

AN APPLICATION OF THE DOUBLE -
DIFFERENCE RELOCATION
TECHNIQUE TO THE MINING
INDUCED SEISMIC EVENTS AT
POLISH COPPER MINES

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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

SE - velocity inversion

DD - constant velocity

DD - velocity inversion

Bayesian Inverse Approach *and* optimizational technique

Optimization procedure:

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

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

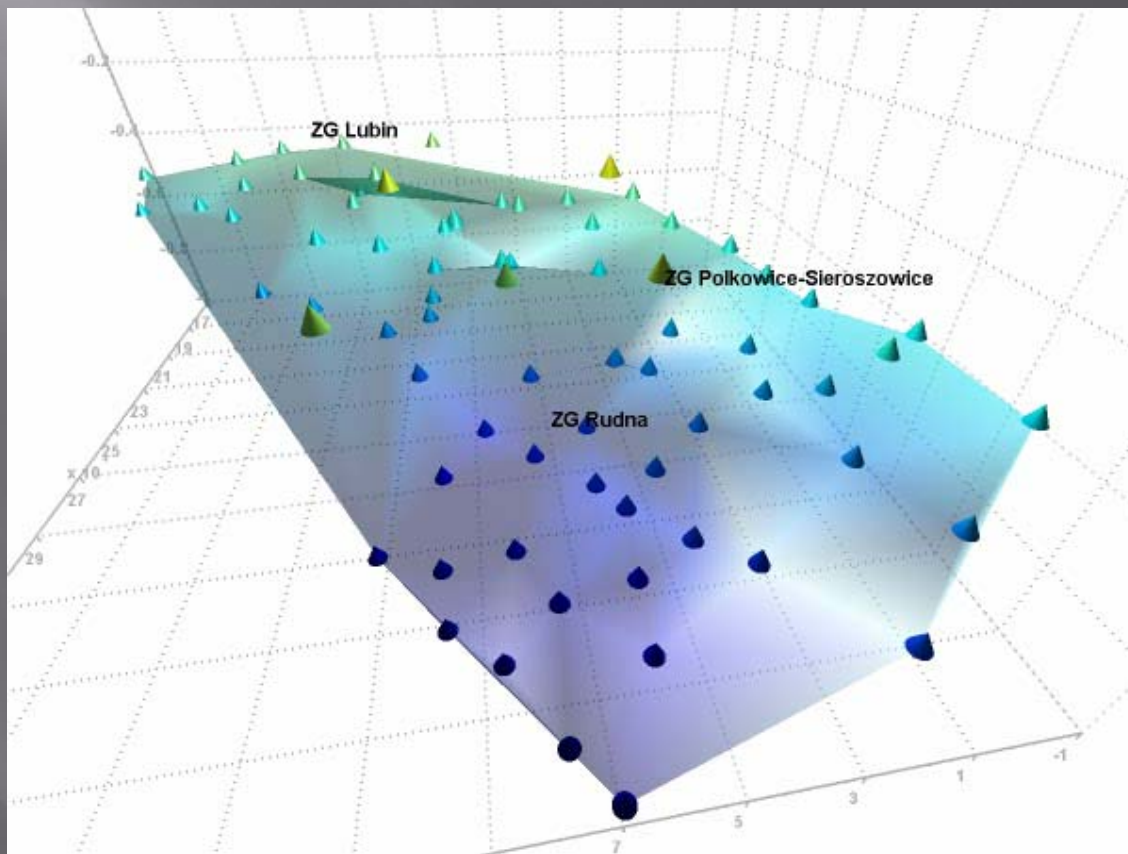
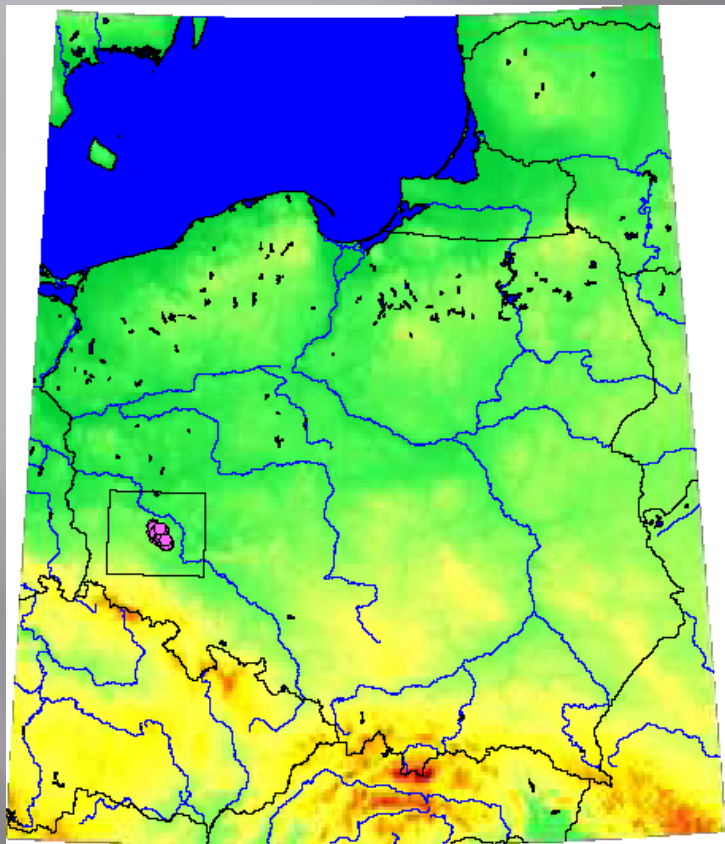
Constant velocity

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

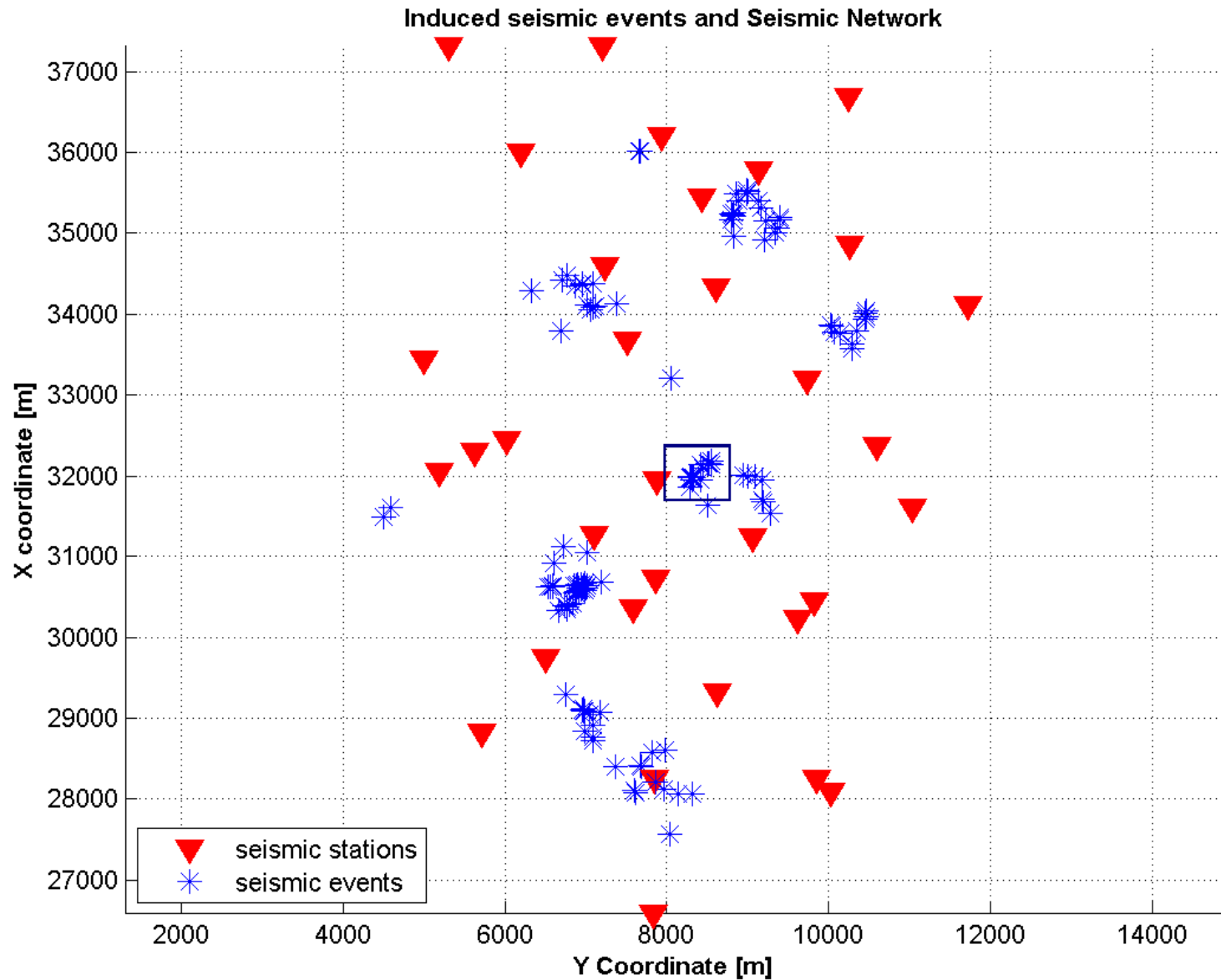
Velocity inverted

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

Lubin Copper Basin – Poland



Seismic Network and data

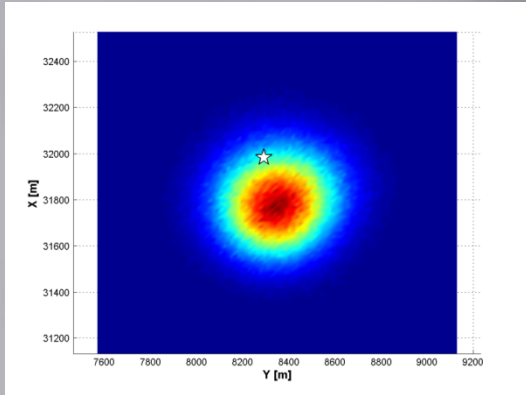


Location procedure

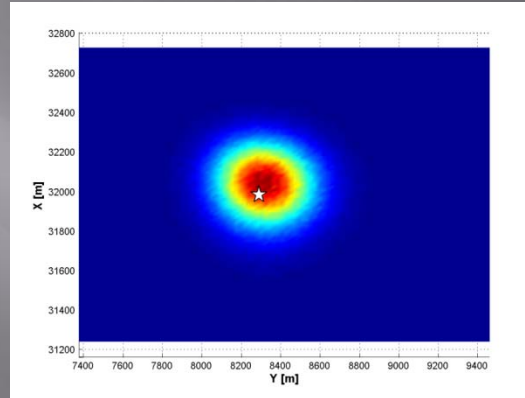
- Single event location with constant velocity,
 - $V = 5300 \text{ m/s}$
 - $V = 5800 \text{ m/s}$
- Single Event location with velocity inversion
- Double – Difference location with constant velocity
 - $V = 5300 \text{ m/s}$
 - $V = 5800 \text{ m/s}$
- Double – Difference location with velocity inversion

SE: - epicentral *a posteriori* PDF and solution obtained by mine

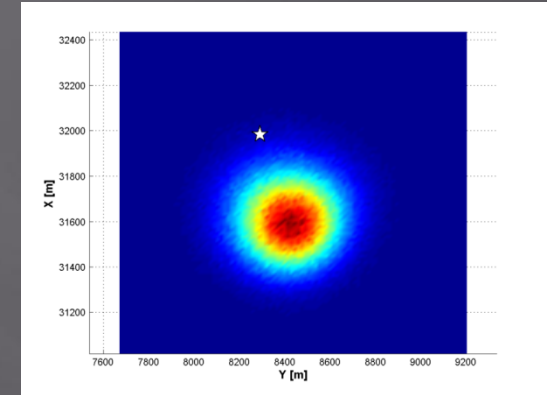
$V = 5300$ m/s



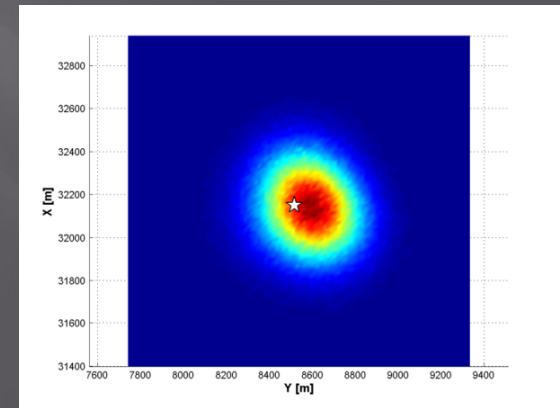
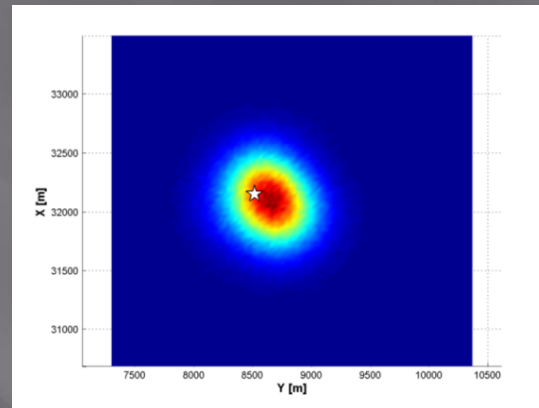
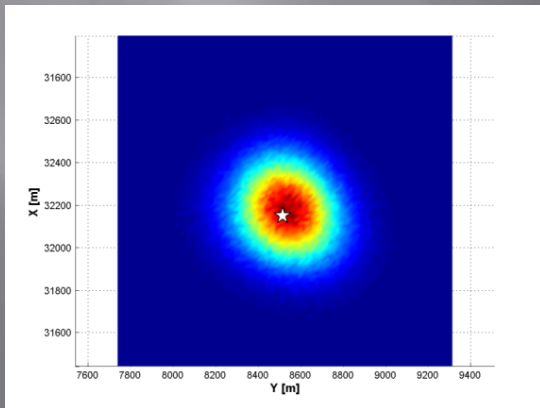
Velocity inverted



$V = 5800$ m/s



the worst case



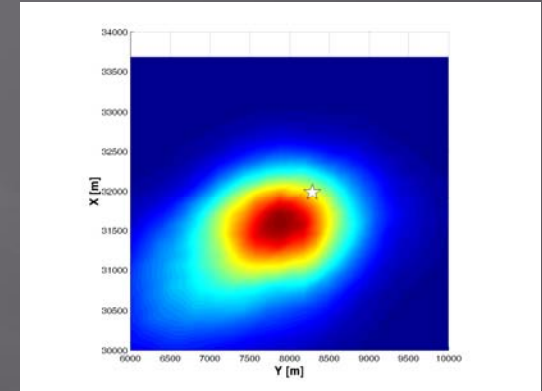
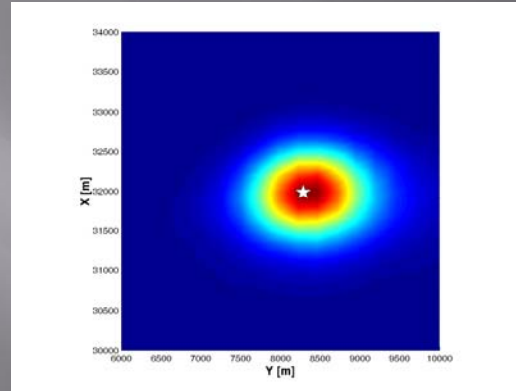
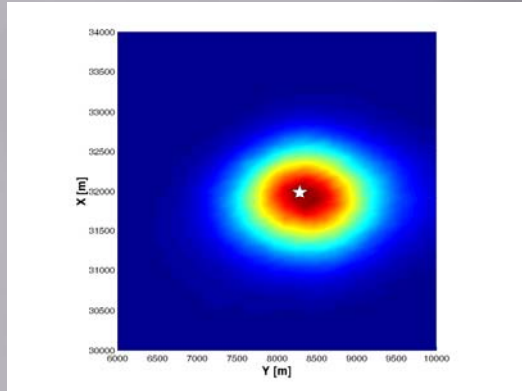
the best case

DD: - epicentral *a posteriori* PDF and solution obtained by minie

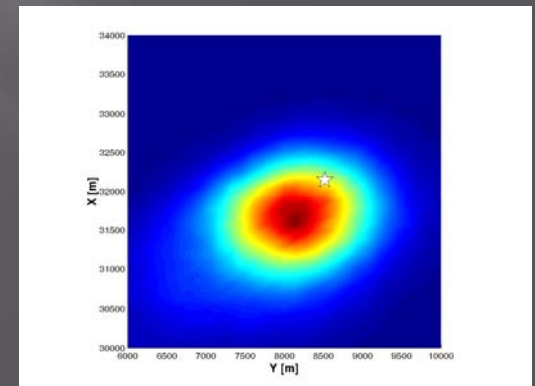
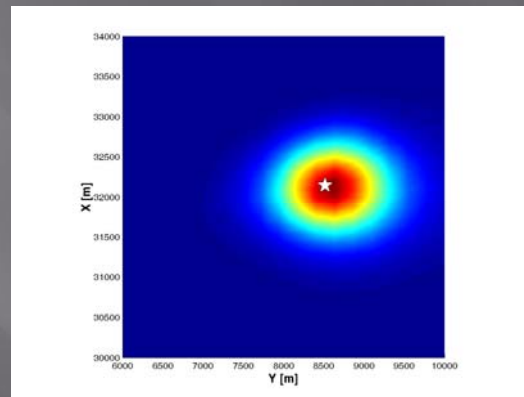
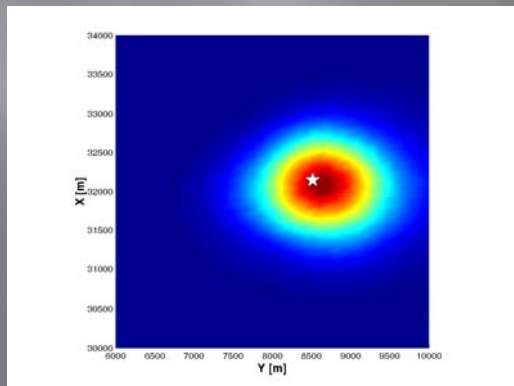
$V = 5300 \text{ m/s}$

Velocity inverted

$V = 5800 \text{ m/s}$



the worst case



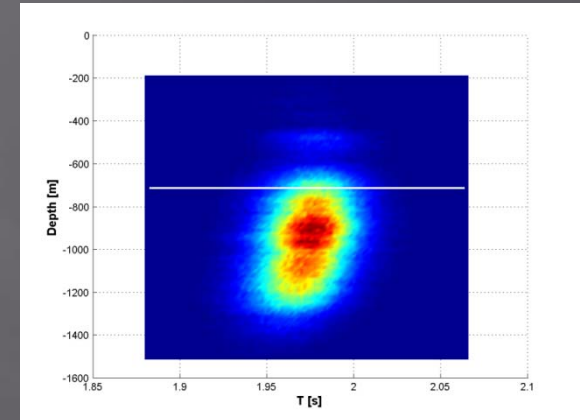
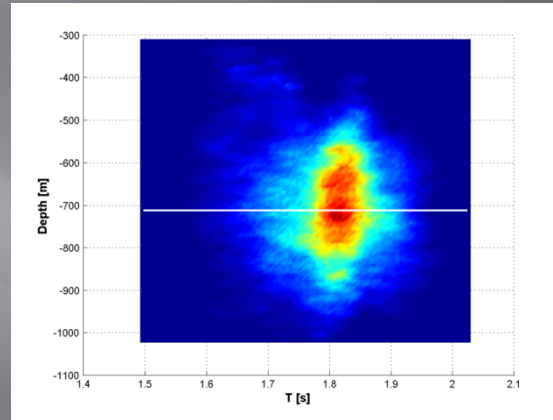
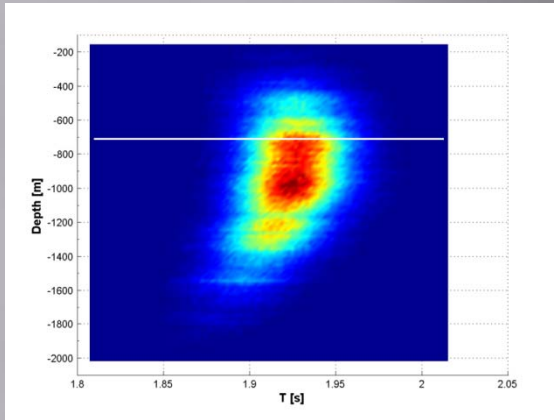
the best case

SE: depth - origin time:

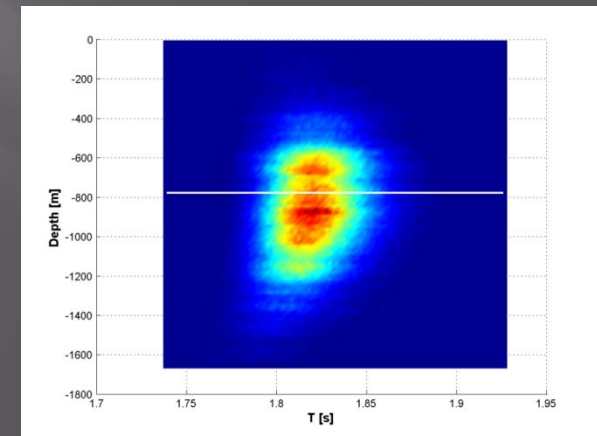
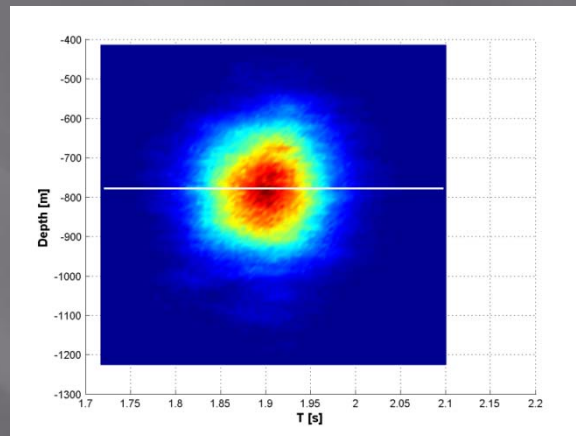
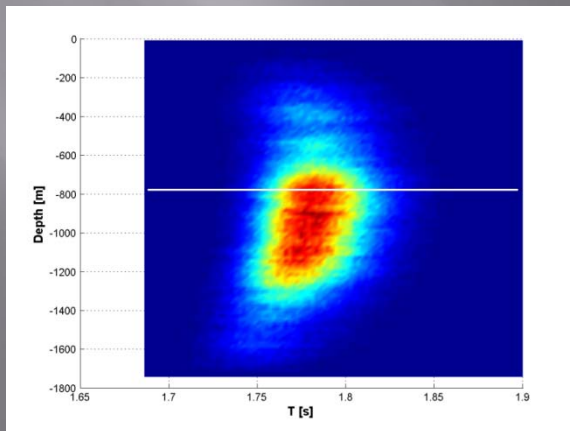
$V = 5300 \text{ m/s}$

Velocity inverted

$V = 5800 \text{ m/s}$



the worst case



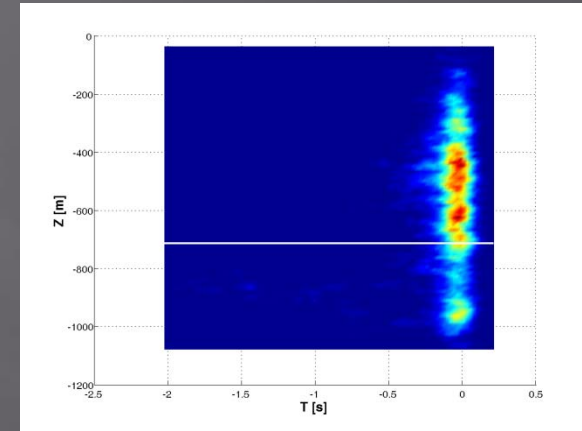
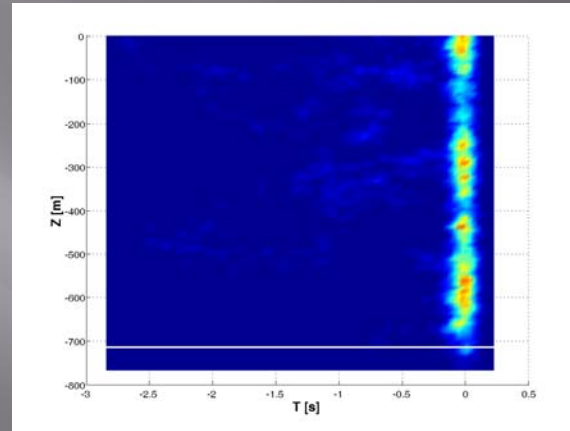
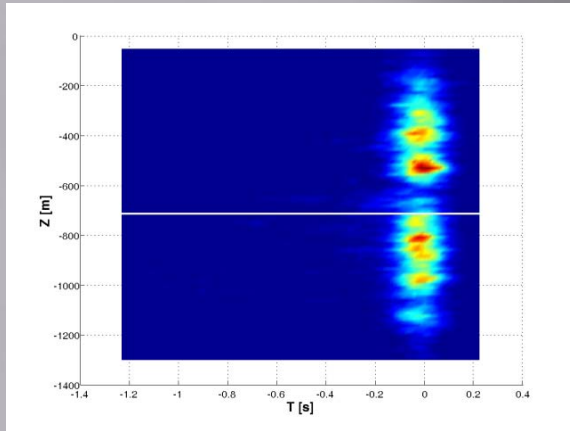
the best case

DD: *depth* – *origin time*:

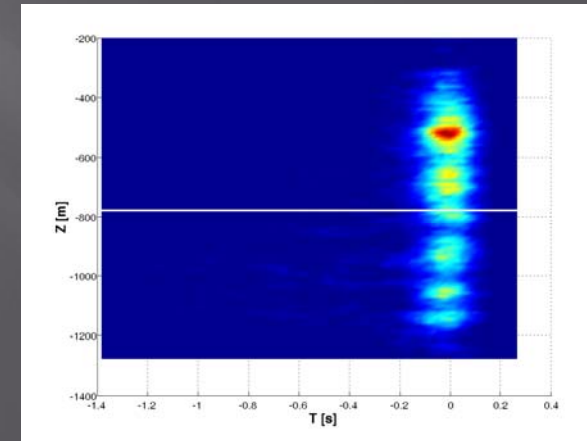
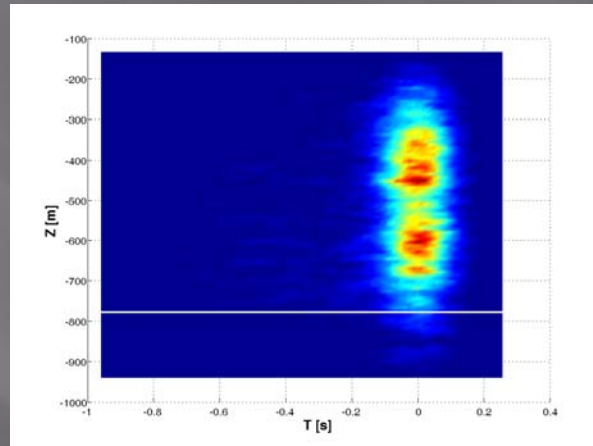
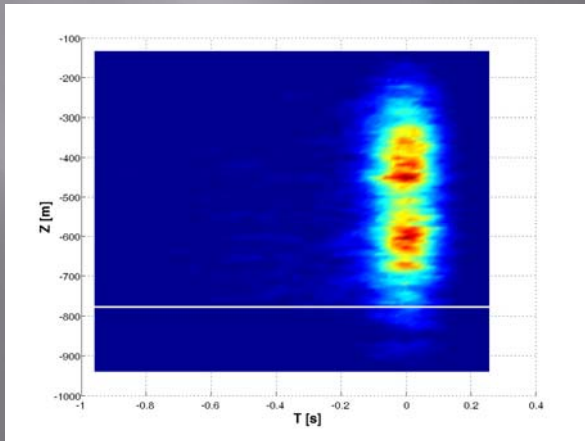
$V = 5300 \text{ m/s}$

Velocity inverted

$V = 5800 \text{ m/s}$

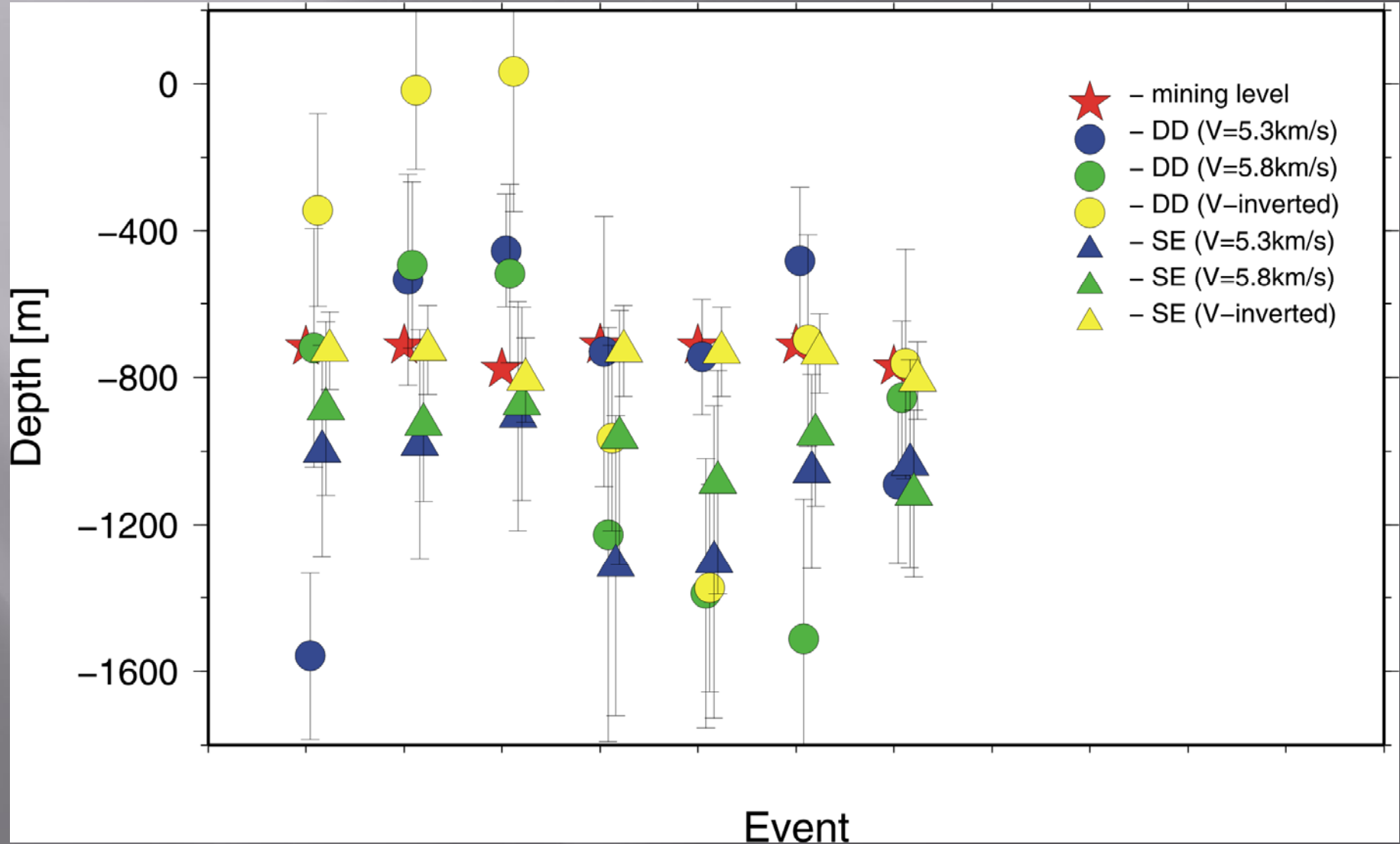


the worst case

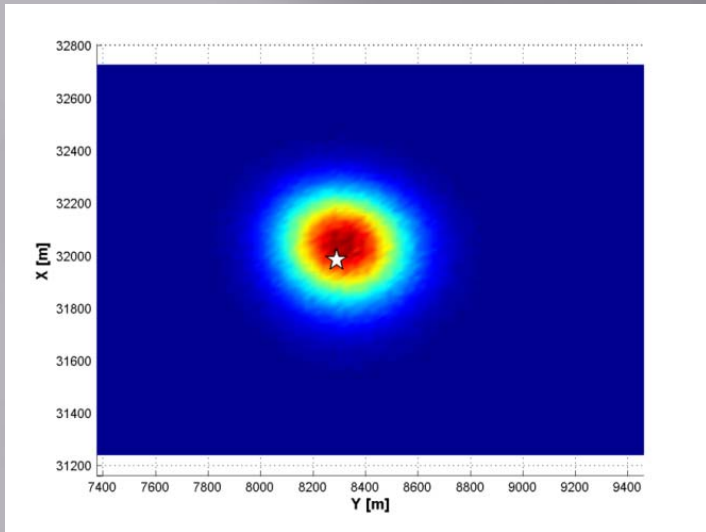


the best case

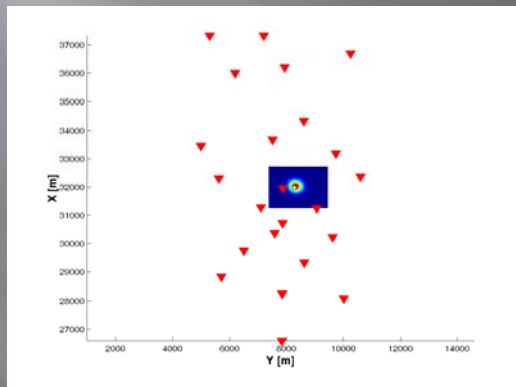
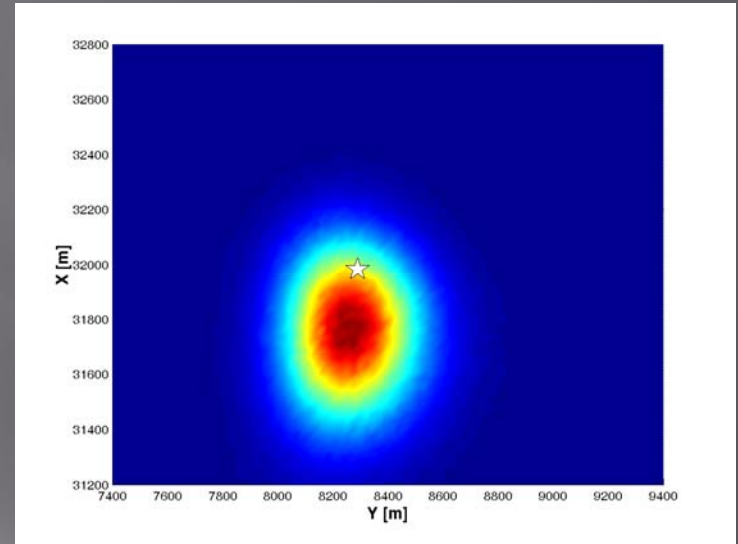
Depth: maximum likelihood and dispersion



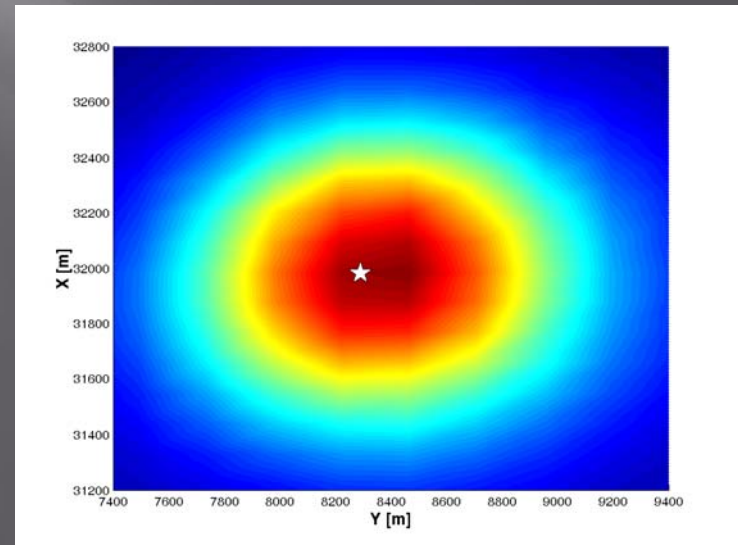
SE location comparison



Inversion with 24 stations

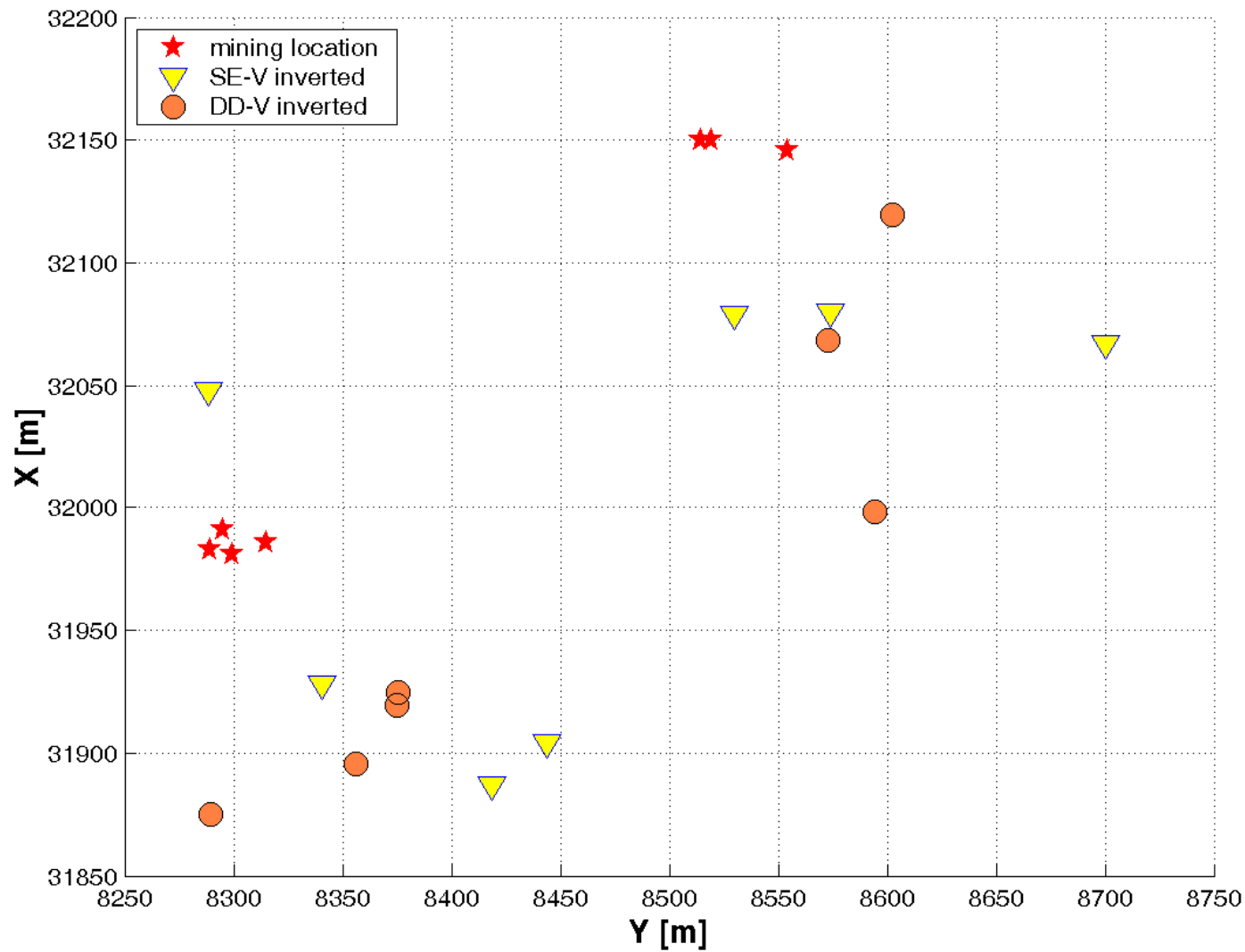


20 station configuration



Inversion with 10 stations

Epicaltral maximum likelihood: V inverted



Conclusions

Pros & Cons

DD

- + reduce Depth - Time correlation - improved depth resolution
- use only part of available data - larger location errors

SE

- + use all available data
- large correlations

Single Event + V inversion the most efficient technique

Thank You for Your attentions

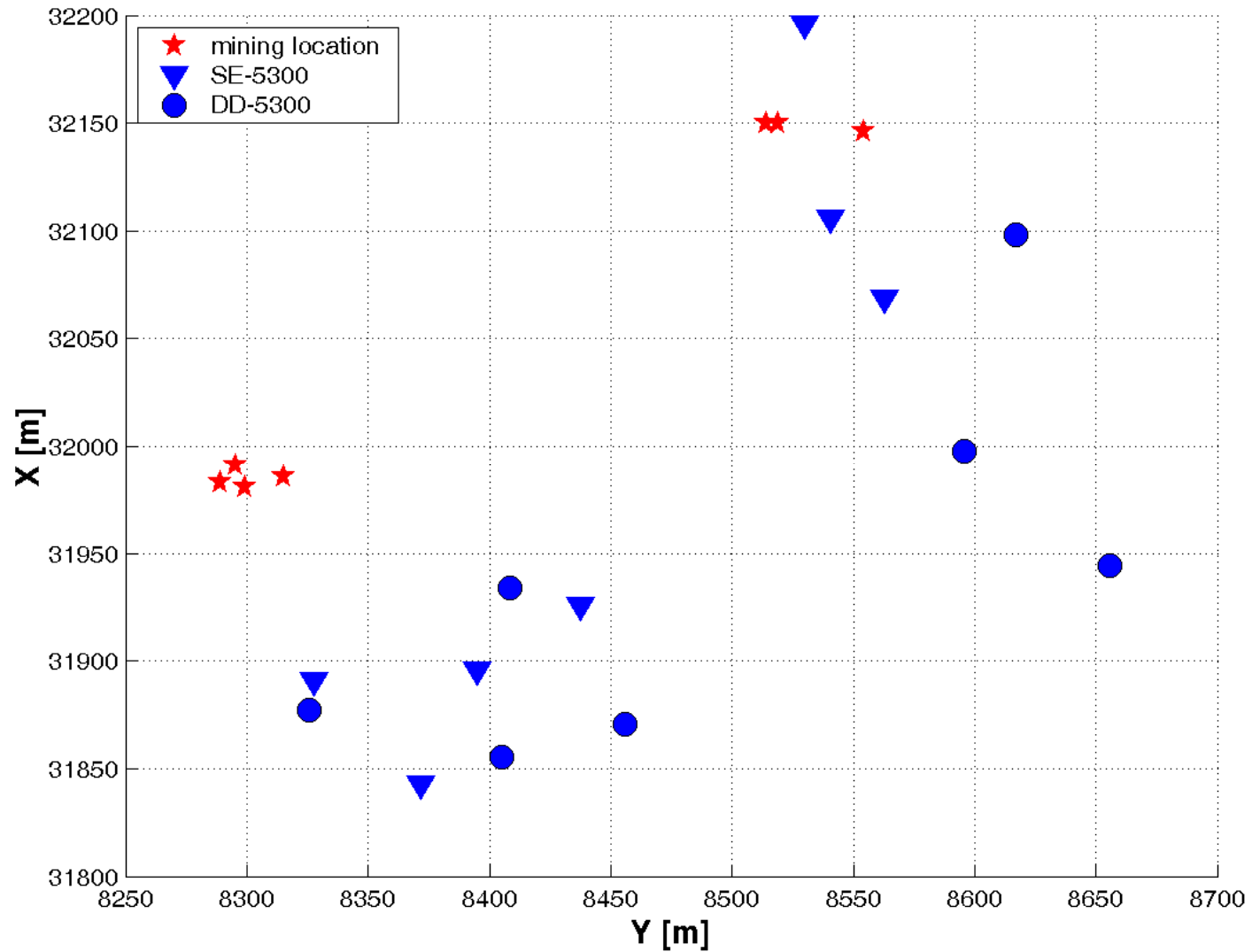
Mining location and maximum likelihood results with dispersion for all methods (the worst case)

Event 9	X Rudna	X ml	δX	Y Rudna	Y ml	δY	Z Rudna	Z ml	δZ
SE - 5300	31983	31843	156	8289	8372	170	-713	-982	312
SE - 5800	31983	31586	152	8289	8399	162	-713	-928	209
SE - V inv.	31983	32048	150	8289	8288	174	-713	-725	120
DD - 5300	31983	31877	491	8289	8325	936	-713	-533	287
DD - 5800	31983	31406	1047	8289	7908	1261	-713	-493	227
DD - V inv.	31983	31924	747	8289	8375	3870	-713	-16	215

Mining location and maximum likelihood results with dispersion for all methods (the best case)

Event 17	X Rudna	X ml	δX	Y Rudna	Y ml	δY	Z Rudna	Z ml	δZ
SE - 5300	32150	32196	156	8514	8530	170	-778	-906	311
SE - 5800	32150	32123	170	8514	8602	163	-778	-871	263
SE - V inv.	32150	32067	279	8514	8700	279	-778	-806	114
DD - 5300	32150	32098	494	8514	8616	929	-778	-453	153
DD - 5800	32150	31538	891	8514	8179	1161	-778	-516	243
DD - V inv.	32150	32119	784	8514	8602	3842	-778	-34	380

Epicentral maximum likelihood: $V = 5300$ m/s



Epicentral maximum likelihood: $V = 5800$ m/s

