Local Uncertainty Benchmarking

A coal case study

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Acronyms

SMU -> Selective mining unit

(the smallest volume used for ore/waste delineation)

CS -> Conditional Simulations

DHSA -> Drill Hole Spacing Analysis (global)

Local uncertainty

Why is it important?

- Kriged estimate -> block scale (≅drill hole spacing)
- But short term mining decisions based on SMU scale

- Variability, $\sigma_{\text{SMU}} >> \sigma_{\text{Block}}$

- Penalty elements, ore specification, delivery contracts

- Need to understand local uncertainty
  -> at smaller than drill hole spacing -> at SMU scale

- Investigate shorter term uncertainty
-> integrate method into mine planning and operational decisions

At the SMU scale

Can relative uncertainty be approximated by co-kriging?

Key project objectives

#1 Investigate feasibility of using SMU kriging variances

#2 Develop and validate a relative simple methodology to
- provide timely local uncertainties on SMUs
- be implemented on site

#3 Use stringent benchmarking to
- validate results
- support and defend proposed methodology

Methodology

ST = seam thickness
Var_{ACC} = Accumulated Variable, eg. Ash_{ACC} = ASH x ST
P5 = 5th percentile

	Co-Kriging	Conditional co-simulations
1	Clean data set - ST and Var_{ACC} Calculate residuals	
2		Gaussian Anamorphosis of data
3	Cross-variography	Cross-variography of Gaussian variables
4	Co-Krige ST, Var_{ACC} into SMUs	Co-simulate Gaussian variables (1000 realisations) Back-transform to ST*, Var_{ACC}*
5	Add global drift trend to each estimate	
6	Ash* = Ash_{ACC}* / ST*	
7	St. Dev of Ash*	Average point values in each CS realisation into SMUs
8	P5, P95 ≈ Ash* ± 1.645*St Dev	P5, P95 extracted from simulations 90% CI = [P5,P95]

Results

- Thickness, Fluorine, Phos closest to normally distributed
- Ash – peaked distributions (higher kurtosis)
- Sulphur – right skewed
- Benchmark uncertainty estimates will typically have 4.6% sampling uncertainty

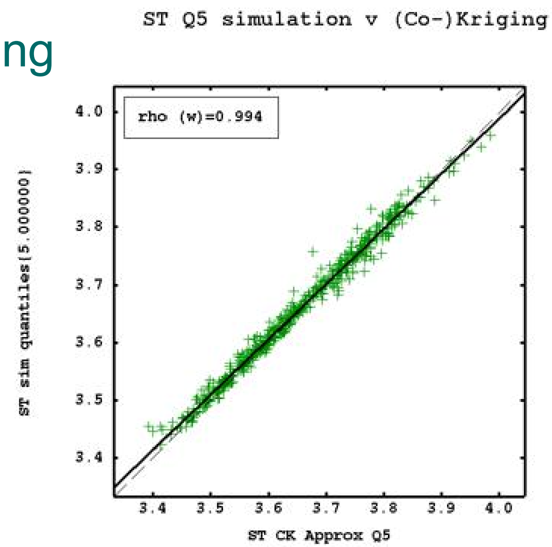
- 90%CI

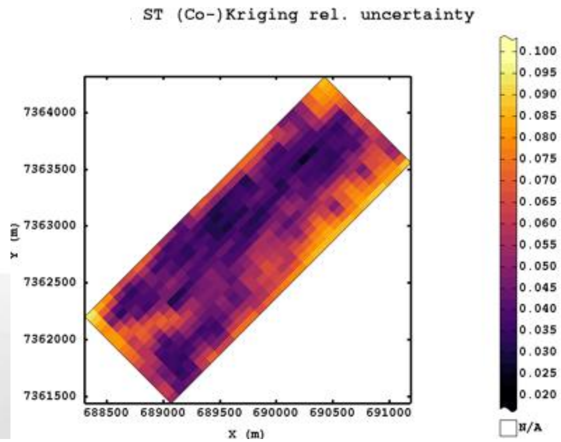
- Relative uncertainty = $\dfrac{\text{90\% CI}}{\text{estimated SMU value}}$

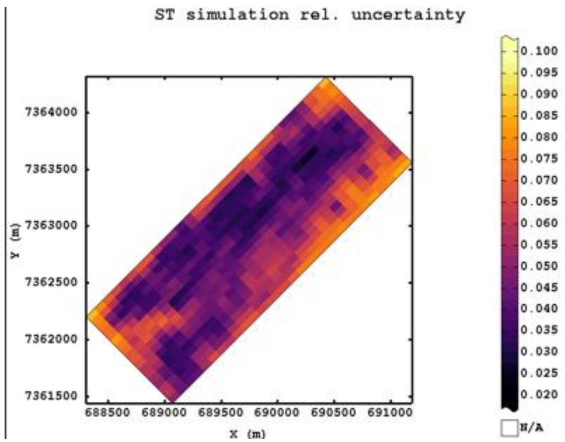
Results

Relative uncertainty for Conditional Simulations and Co-Kriging

Variable	CS	CoK
Thickness	5.0%	5.2%
Ash	11.8%	14.7%
Fluorine	45.6%	40.8%
Phos	35.8%	37.3%
Sulphur	35.8%	37.3%







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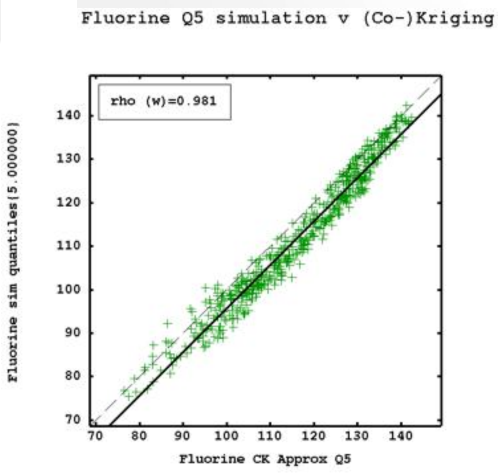

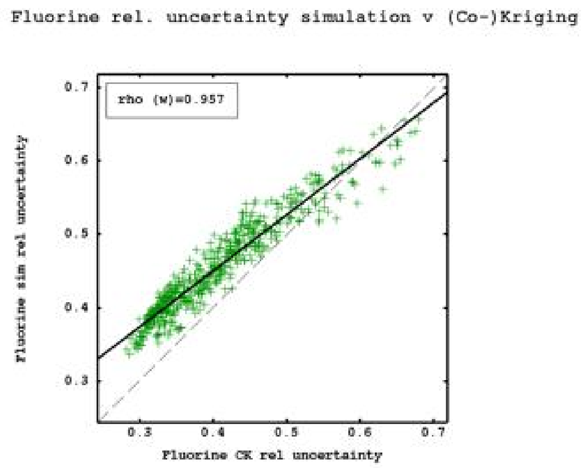

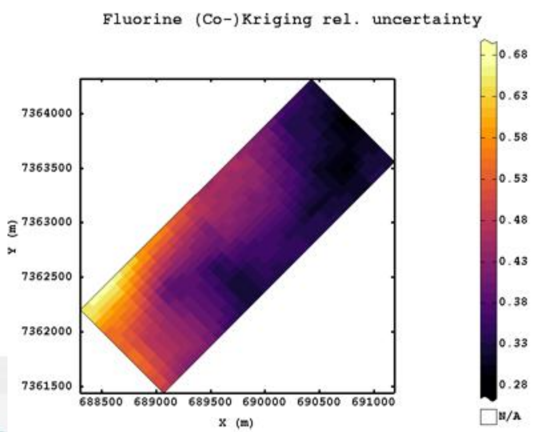

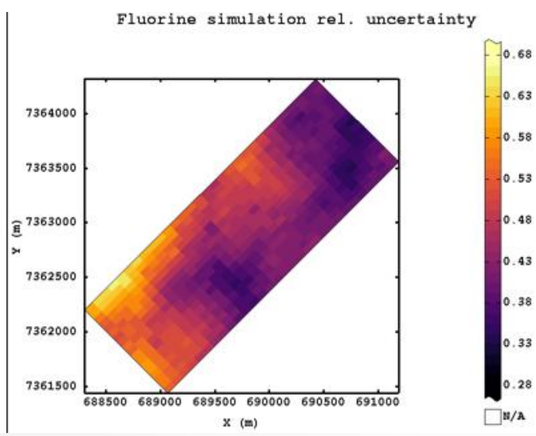

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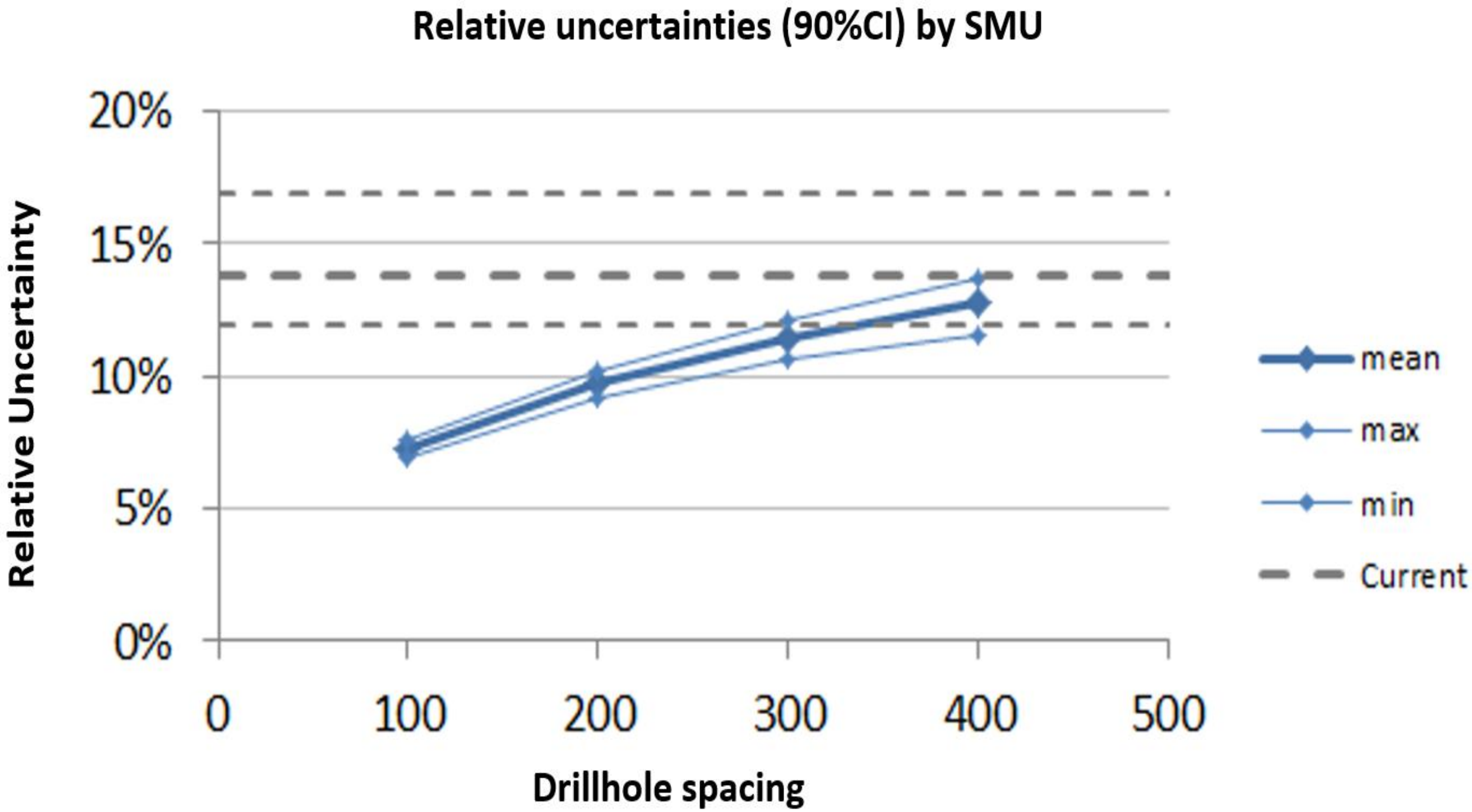
Relative uncertainties (90%CI) by SMU
20%
15%
10%
5%
0%
Relative Uncertainty
0
100
200
300
400
500
Drillhole spacing
mean
max
min
Current

Conclusions

- Agreement between kriged and simulation methods is
  - Excellent for thickness
  - Very reasonable for quality variables

- CS benchmarking supports use of Co-kriging variances to estimate SMU uncertainties.

In hard rock mining using CS for local uncertainty estimates is certainly more common than in coal. However, definitely not mainstream yet. DHSA gives first pass answer so there is a potential to extend this coal, 2D case study into 3D, non coal applications. *Bearing in mind, it is only the first pass application.*

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