De-clustering weights and MIK variography

IAMG 2017

Danny Kentwell
SRK Consulting, FAusIMM, MIAMG

srk consulting

Abstract

When data is clustered within a single domain some sort of spatially based weighting is often applied during statistical analysis to attempt to allow for the spatial representivity of each sample within the domain volume. There are conflicting views in the geostatistical literature on the use of de-clustering weights during calculation of experimental variograms. When it comes to using Multiple Indicator Kriging and multiple indicator variograms the differences between fitted variogram models using raw or de-clustered experimental variograms can be extreme, particularly at higher indicators from highly skewed distributions. This issue cannot easily be separated from the decision on the need for and choice of top cut for use in statistical analysis and estimation.

This presentation explores situations where de-clustering makes significant differences to high end indicator variograms, what data configurations cause this to occur and the implications for the grade and tonnage curves of MIK estimates in a mining context.

Overview

- Why we use multiple indicator kriging
- Looking at indicators as high end indicators are more sensitive to clustering of high grades
- Clustering and de-clustering
- Not proposing a new variogram weighting methodology
- A case study using an extreme case with conventional cell de-clustering in the context of current practice in the mining industry
- Conclusions

Why are indicators used in the first place?

- Because the domain has mixed populations which are difficult to effectively sub domain;
- Because we think we don’t have to sub domain because the indicators will take care of the different spatial variability characteristics of the different grade ranges regardless of weather they could be sub-domained or not;
- Because we think indicators are better at estimating skewed distributions without the use of top cutting.

- In the authors experience, for cases where we think indicators may be useful, there is often a degree on non-stationarity at some scale

Why does clustering occur?

- Preferential sampling of higher grade
- Restricted access issues

- In the authors experience, the existence of clustered sampling also often coincides with non-stationarity at some scale.

Conventional de-clustering - Methods

- Grid cell
- Sample centred cell (Isatis)
- Voronoi
- Nearest neighbour
- Kriging weights

- All have drawbacks are sensitive to aspects such as cell dimensions and edge effects

Theory 1

- It is considered that de-clustering methodologies aimed at removing bias from the global mean of a domain and for inferring the distribution shape are not well suited to weighting experimental variograms.

- Variography deals with two point statistics whereas conventional de-clustering deals only with one point statistics. The required weights should be different at different separation distances to account for the degree of spatial continuity as well as separation distance.

- Using conventional de-clustering weights for experimental variography can lead to “de-structuring” of the experimental variogram.

Theory 2

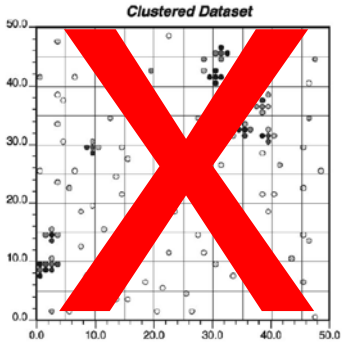
- A number of variogram weighting schemes have been proposed
- Rivoirard - 2000
- Richmond - 2002
- Emery and Ortiz - 2005
- Olea – 2007
- Reilly & Gelman - 2007
- And others…..

- But none are in common use or available in commonly used software in the mining industry

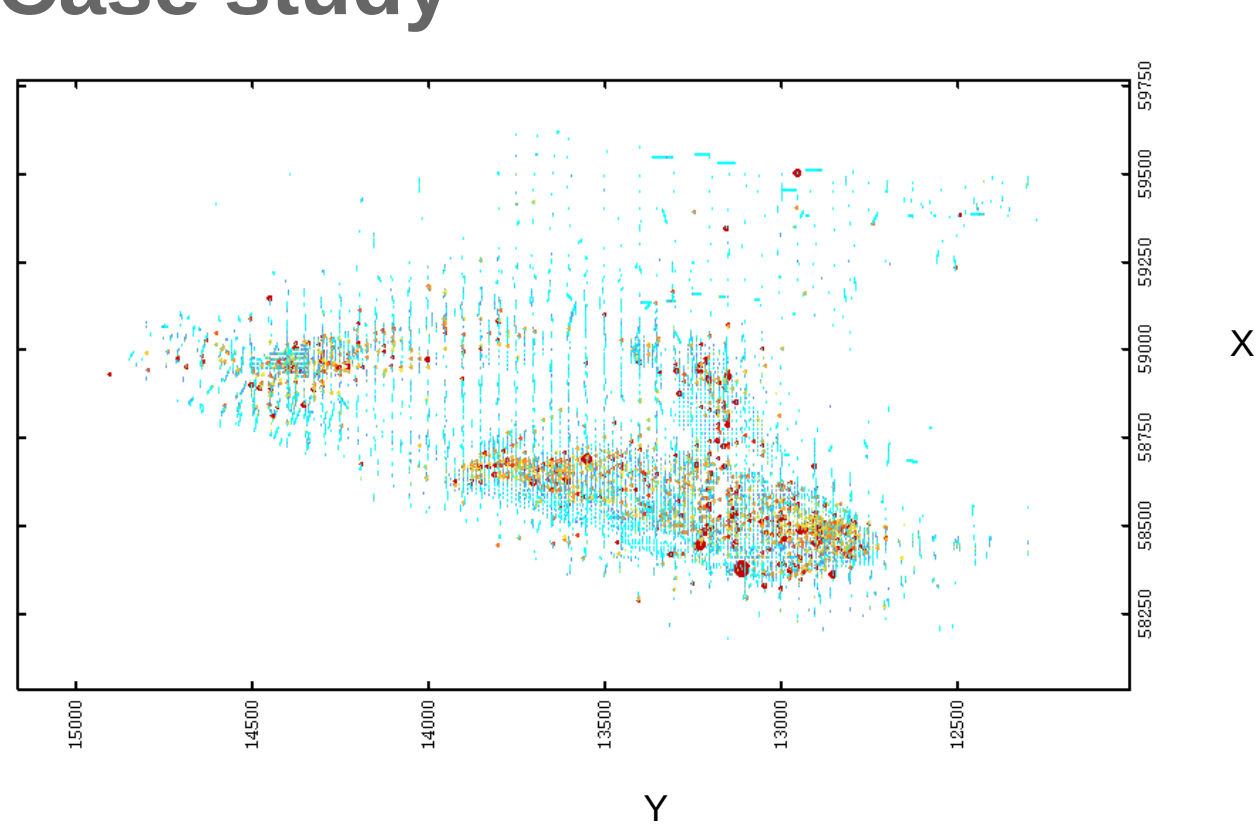
Case Study

- We will examine what happens when conventional 1 point de-clustering weights are applied to indicator variograms in an extreme case

- This is a real 3D mining dataset, not a simplified, idealized 2D simulation.



Case study



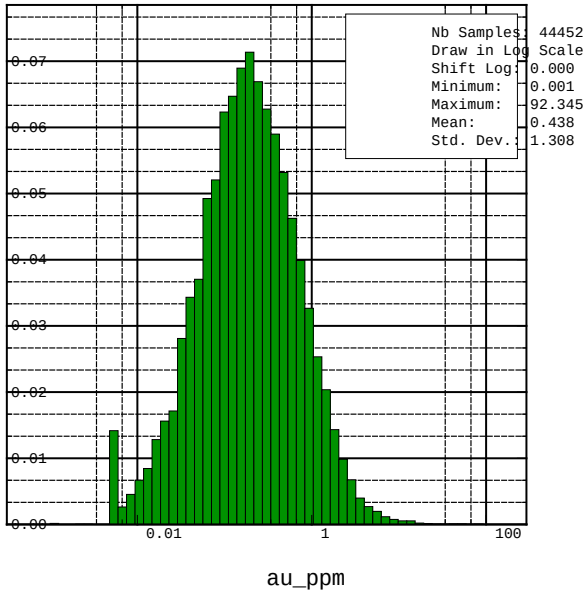
An extreme example?

Yes.

To better illustrate the points.

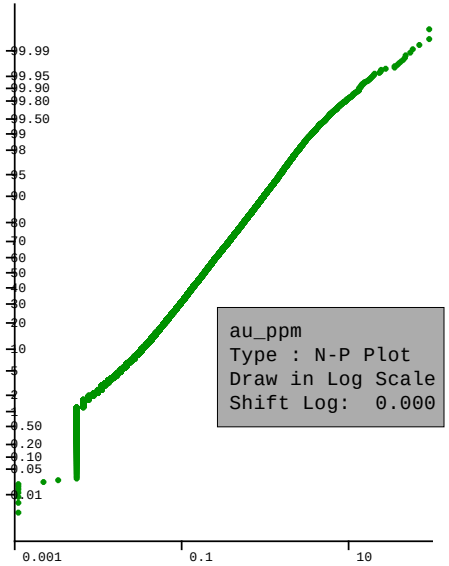
srk consulting

One population?



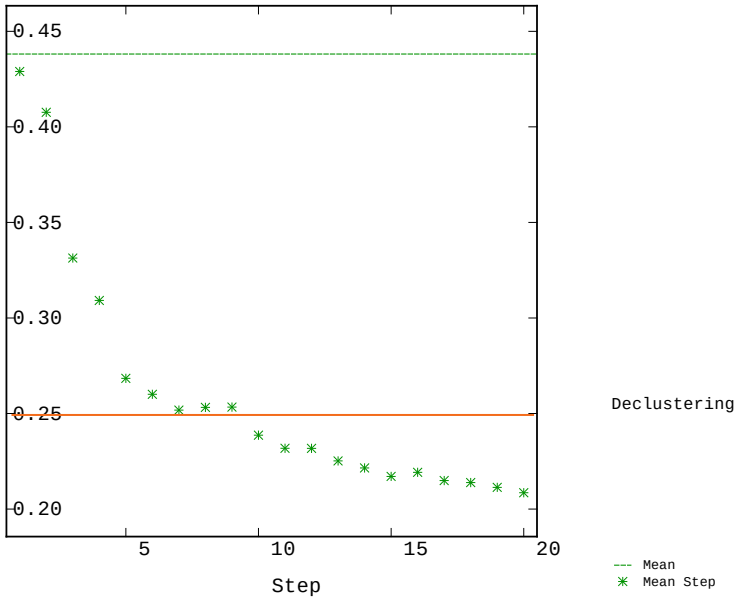
Not multi modal

Small detection limit spike



srk consulting

De-clustering sensitivity



20 tests from 5x5x5 to 250x250 x250

Raw mean 0.44

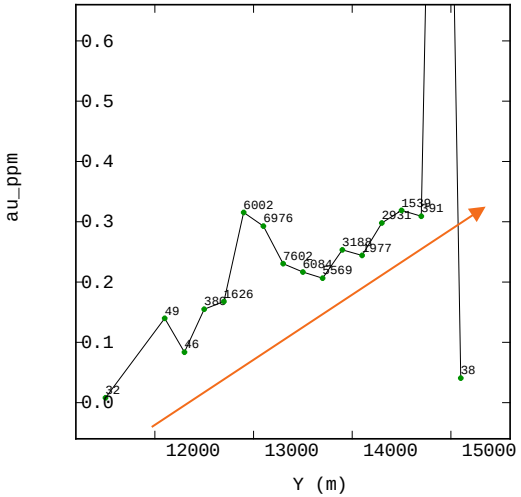
Chosen de-clustered mean 0.25 using 100x100x50

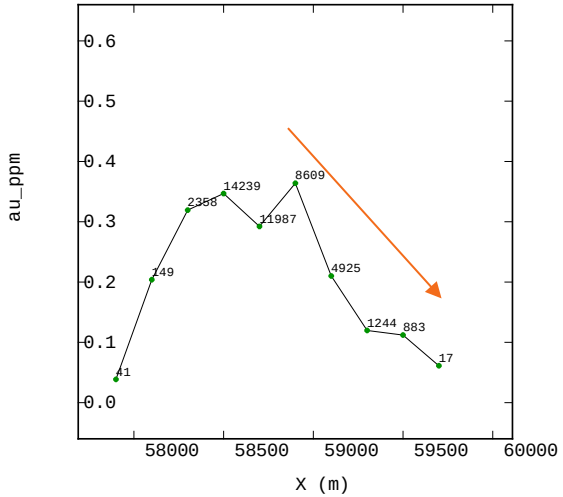
Close spaced drilling 12.5 x 12.5

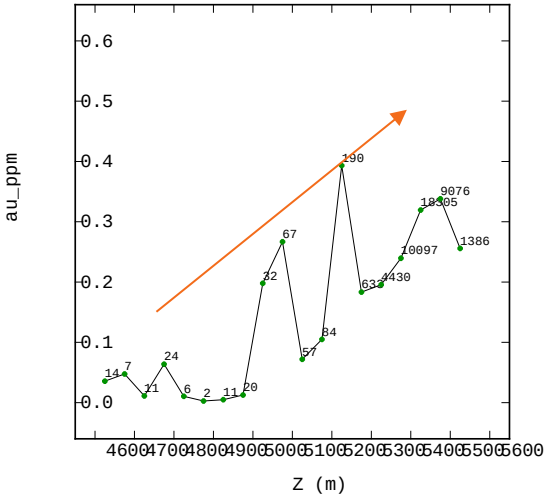
Wide spaced drilling 50x 50 to 100 x 100

srk consulting

Stationarity (de-clustered)







srk consulting

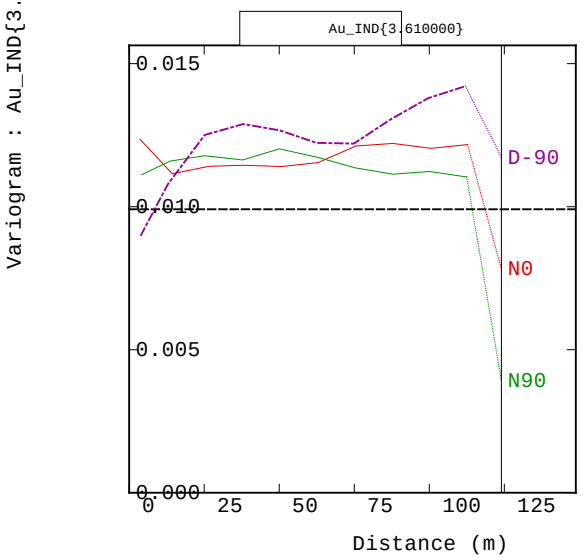
Indicator bins (unweighted)

Percentile	Cut off
20	0.06
30	0.10
40	0.13
50	0.19
60	0.26
70	0.37
80	0.55
90	0.96
95	1.51
99	3.61

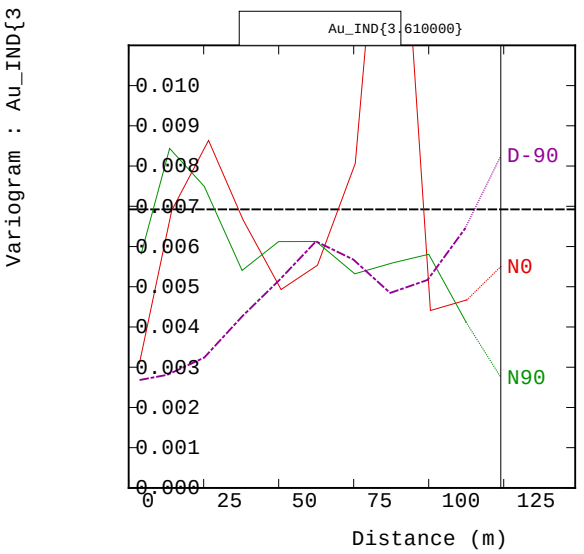
Why indicators? Same issue with any variogram. Indicators show even larger differences

Top indicator experimental variogram

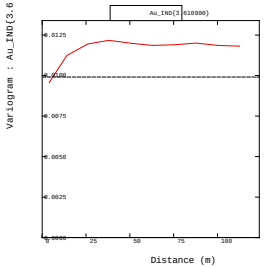
All above population variance – why?

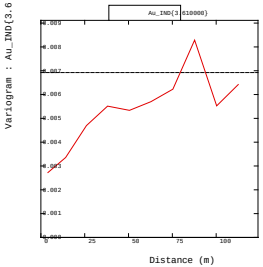


un-weighted



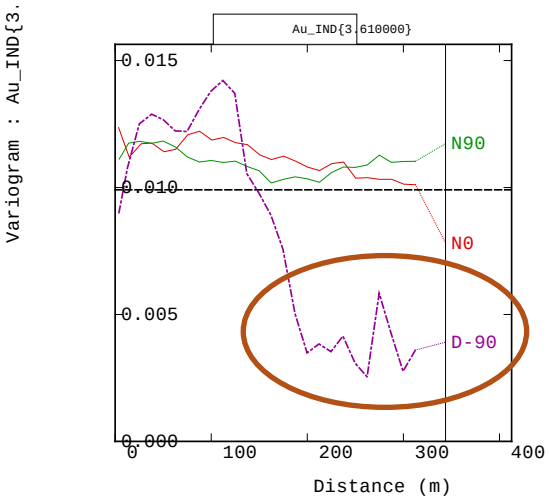
weighted



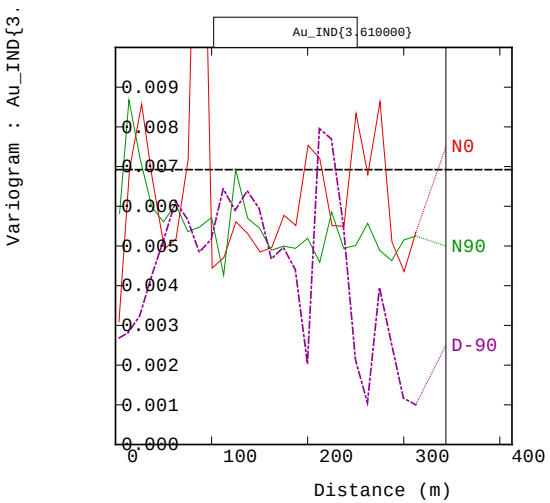


srk consulting

Top indicator experimental variogram – long range



un-weighted



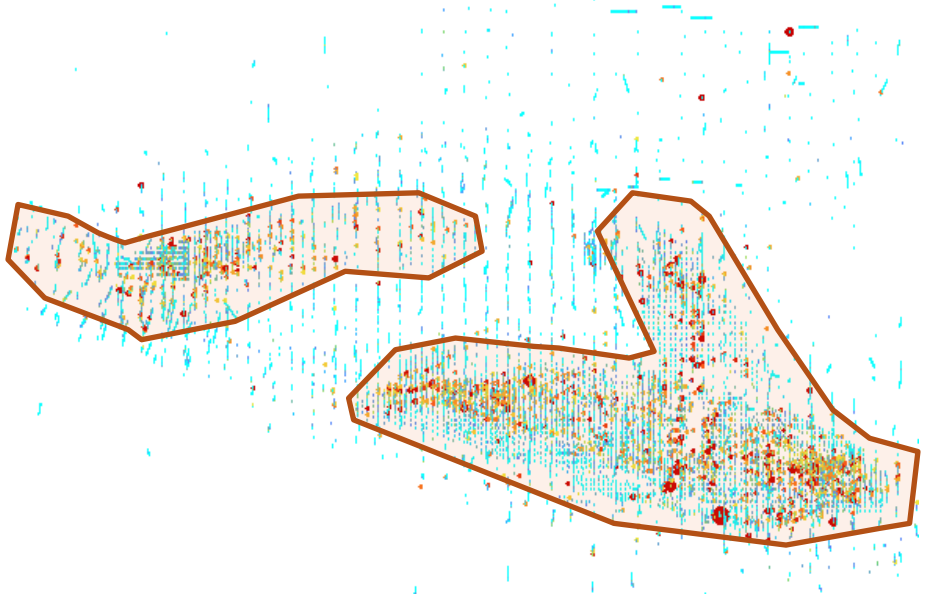
weighted

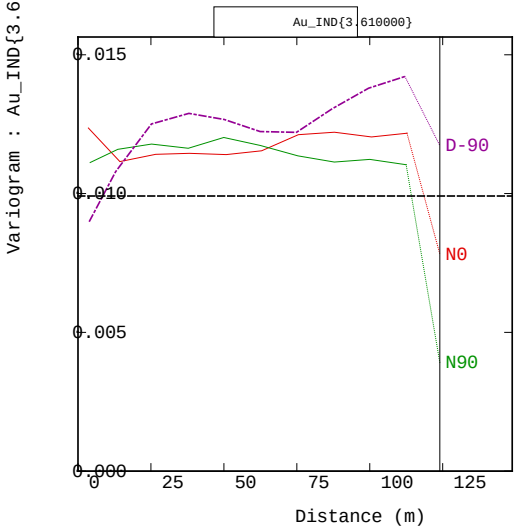
De-structuring evident

srk consulting

Why the difference? – no de-clustering

The un-weighted experimental variograms preference the short range variability associated with the high grade closely spaced samples leading to higher nugget and lower ranges compared to the de-clustered experimental indicator variogram.

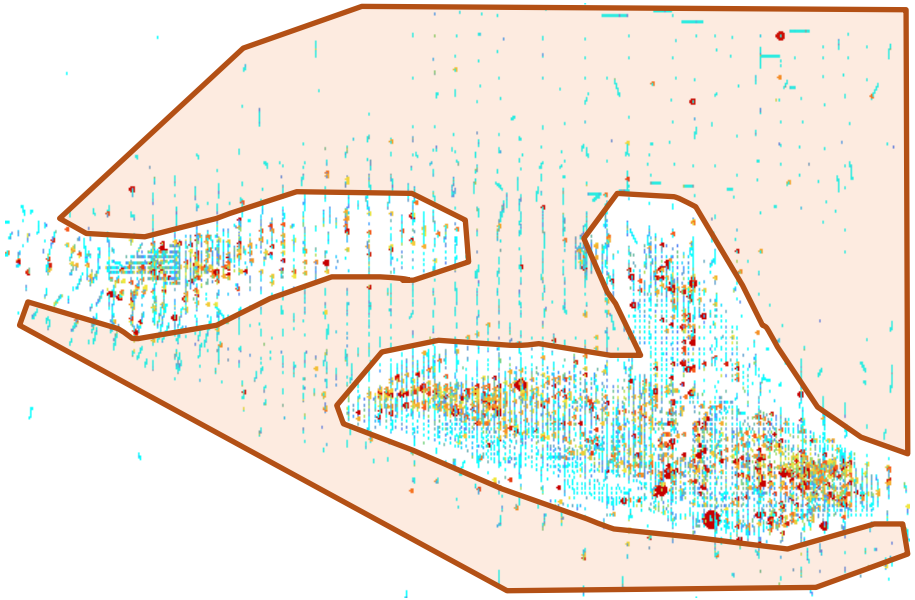


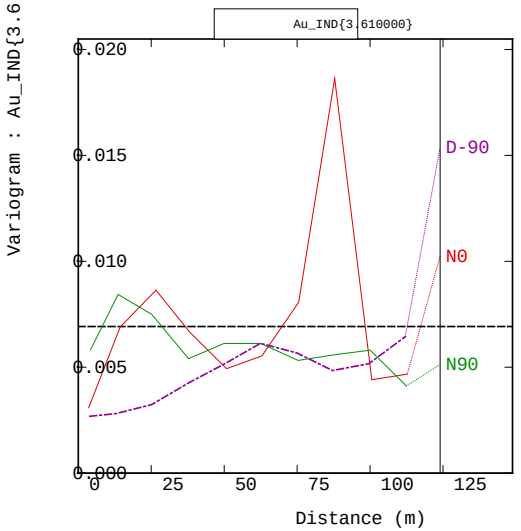


srk consulting

Why the difference? – de-clustering

The de-clustering gives equal weight to both close and wide spaced sampling leading to averaging of the nugget and spatial variability over the domain with overall lower nugget and longer ranges due to the high continuity of the low grades.





srk consulting

Are both wrong?

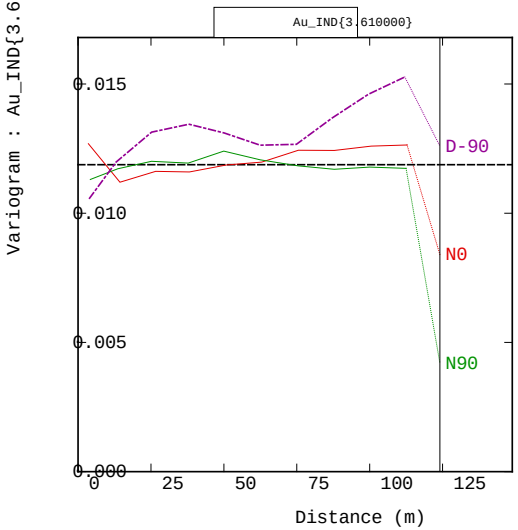
- Yes
- Neither takes account of the spatial 2 point aspects
- If de-clustering is used the spatial continuity of the close spaced (high grade) sampling is exaggerated
- If de-clustering is not used the spatial continuity of the wide spaced (low grade) sampling is incorrectly reduced.

Implications for Grade and Tonnage

- Which has more impact in the mining context?
- We don’t really care if the low values are wrong but getting the high grades wrong is a big problem!
- So, in this case and in most cases in mining, the high grades are clustered and it is these grades we are most interested in getting right. So **in this case**, if we must use the domain without further subdivision, **de-clustering should not be used** for variography.
- **The obvious answer for this data set is to sub domain and re examine**

- Every data set is different and the split between “low” and “high” may not always coincide with the economic circumstances of a particular project.

Close spaced sub domain - Same indicator



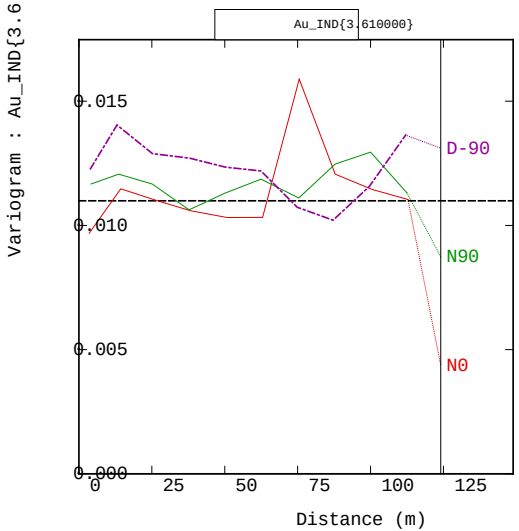
This is what we expect top bin indicators to look like

Now not much difference.

Stationary – less clustered

Total sill now back on the population variance

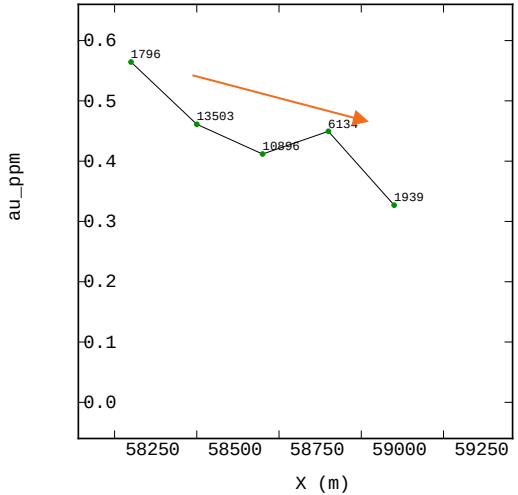
Un-weighted

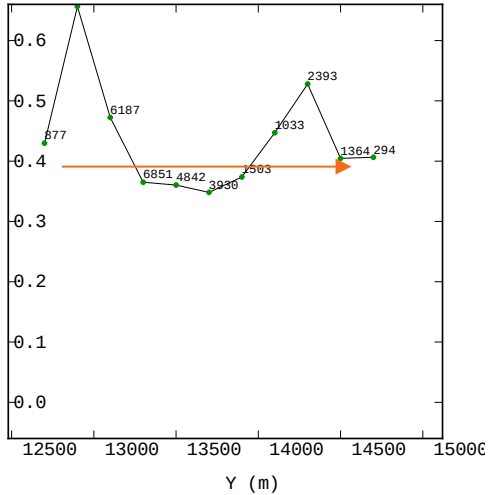


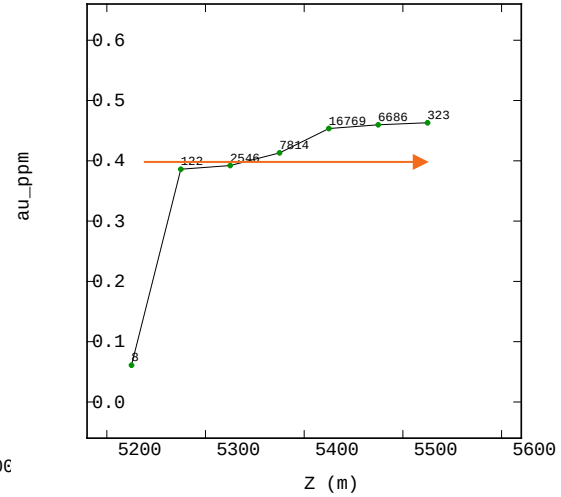
Weighted – new weights

srk consulting

Close spaces swath plots

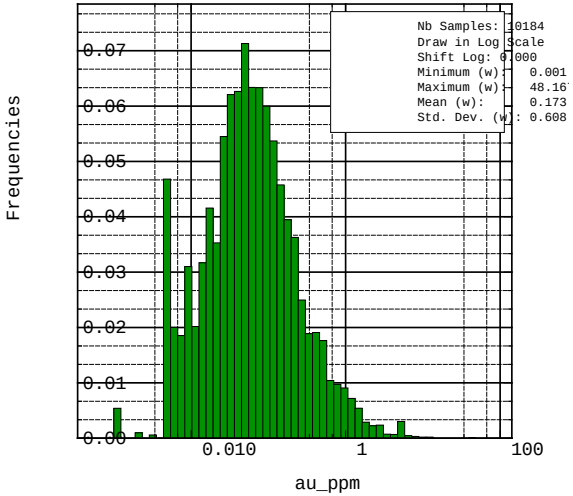


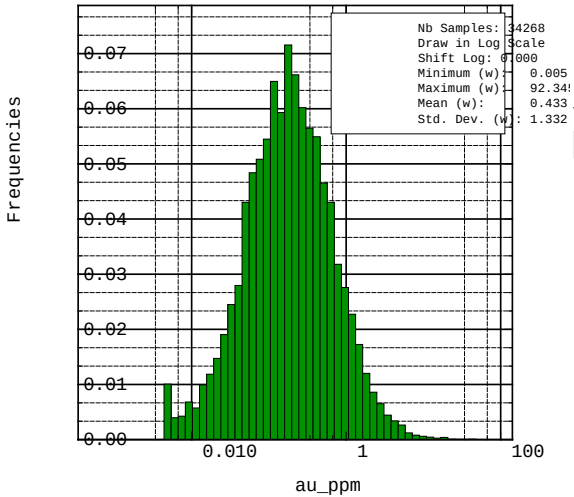




srk consulting

Histograms close and wide spaced sub domains





Still approximately lognormal

srk consulting

Can we use conventional de-clustering techniques to de-cluster for indicator variography……

- In a practical sense the question is not so much, is the use of conventional de-clustering weights for variography correct (it is not), but is using them better than not using them?

* de-clustering for statistical inference of the global mean and histogram should still be done in all cases

Maybe

- If the domain is close to stationary then de-clustering should not be necessary, so it probably doesn't matter
- **For non-stationary domains, if it makes sense to sub domain further this is a better solution**
- If further sub domaining is not possible or practical and;
  - the high grades are clustered then NO
  - the low grades are clustered then YES
  - a balance at all grade levels is required then YES

- This still doesn't address the potential de-structuring effect of using conventional de-clustering weights which can be problematic for small data sets

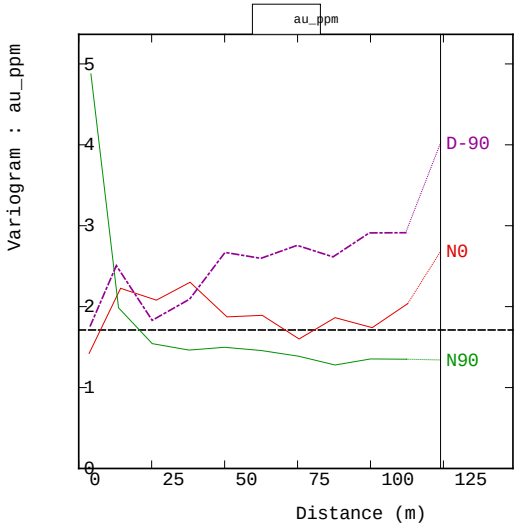
Thank You – Questions?

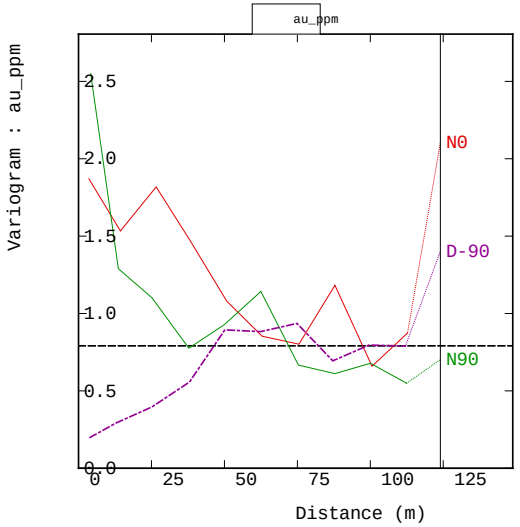
srk consulting

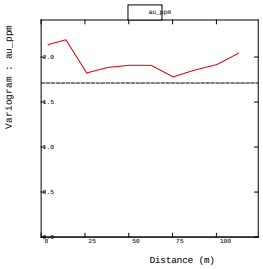
De-clustering for variography - ?

- Journel & Huijbregts
- Isaacs & Shrivastava
- Chiles & Delfiner
- Rossi and Deutsch
- Coombs
- More…

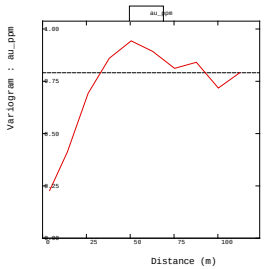
Extras - uncut grade experimental variogram







un-weighted



weighted

srk consulting

Extras - other forms

- Pairwise relative – gives similar results on unweighted data to a variogram with declustering weights but only with raw data – does not work with indicators.

- Correlogram?

Extras - Strong non-stationarity

- Often found with highly clustered data
- Different variances (variogram total sills) in different parts of the domain
- Possible zonal anisotropy - messy
- Makes Indicator variography spatially biased?
- Subdomain further?
  - Can lead to insufficient samples for useable experimental variography
- Local variography?
  - Same problem
- Locally weighted variograms (Machuca and Deutsch)?
  - Anyone tried this on a real data set?

Extras - Indicator bin definition

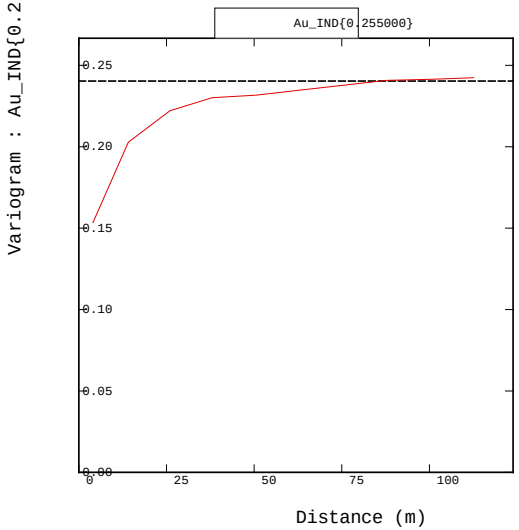
- In the presence of non stationarity
- In the presence of outliers
- From highly skewed distributions

- Before we even get to the variography
- Bin definition with/without de-clustering weights?
- Do we need separate weights for each indicator?

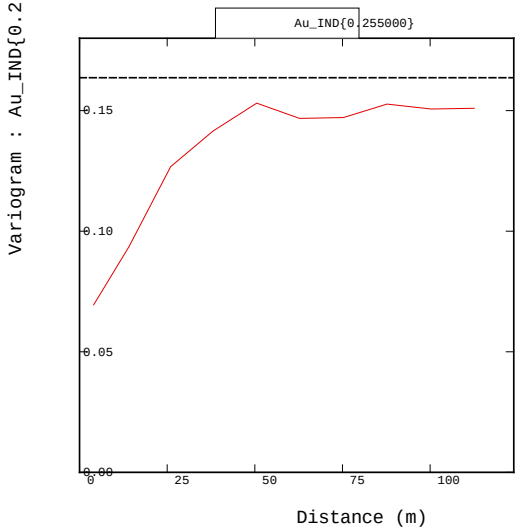
Extras - Top cutting

- Is it required with MIK?
- Are all the very high values clustered?

Extras - Mid range omnidirectional indicator



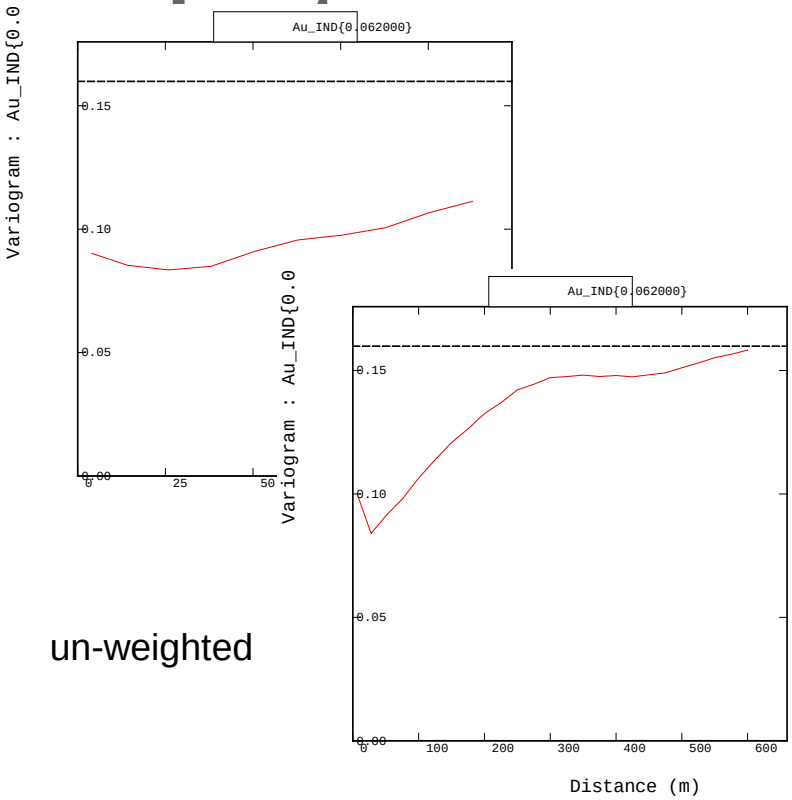
un-weighted



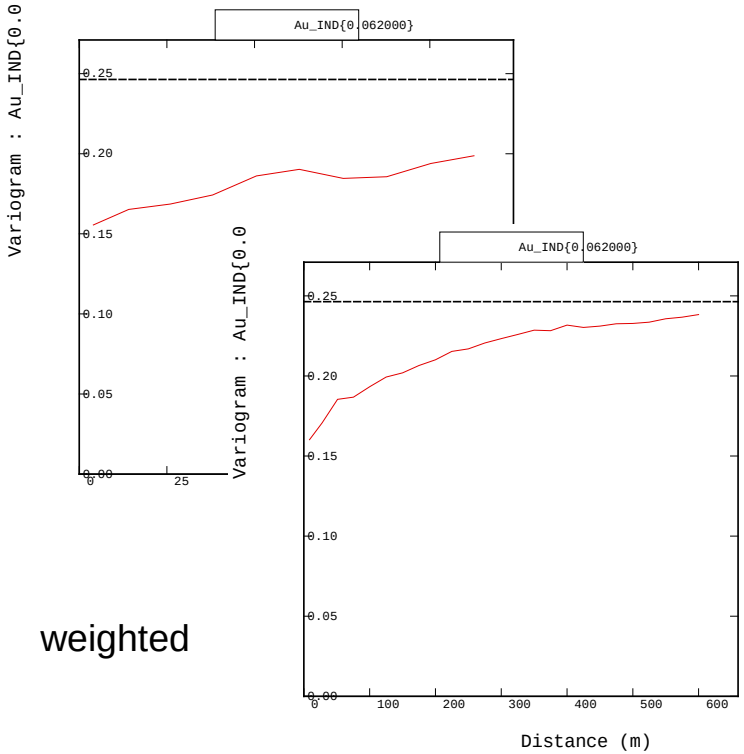
weighted

srk consulting

Extras - Low grade omni



un-weighted



weighted

srk consulting