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Publication date
2016

Document Version
Final published version

Citation (APA)
Yüksel, C., & Benndorf, J. (2016). *Performance Analysis of Continuous Resource Model Updating in Lignite Production (PPT)*. 10th International Geostatistical Congress, Valencia, Spain.

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Performance Analysis of Continuous Resource Model Updating in Lignite Production

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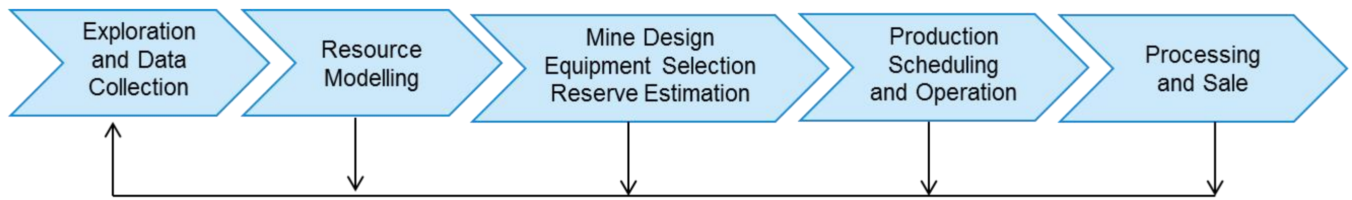
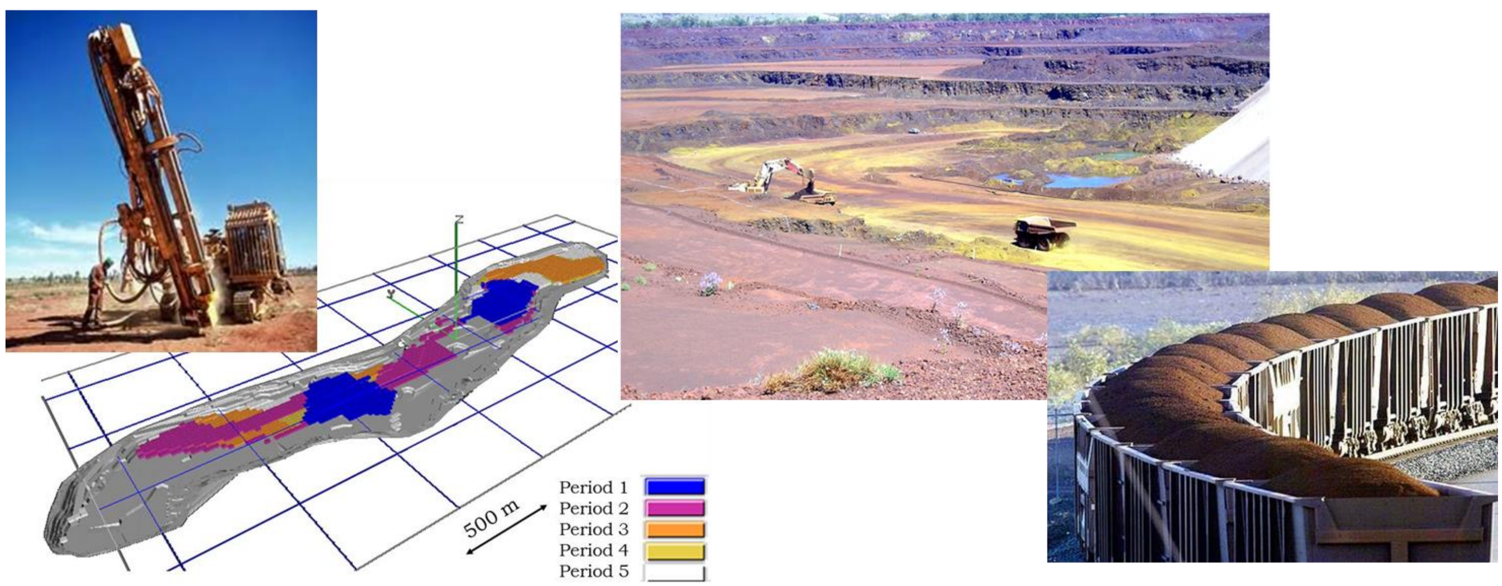
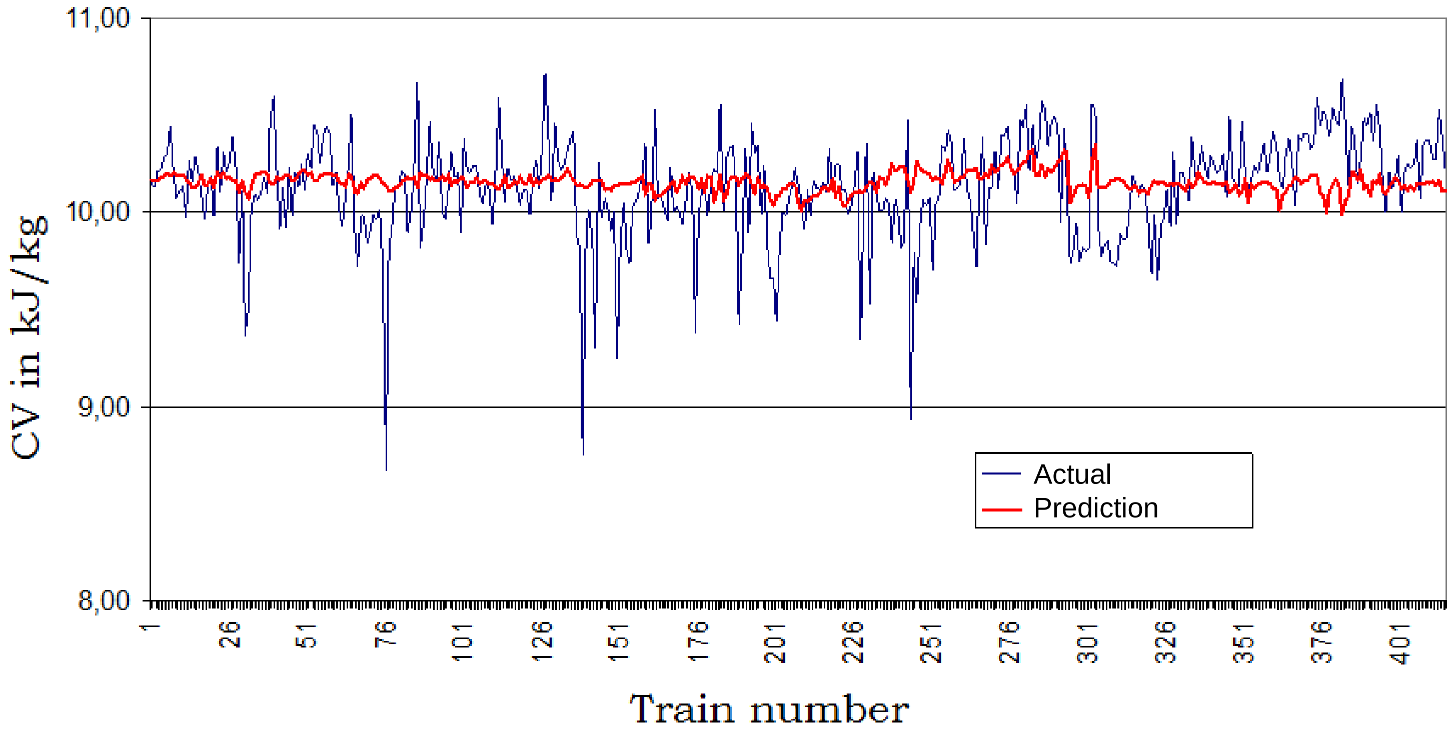
The Flow of Information





Uncertainty in Model-Based Prediction



New Potential: Online Sensor Data

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Content

How can we make best use of the available data?

- Closing the Loop: A feed-back framework for Real-Time Resource Model Updating
- Case Study: Application in a Real Coal Production Environment
- Performance analysis with respect to main parameters:
  - Ensemble size
  - Localization and neighborhood strategies
  - Sensor precision

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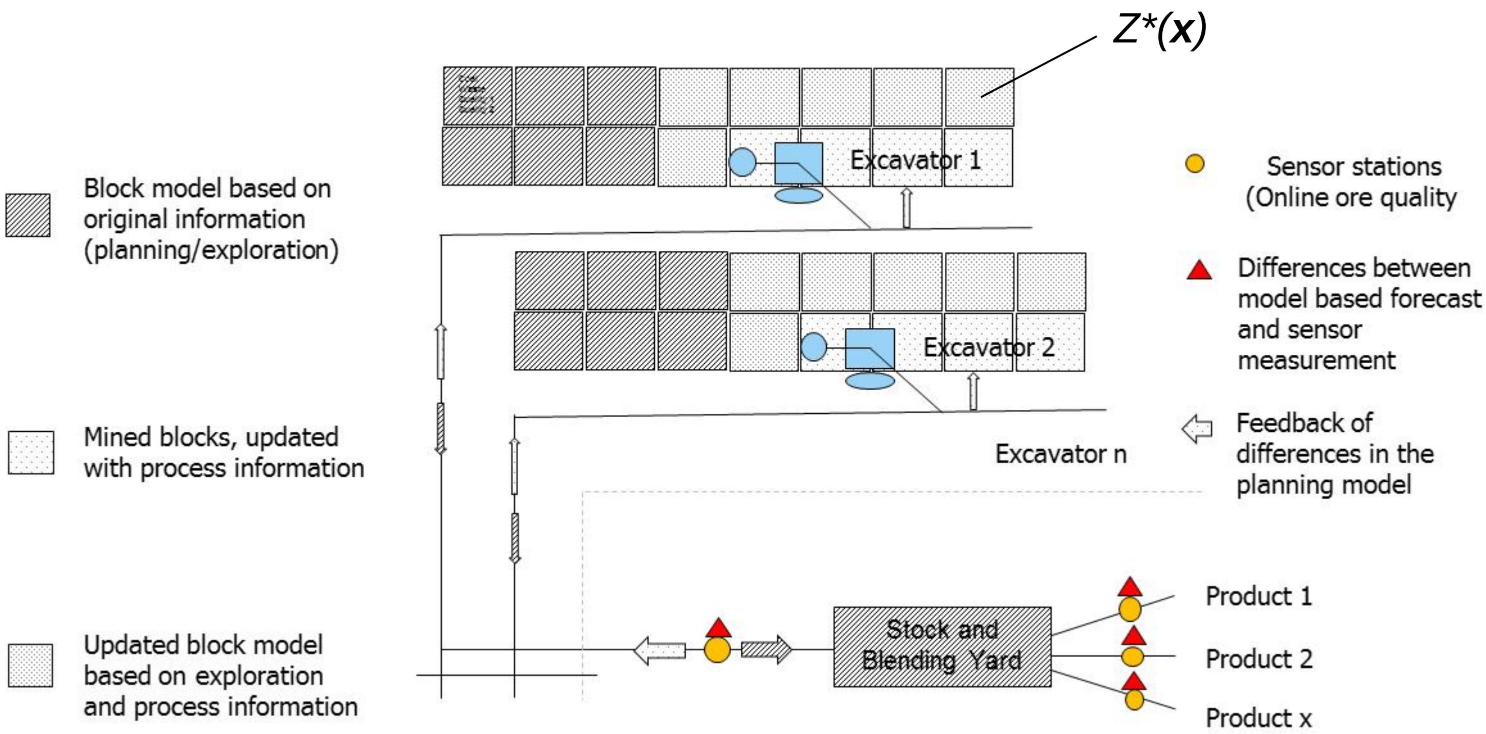
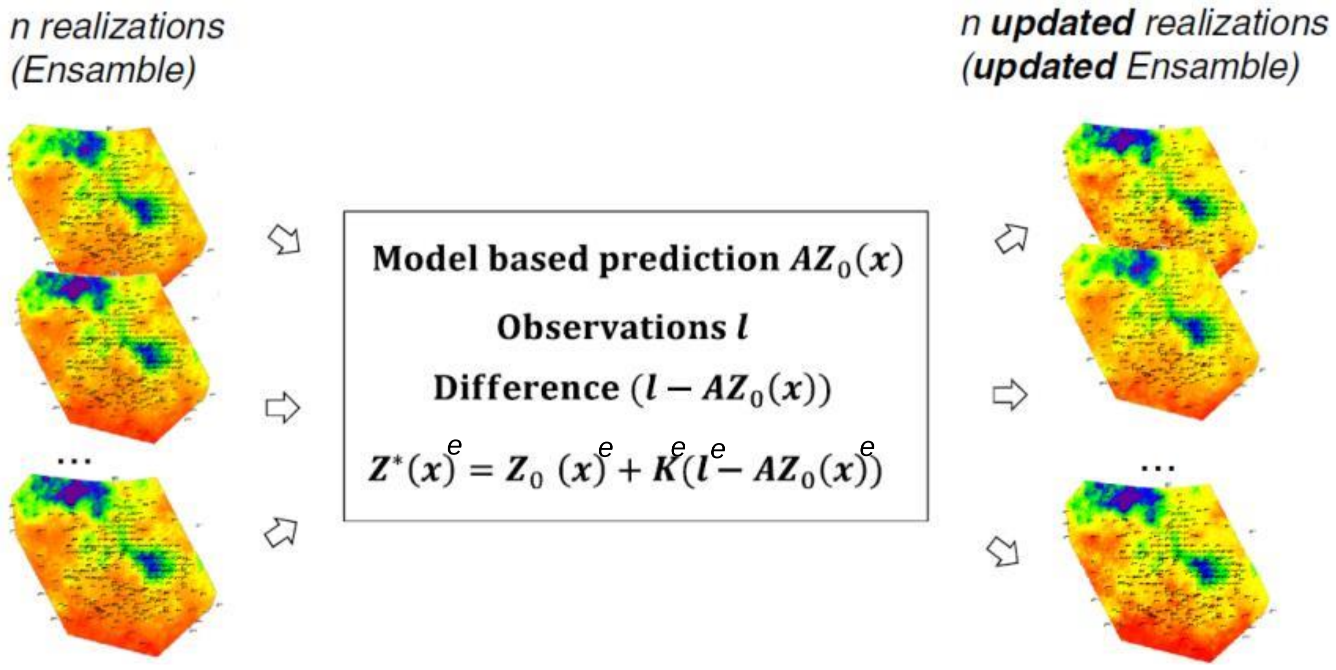
Towards Closed-Loop Management



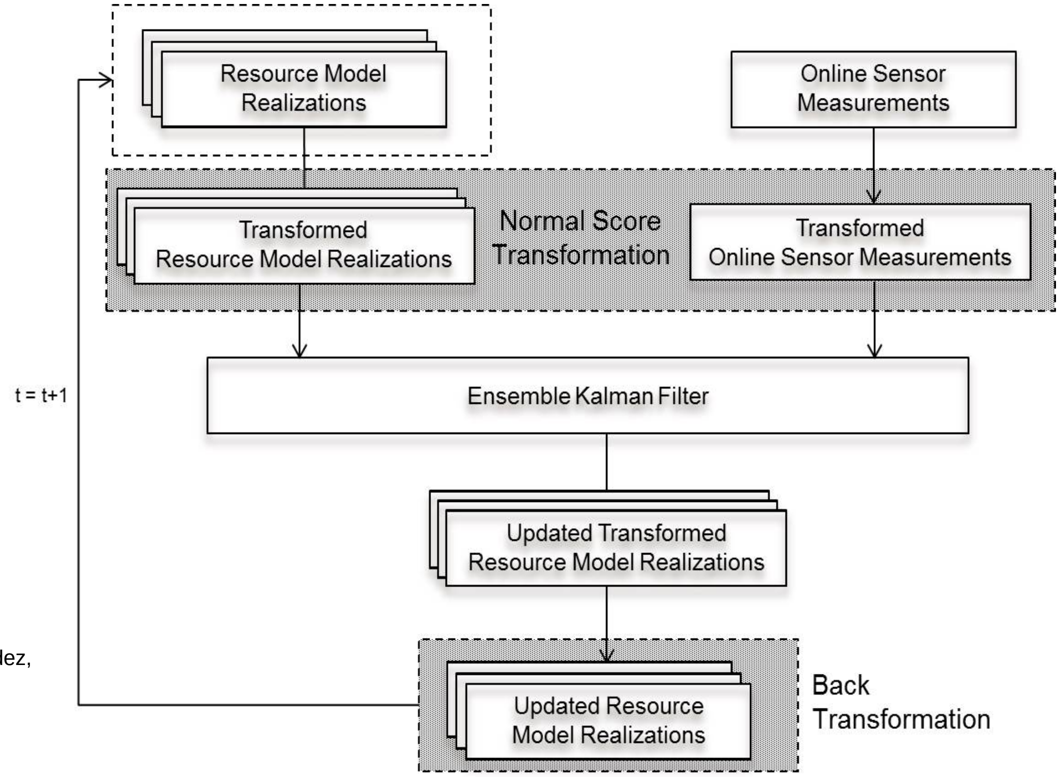
Resource Model Updating

Sequential Model Updating
A Non-Linear Version – The Ensemble Kalman Filter



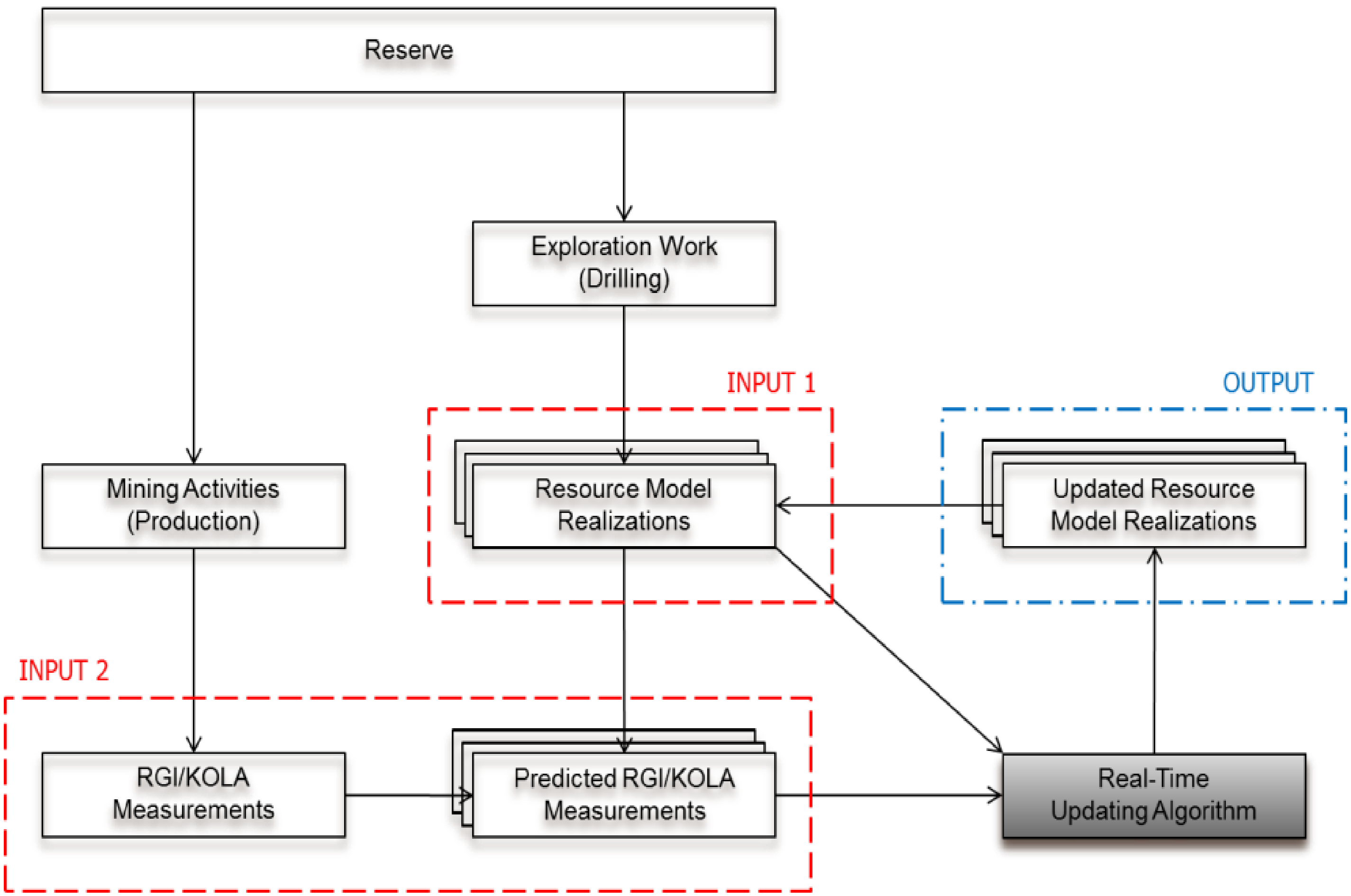
Resource Model Updating

Sequential Model Updating
To handle Non-Gaussian Data…
N-Score-Ensemble Kalman Filter*



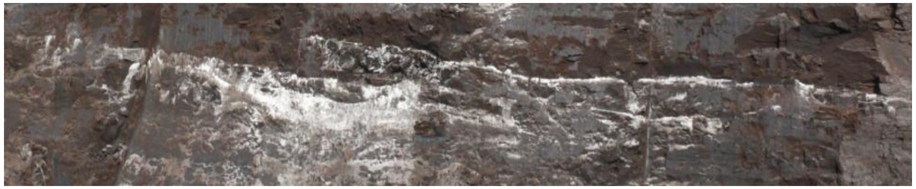
*Z Haiyan, J J Gomez-Hernandez, H H Franssen, L Li. 2011. An approach to handling non-Gaussianity of parameters and state variables. *Advances in Water Resources*, 844-864.

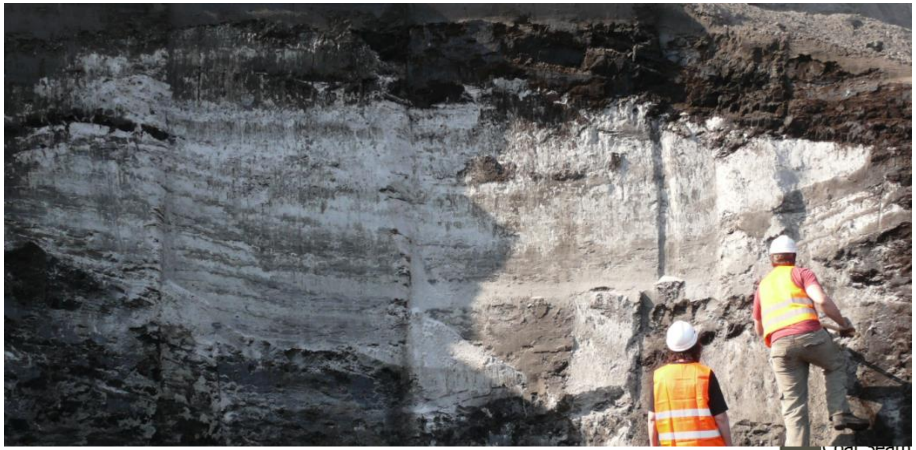
Resource Model Updating



Application in a Real Coal Production Environment

Performed on:
a particular lignite seam in a mining operation in Germany

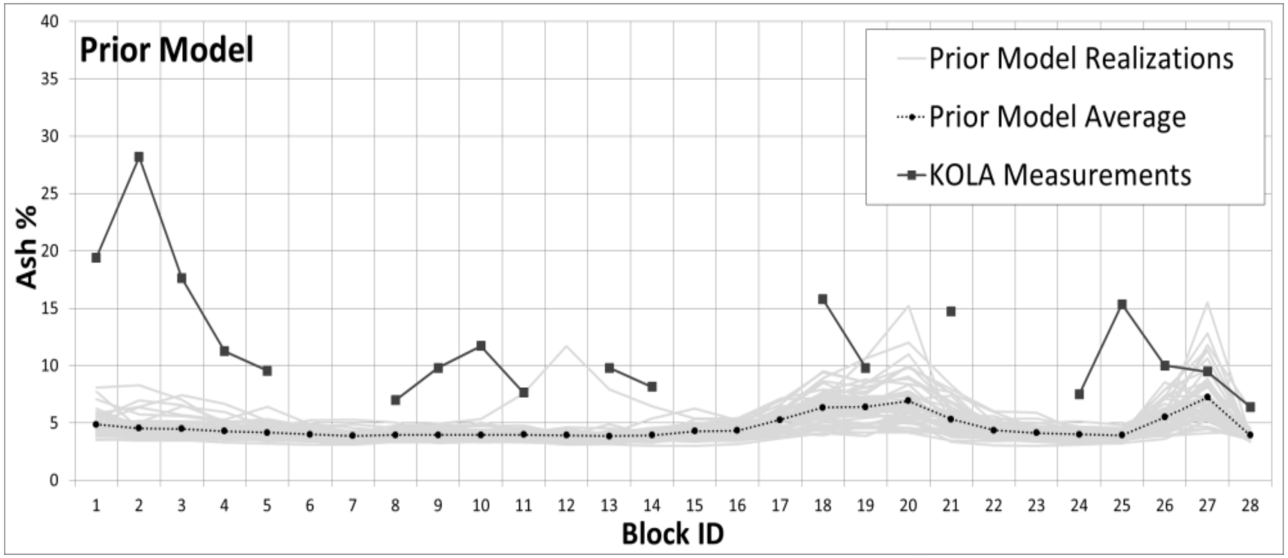




Sand intrusions in the seam Frimmersdorf

Application in a Real Coal Production Environment

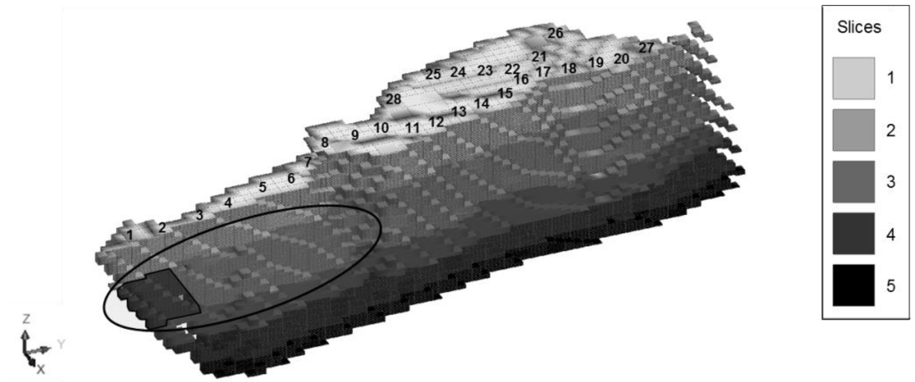
32x32x1m quality model is generated with different number of simulations (24, 48, 96, 192 and 384)

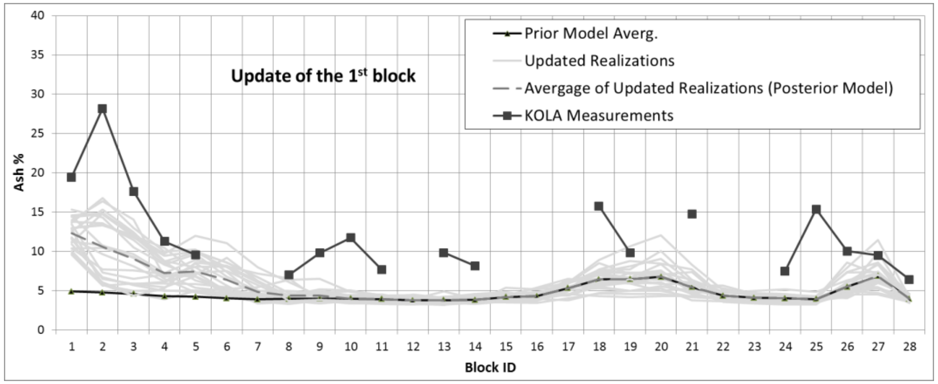


prior model of 48 simulations

Application in a Real Coal Production Environment

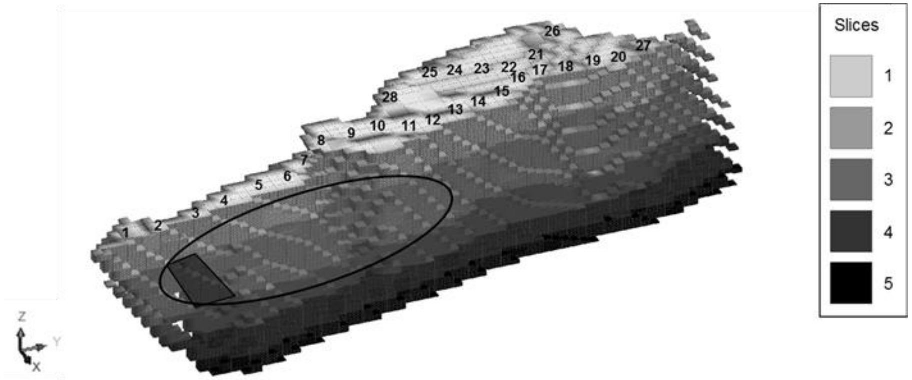
Experiment 1

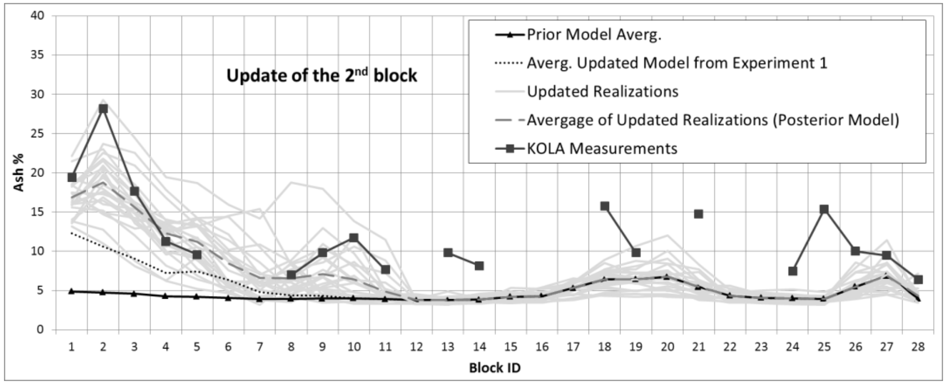




Application in a Real Coal Production Environment

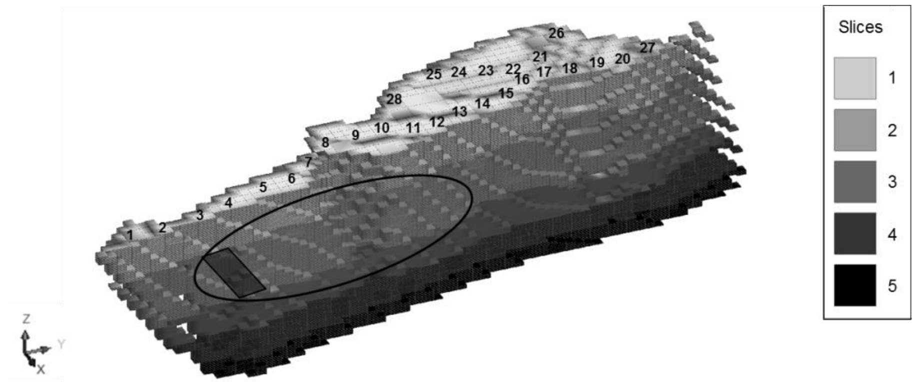
Experiment 2

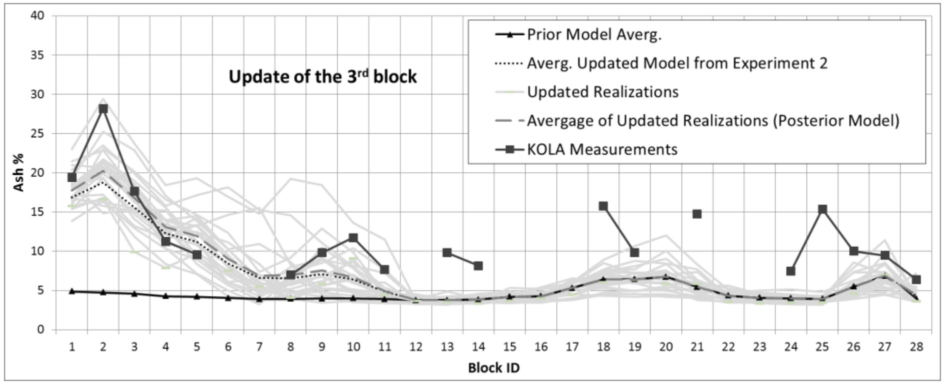




Application in a Real Coal Production Environment

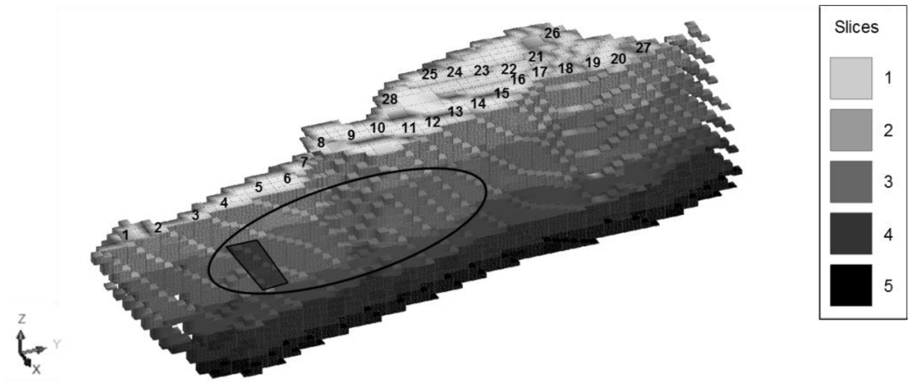
Experiment 3

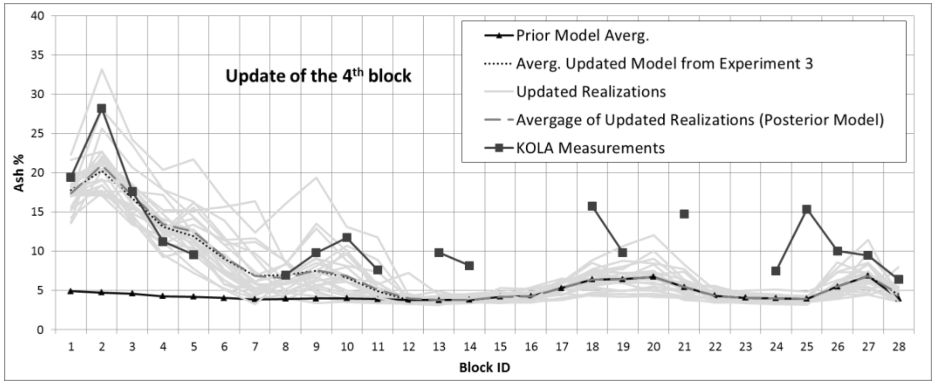




Application in a Real Coal Production Environment

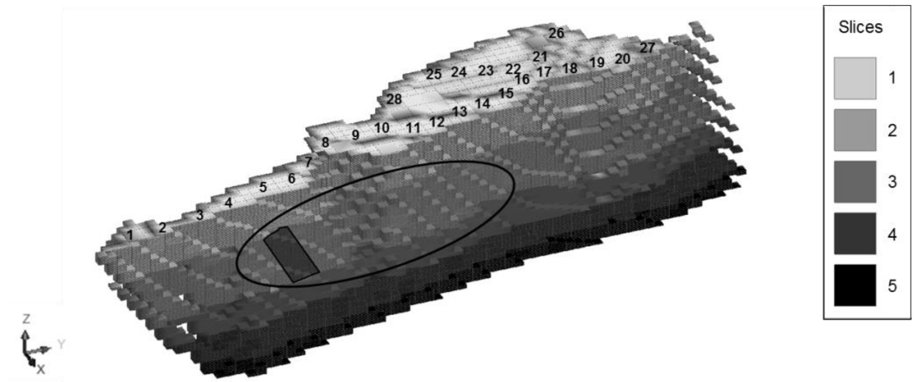
Experiment 4

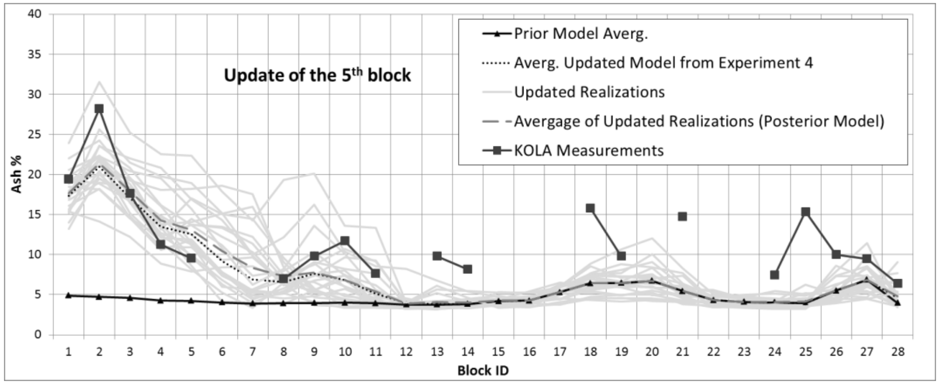




Application in a Real Coal Production Environment

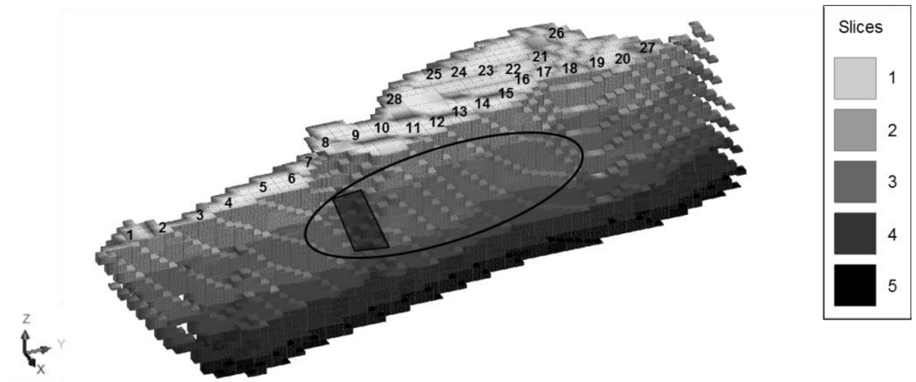
Experiment 5

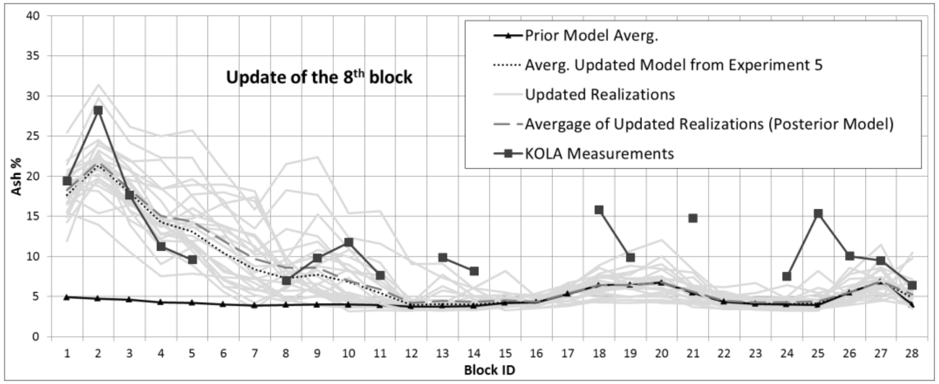




Application in a Real Coal Production Environment

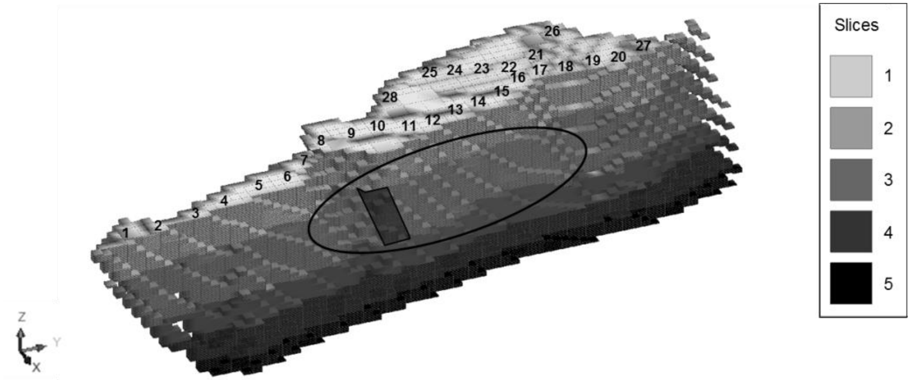
Experiment 6

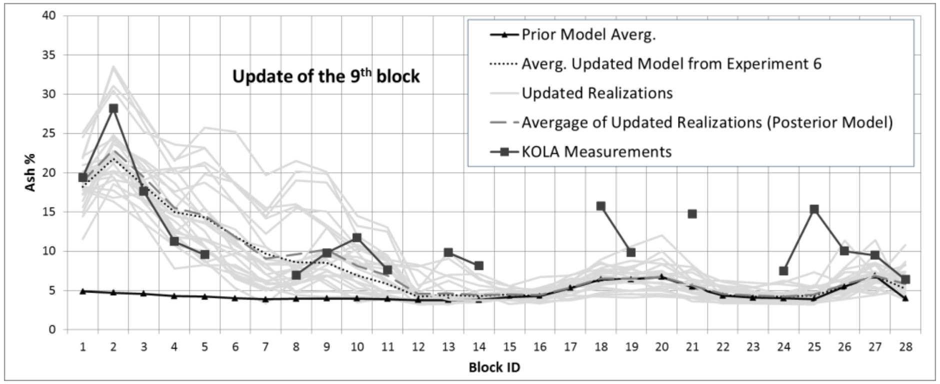




Application in a Real Coal Production Environment

Experiment 7





Application in a Real Coal Production Environment

To conclude:

- Already from the second experiment, KOLA measurements are well covered by the range of uncertainty in the updated neighbourhood.

- While the integrated measurement number increases (experiment 2, 3, …, 7) it is observed that the uncertainty in the near neighbourhood gets slightly smaller and more of the actual KOLA measurements are captured by this uncertainty range.

- The improvements from the very initial averaged prior simulation to the most recent updated simulations are clearly observable.

- Successful results are achieved in an industrial full scale case application of the resource model updating.

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Performance analysis

- Aim: Optimizing the performance of the developed method by performing sensitivity analyses on critical parameters:

  - Ensemble size,
    - To define the optimal realization number (subsequently used as ensemble size)
    - by performing resource model updating experiments with different sized ensembles
  - Localization strategies
    - To avoid long range spurious correlations caused by limited ensemble size
    - a covariance localization technique is applied
    - Covariance localization modifies update equations by replacing the model error covariance by its element-wise (The Schur) product with some distance-based correlation matrix
  - Sensor error
    - For each experiment, different amounts of standard error is added to the actual measurement values.
    - The standard error:

$$SE_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

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Performance analysis

	Experiment #	Ensemble Size	Localization Option on/off and Size (X,Y,Z) (m)	Neighborhood Size (X,Y,Z) (m)	Relative Sensor Error (%)
Ensemble Size Experiments	1	24	on, 125,125,3	225,225,6	0
	2	48	on, 125,125,3	225,225,6	0
	3	96	on, 125,125,3	225,225,6	0
	4	192	on, 125,125,3	225,225,6	0
	5	384	on, 125,125,3	225,225,6	0
Localization & Neighborhood Strategies Experiments	6	48	off	225,225,6	0
	7	48	on, 225,225,3	450,450,6	0
	8	48	off	450,450,6	0
	9	48	off	900,900,6	0
	10	48	on, 450,450,3	900,900,6	0
	11	48	on, 450,450,6	900,900,6	0
Sensor Error Experiments	12	48	off	450,450,6	4
	13	48	off	450,450,6	8
	14	48	off	450,450,6	20
	15	48	off	450,450,6	40

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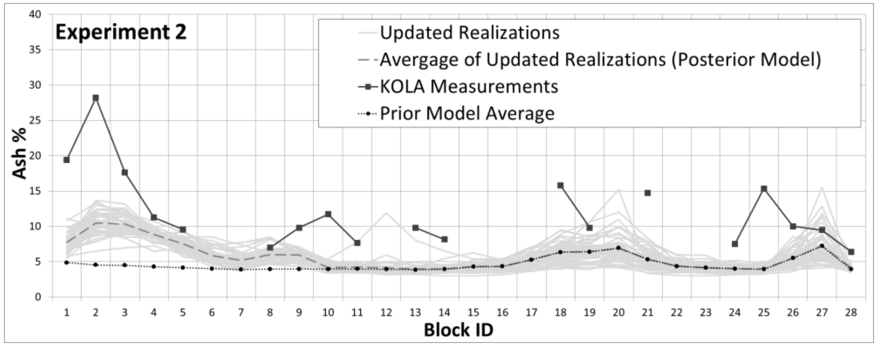
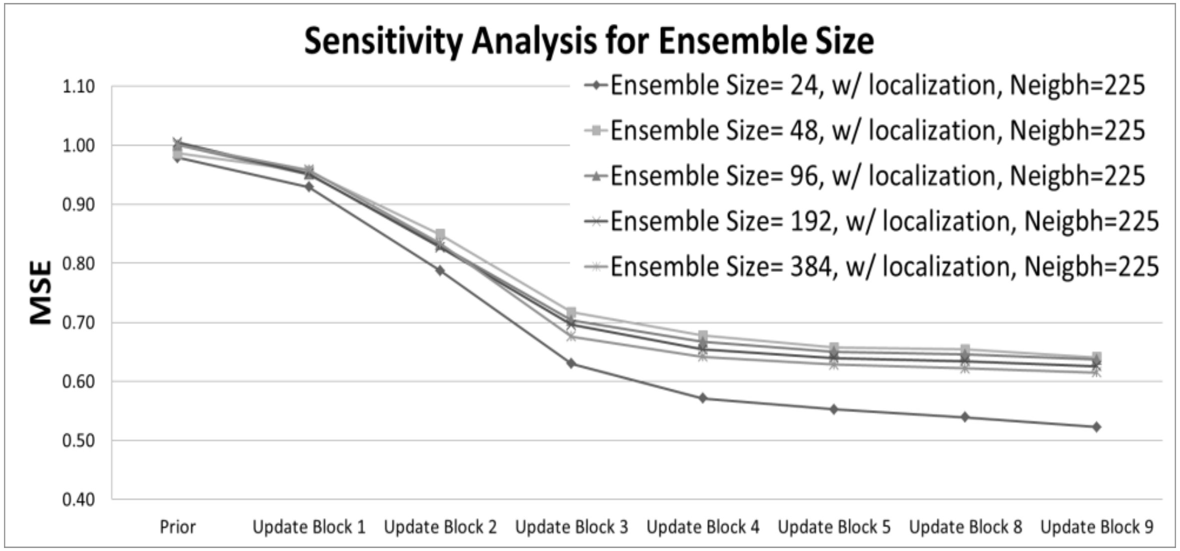
Performance analysis:
Ensemble Size

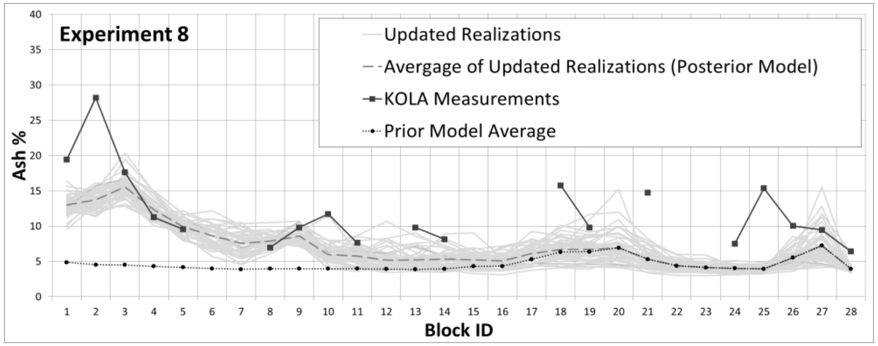


Experiment 2 – Ensemble Size: 48

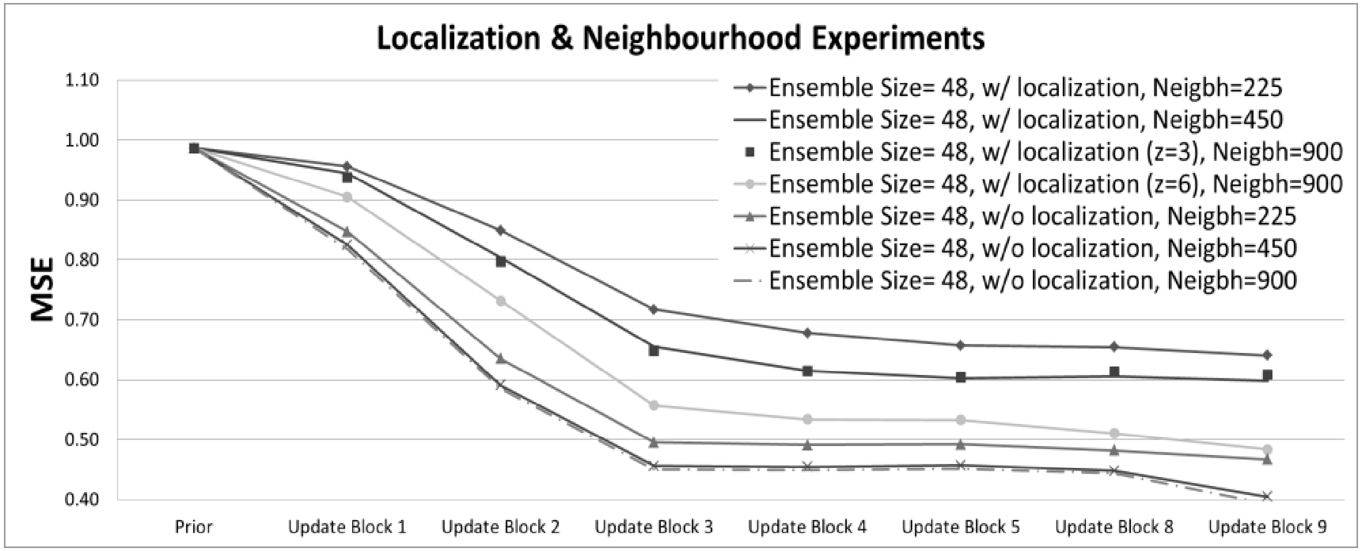


Comparison graph for different ensemble sized experiments

Performance analysis:
Localization and Neighborhood Strategies



Experiment 8 – Localization Option off, Neighborhood Size: 450,450,6 m



Comparison graph for different localization and neighborhood strategies experiments

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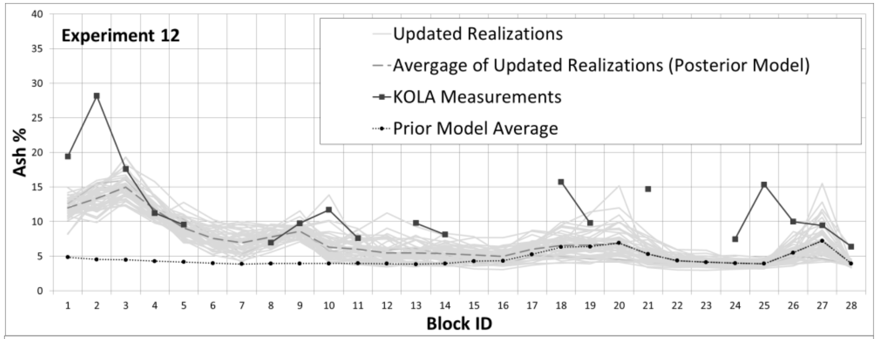
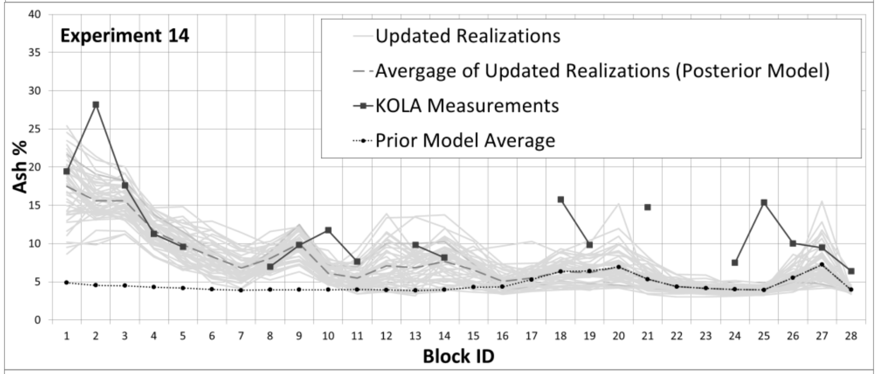
Performance analysis:
Sensor Precision

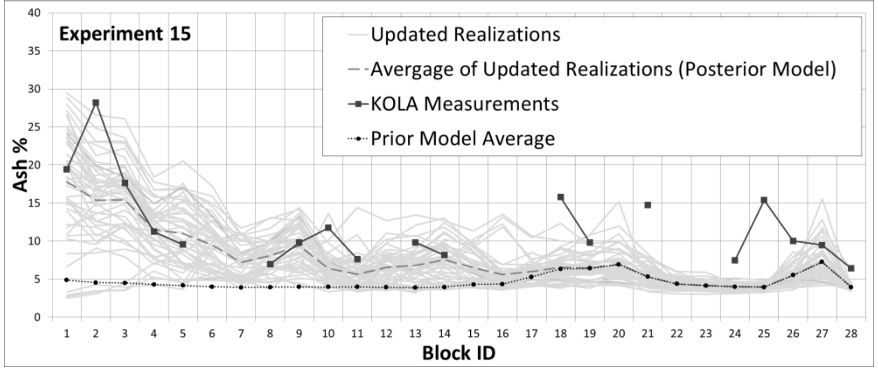
Experiment 14 – Relative sensor error: 20%



Experiment 12 – Relative sensor error: 4%



Experiment 15 – Relative sensor error: 40%



Conclusions

- The findings of ensemble size sensitivity analysis :
  - supported the existed literature: more accurate updates are achievable by using a bigger ensemble size.
  - Although 24 ensembles provided the best results in terms of MSE, they are not chosen as the optimum ensemble size since they were not representative enough of the lignite seam.
  - Instead 48 ensembles was because it was the second best and was more representative of the lignite seam.
- The sensitivity analyses of the localization and neighborhood strategies:
  - concluded that the applied localization strategies need to be improved and the neighborhood size needs to remain as 450,450,6 m in X,Y,Z directions, as previously defined in the variogram modelling.
- Sensitivity analyses for different sensor precision:
  - showed that the lower sensor precision increases the uncertainty of the posterior model, due to the significant difference between prior model and the actual sensor data.
- In general, the KOLA data is well covered by the range of uncertainty in the updated neighborhood.
- Future research: a case study where two, three or four excavator are operating. This will require an update to the coal quality parameters in different production benches based on one combined material measurement.

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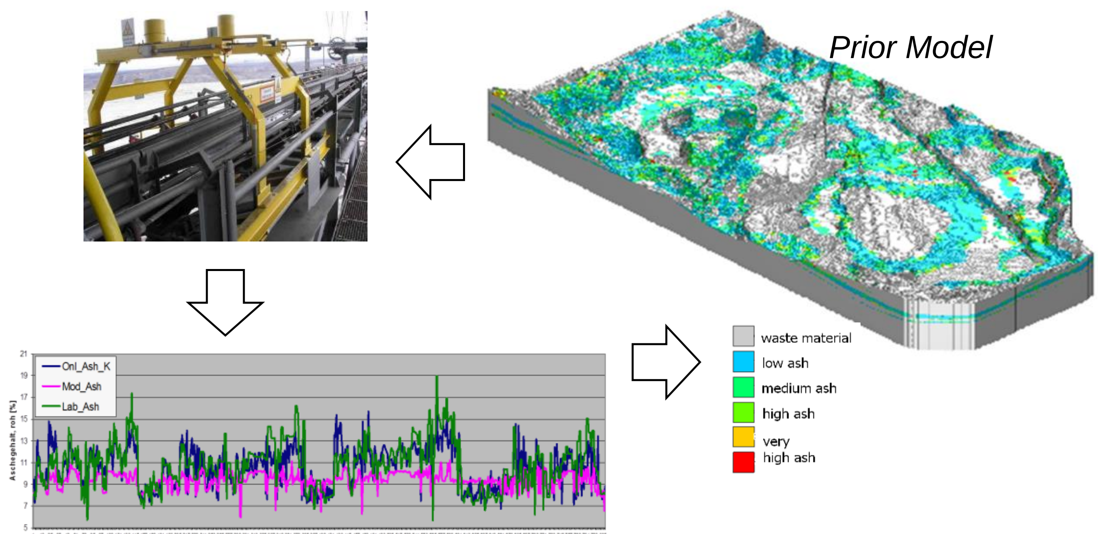
Current Work

- EU - RFCS funded project RTRO-Coal



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Contact: Cansın Yüksel
C.Yuksel@tudelft.nl

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