Comparison of performance of Double Difference and Single Event location techniques in mining environment

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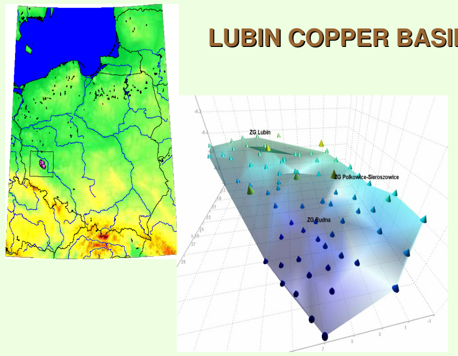
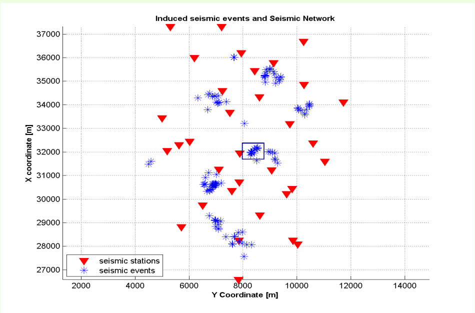
INTRODUCTION

Problem of precise location of mining tremors is very important not only from mining and engineering point of view, but is also crucial for some advanced seismological analysis of the mining induced seismicity such as velocity and attenuation tomography and many others. Since the mining seismicity tends to cluster in space the location techniques using this feature such like DD method should be favourable in the advanced data analysis processing. The Double-Difference relocation method allows to reduce the location uncertainty of the different events in a cluster and it also reduces the influence of the velocity structure on the location results. Comparison with Single Event location method should help evaluate if the clustering of events for particular known network configuration improves the location estimations for DD technique. In this presentation such an evaluation based on the Rudna (Poland) copper mine data set has been carried out using Bayesian inversion approach.

LUBIN COPPER BASIN



Seismic network and data



Main problem: Local Seismic Tomography

Problems

lack of *origin time* | inaccuracy in *depth* estimation

Single Event (SE) and Double – Difference (DD) method

Origin time and *depth* correlation | accurate *depth* estimation

Seismicity induced by mining → method used

SE – constant velocity | DD – constant velocity
SE – velocity inversion | DD – velocity inversion

Bayesian inverse approach and optimalization technique

Optimalization procedure

$$\left\|G(m)-t^{obs}\right\|+\left\|m-m^{apr}\right\|=\min$$

Solution – single best model

Bayesian approach

$$\sigma(m)=f(m)L(m)$$

Solution: ***a posteriori*** Probability Density Function which gives us:
- errors estimations
- models parameters correlations control

Double Difference method

$$dr_k^{ij}=(t_k^i-t_k^j)^{obs}-(t_k^i-t_k^j)^{th}$$

Waldhauser and Ellsworth (2000)

Likelihood function

Constant velocity

$$L(x_{ij},y_{ij}z_{ij},t_{ij}^0)=\exp\left(-\left|\frac{(t_i^{obs}-t_j^{obs})-\frac{1}{V_{const}}\left[t_i^o+l(x_i,y_i,z_i)-t_j^0+l(x_j,y_j,z_j)\right]}{s_{ij}}\right|\right)$$

Velocity inverted

$$L(x_{ij},y_{ij}z_{ij},t_{ij}^0,V_{inv})=\exp\left(-\left|\frac{(t_i^{obs}-t_j^{obs})-\frac{1}{V_{inv}}\left[t_i^o+l(x_i,y_i,z_i)-t_j^0+l(x_j,y_j,z_j)\right]}{s_{ij}}\right|\right)$$

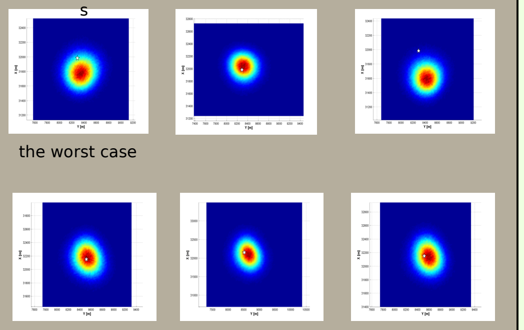
Location Procedure

Single event location with constant velocity,
V = 5300 m/s
V = 5800 m/s
Single Event location with velocity inversion
Double – Difference location with constant velocity
V = 5300 m/s
V = 5800 m/s
Double – Difference location with velocity inversion

Epicentral aposteriori PDF and solution obtained by mine

Single Event

V = 5300 m/s | Velocity inverted | V = 5800 m/s

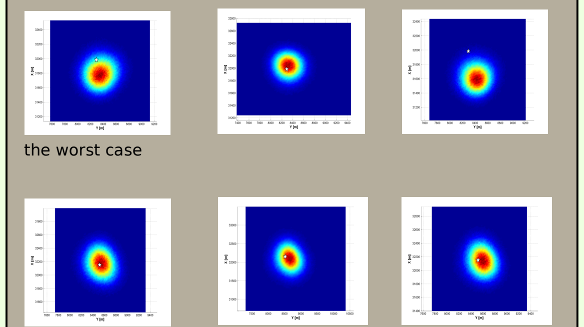


the worst case

the best case

Double Difference

V = 5300 m/s | Velocity inverted | V = 5800 m/s



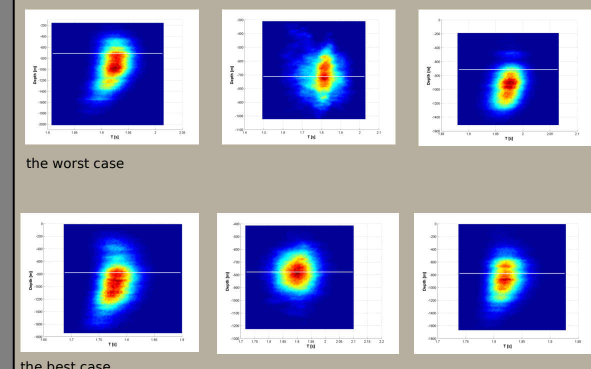
the worst case

the best case

Depth – Origin Time

Single Event

V = 5300 m/s | Velocity inverted | V = 5800 m/s

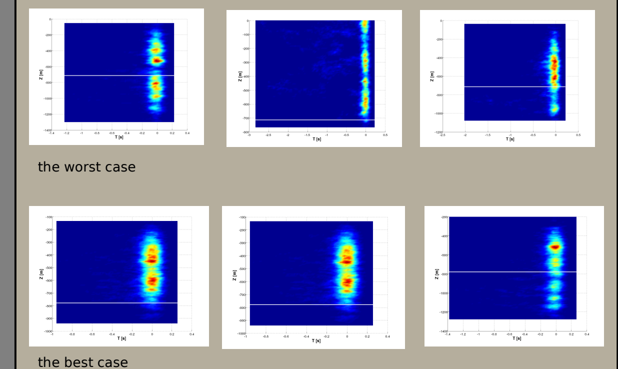


the worst case

the best case

Double Difference

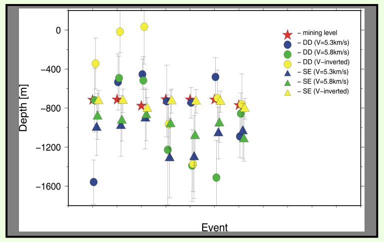
V = 5300 m/s | Velocity inverted | V = 5800 m/s



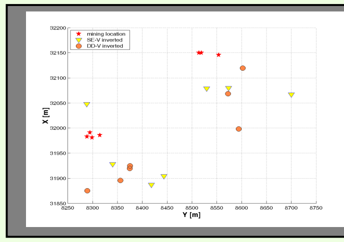
the worst case

the best case

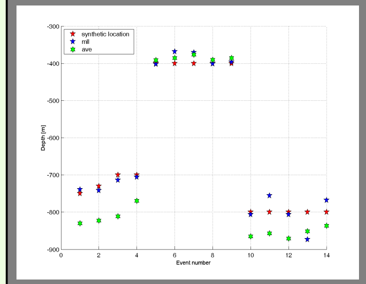
Depth: maximum likelihood and dispersion

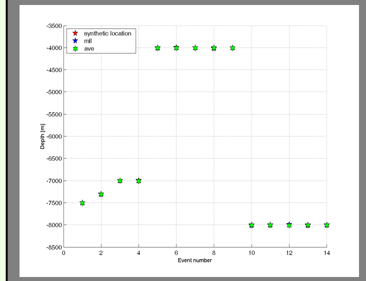


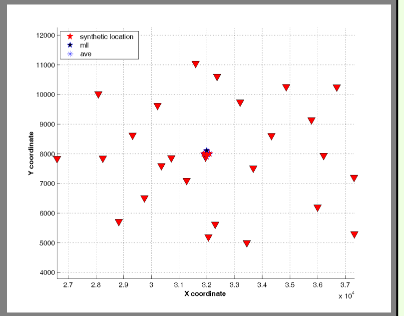
Epicentral maximum likelihood V inverted



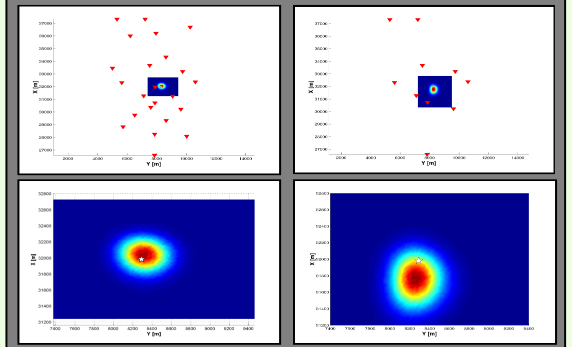
Double Difference method for synthetic data





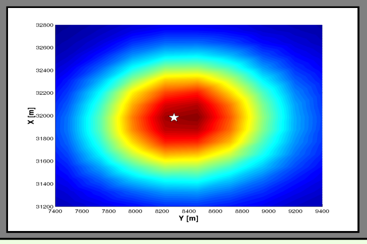


Single event location comparison



24 station configuration | 10 station configuration

Double Difference - inversion with 10 stations



CONCLUSIONS

- Only part of available data is used with Double Difference method while with Single Event approach all of data from all stations can be used
- With DD correlation between origin time and depth is reduced, depth resolution is improved, but depth estimation errors are larger than when SE method is used
- Synthetic data analysis indicate the sensitivity of DD method in relation to vertical configuration of network is very likely
- In this case SE location with velocity inversion provided the most consistent results

Literature

Dębski, W.: 2004, Application of Monte Carlo techniques for solving selected seismological inverse problems. Publs. Inst. Geophys. Pol. Acad. Sc. B-34(367), 1–207.
Rudziński Ł. and Dębski W.: 2008, Relocation of mining-induced seismic events in the Upper Silesian Coal Basin, Poland, by a Double-Difference method. Acta Geodyn. Geomater., Vol. 5, No. 2 (150), 97– 104,
Tarantola, A.: 2005, Inverse Problem Theory and Methods for Model Parameter Estimation. Philadelphia: SIAM.
Waldhauser, F. and Ellsworth, W.: 2000, A double difference earthquake location algorithm: method and application to the northern Hayward fault. Bull. Seismol. Soc. Am. 90, 1353–1368.