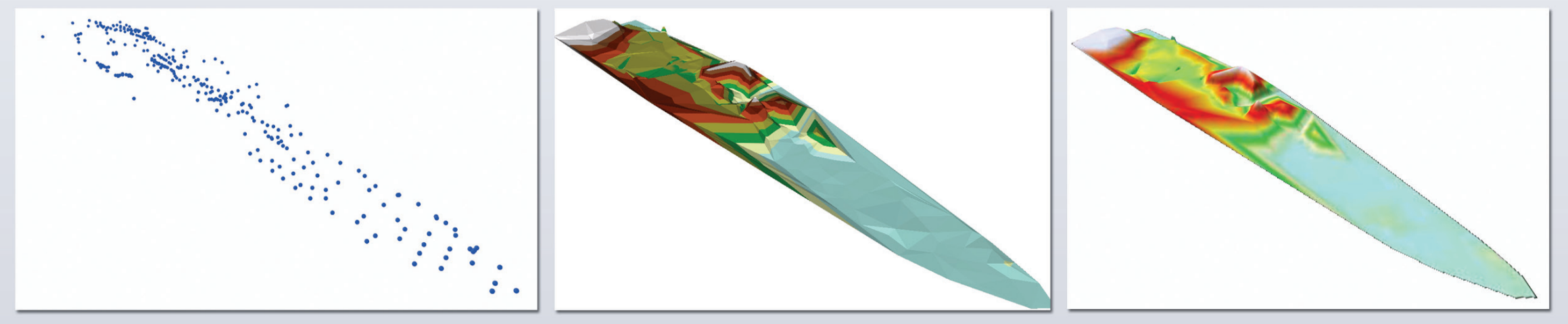
The geostatistical interpolation in this study required the spatial distribution of the dataset to be evaluated prior to subdivision. A single model was created from a combination of input and assessment points and then fit to the semi-variogram.





To construct the geostatistical interpolation surfaces the input points were convert to a surface utilizing the optimized model described above.

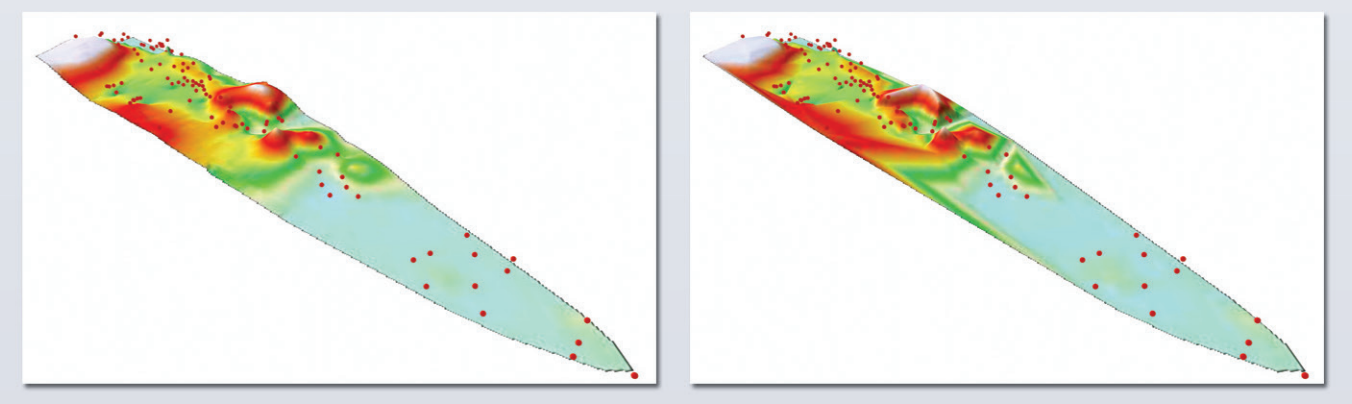
2b. Interpolate

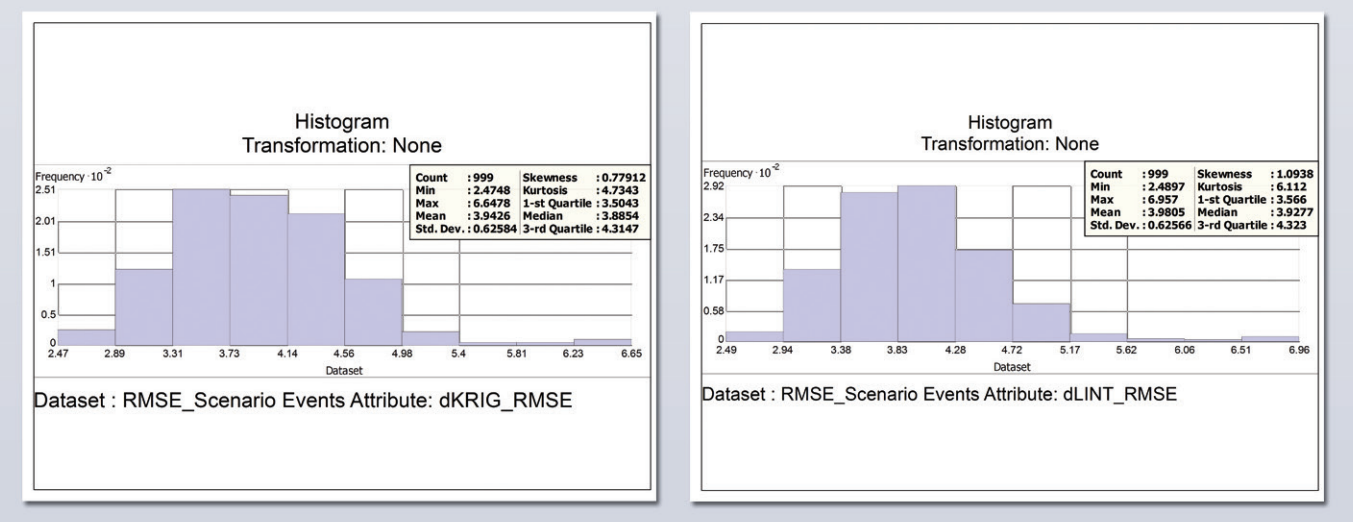


To construct linearly interpolated surfaces the input points were converted to a TIN and then to a raster through standard linear interpolation methods.

3. Evaluate

The assessment points were used to extract values from both the kriging and linearly interpolated surfaces and compare their interpolated values to those collected in the field.





Dataset : RMSE_Scenario Events Attribute: dKRIG_RMSE

Dataset : RMSE_Scenario Events Attribute: dLINT_RMSE

The accuracy of each interpolated surface was then determined through the use of a three-dimensional root mean square error (RMSE).

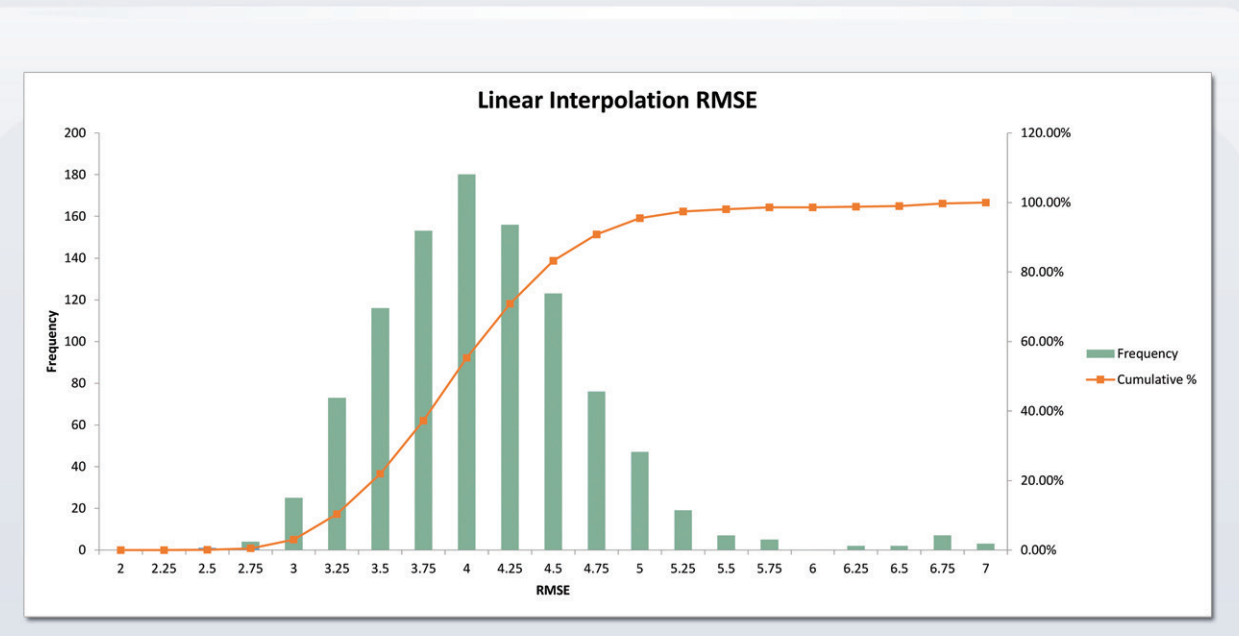
Results

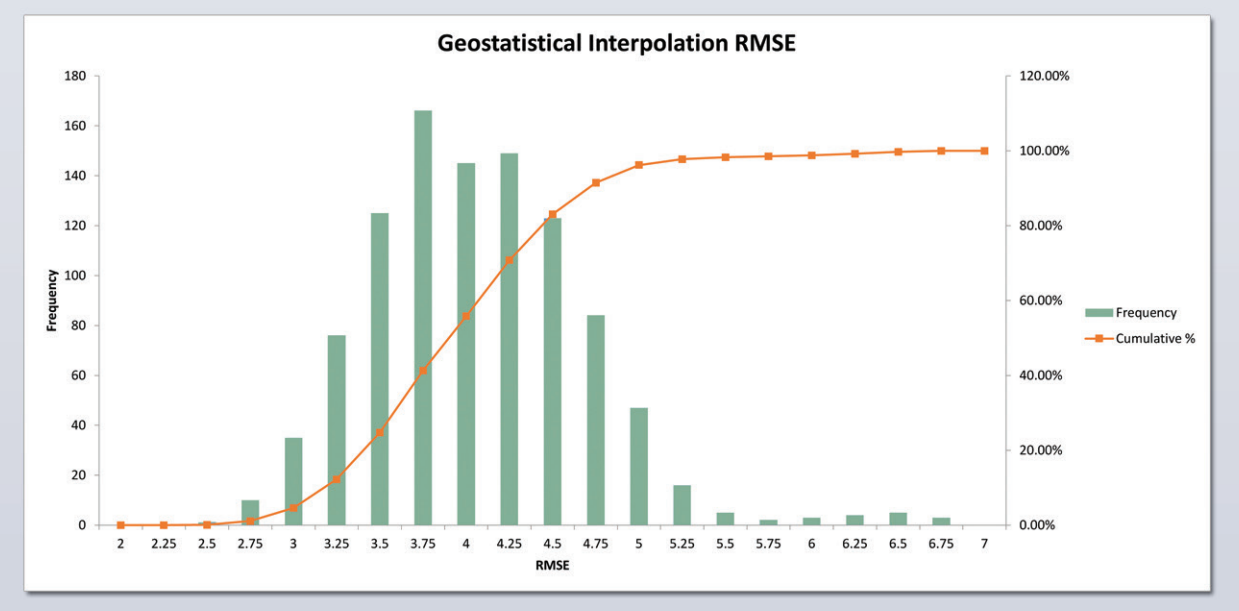
In an effort to validate our resulting surfaces we ensured that all interpolated surfaces for both the geostatistical and linear interpolation methods conformed to the input boring elevations and concluded that an average RMSE of less than one meter for each surface was achieved. When evaluating against the input borings, the linear interpolation surface averaged a lower RMSE, 0.812 meters, than the geostatistical one, 0.988 meters.

When testing against the validation points not used for the interpolation our results illustrate that after 999 runs of the model the geostatistical interpolation resulted in a lower root mean standard error (RMSE) more often than the linear interpolation. The geostatistical interpolation showed a lower RMSE 552 times while the linear interpolation resulted in lower RMSE 447 times. RMSE summary statistics for each of the interpolation methods can be seen in figures ## and ##.

We also compiled all the 25% validation points for each of the 999 scenarios and calculated the RMSE using the entire sampling of 96,931 borings. Geostatistical interpolation again returned a lower RMSE, with a value of 3.991 meters versus a linear interpolation RMSE of 4.028 meters.

In addition to the RMSE evaluation a statistical review of the results was also performed using a combination F and T tests. The F test illustrated equal variance among the RMSE values for each surface type and the T-test evaluated for statistical significant. Among the surfaces being evaluated for RMSE (N=999), there was no statistically significant difference between linear interpolation RMSE (M = 3.9805, SD = 0.62566) and geostatistical interpolation (M = 3.9425, SD = 0.62584), t(1996) = -1.3558 >= .05, CI95 -0.0170, 0.0929. Therefore, we fail to reject the null hypothesis that there is no difference in RMSE in values between linear and geostatistical interpolation.





	Maximum	Minimum	Range	Standard Deviation	Average	Count
RMSE Linear	6.95697	2.48974	4.46723	0.62566	3.98051	447
RMSE Kriging	6.64783	2.47480	4.17303	0.62584	3.94255	552

Interpolation	n	Mean	SD	t	df	p	95% Confidence Interval
Linear	999	3.98051	0.15324	–	–	–	–
Geostatistical	999	3.94255	0.15341	–	–	–	–
Total	1998	3.96153	0.15332	-1.35584	1996	0.17530	-0.017 - 0.0929

Summary

The geostatistical interpolation method of kriging yielded results with a lower RMSE more regularly than those of the linear interpolation. Since the results were so similar additional testing for significance was also performed. These statistical results showed there was no significant difference between the two results. Accordingly, it cannot be said that one method is better than the other, rather they both have a practical application and the ability to yield highly similar results.

Another variable complicating the outcome is the fact that kriging surfaces are hugely a function of their input parameters which possess a limitless combination of possibilities. The selection of kriging parameters is driven by the spatial distribution of the input data and also by the desired outputs of the kriging method.

Furthermore, even though both interpolation methods can be considered exact interpolators an evaluation against the input points illustrates linear interpolation does a better job of conforming to the source data than the geostatistical surface.

An unexpected outcome of this study is documenting the similarities which were created between the two interpolation methods. Assuming linear interpolation is the simpler method because it is derived from simpler mathematics and minimal input parameters, the fact we matched or exceeded its accuracy with the geostatistical surfaces for nearly every run, is a testament to the use of the geostatistical method and the parameters selected to create it.

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