Effects of 1-D versus 3-D velocity models on moment tensor inversion in the Dobrá Voda locality at Malé Karpaty region

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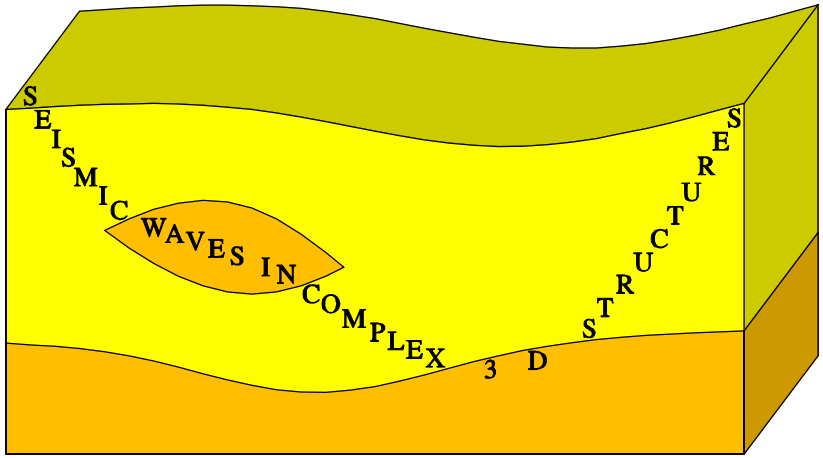

AIM
Advanced Industrial
Microseismic Monitoring

http://sw3d.cz

http://www.ig.cas.cz/en/personal-pages/vaclav-vavrycuk/aim/

SW3D Consortium meeting, Prague, 17-18.6.2013

Idea of the moment tensor inversion

Seismic source parameters	*	Response of the medium	=>	Seismic signal in the receiver

Idea of the moment tensor inversion

Seismic source parameters * Response of the medium => Seismic signal in the receiver

Moment tensor * Green function => Recorded seismogram

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Moment tensor <= Green function + Recorded seismogram

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P.B.

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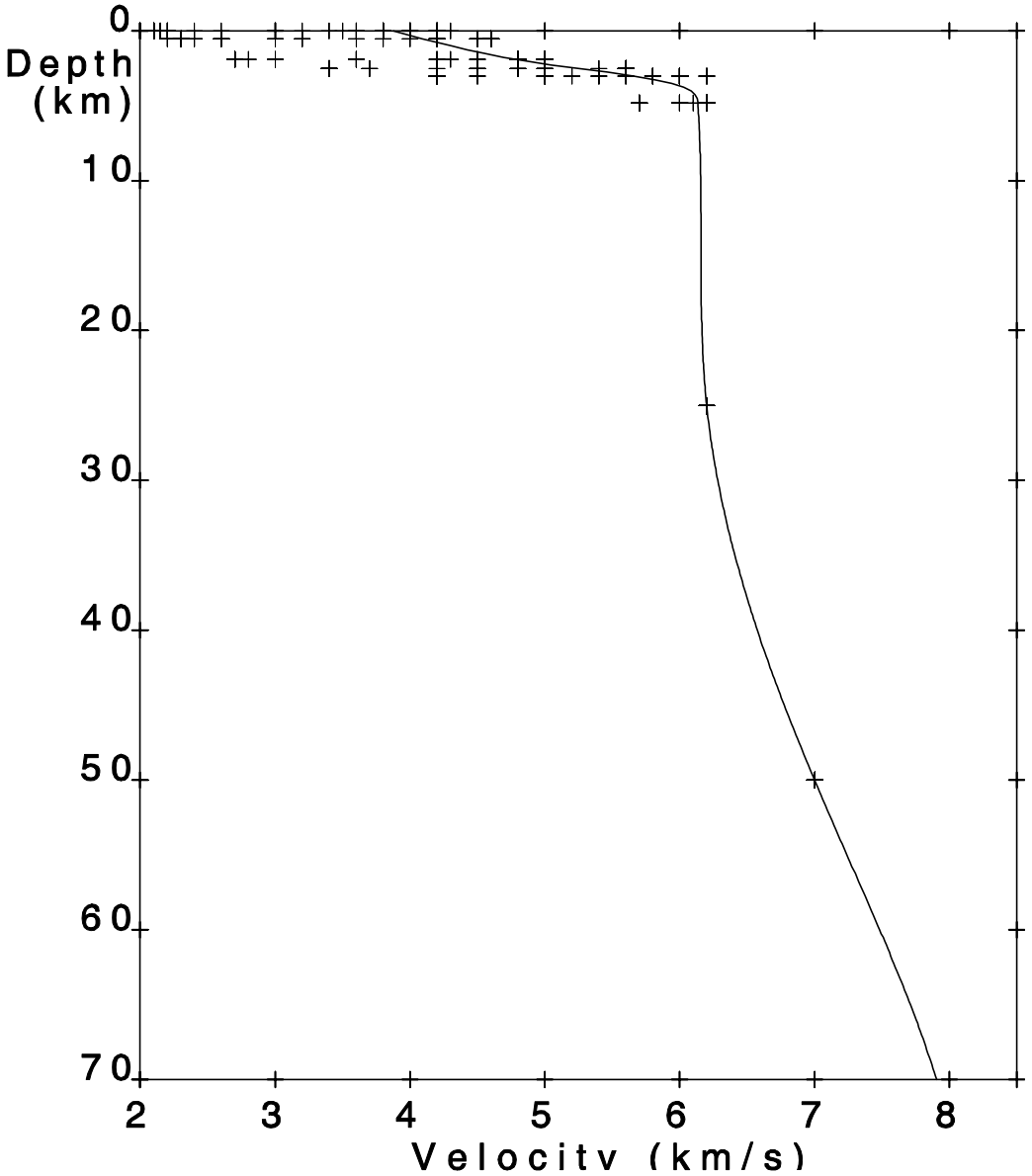
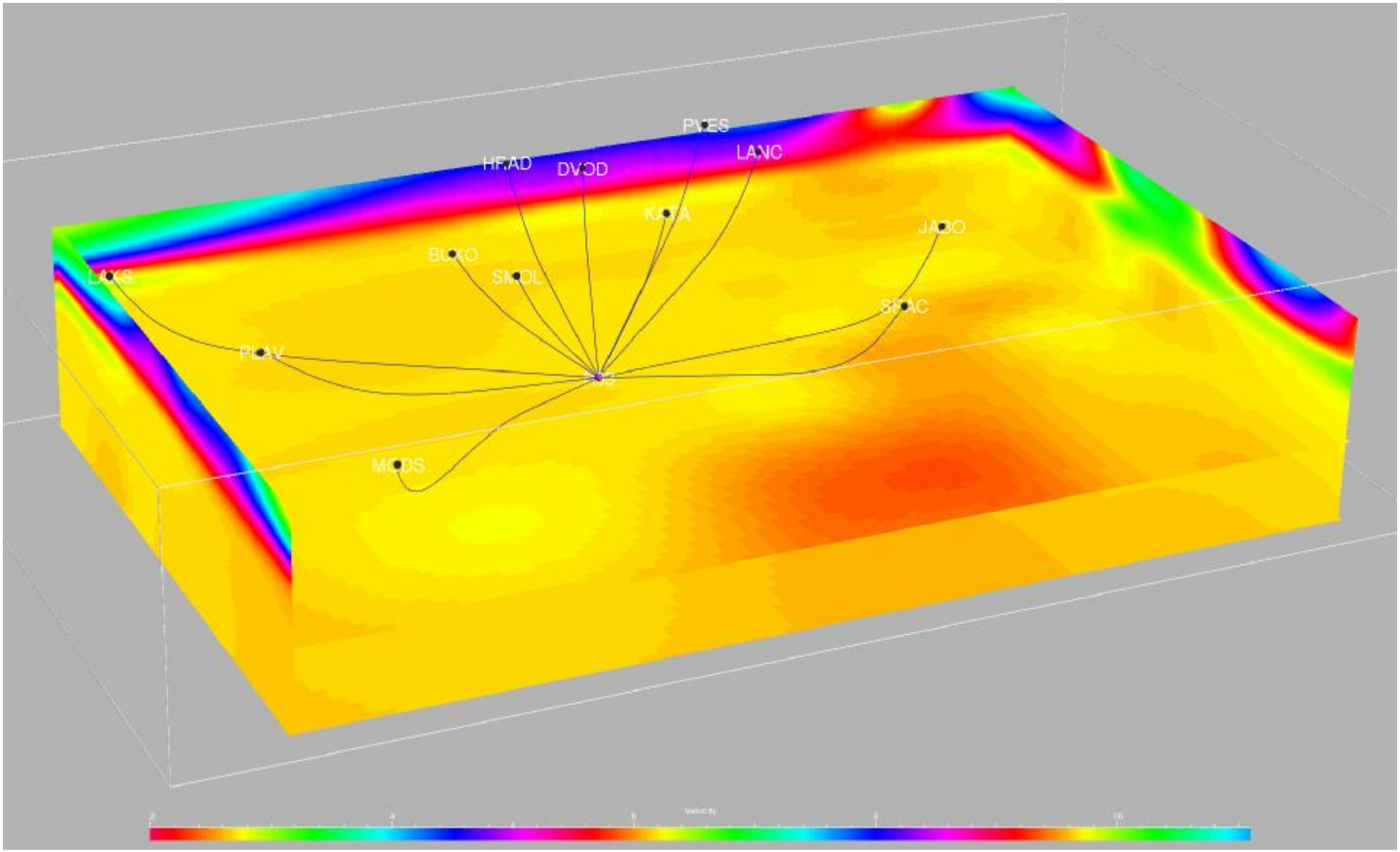
Z.J. P.B.

Dobrá Voda locality on a map

1-D model of the Dobrá Voda locality



3-D model



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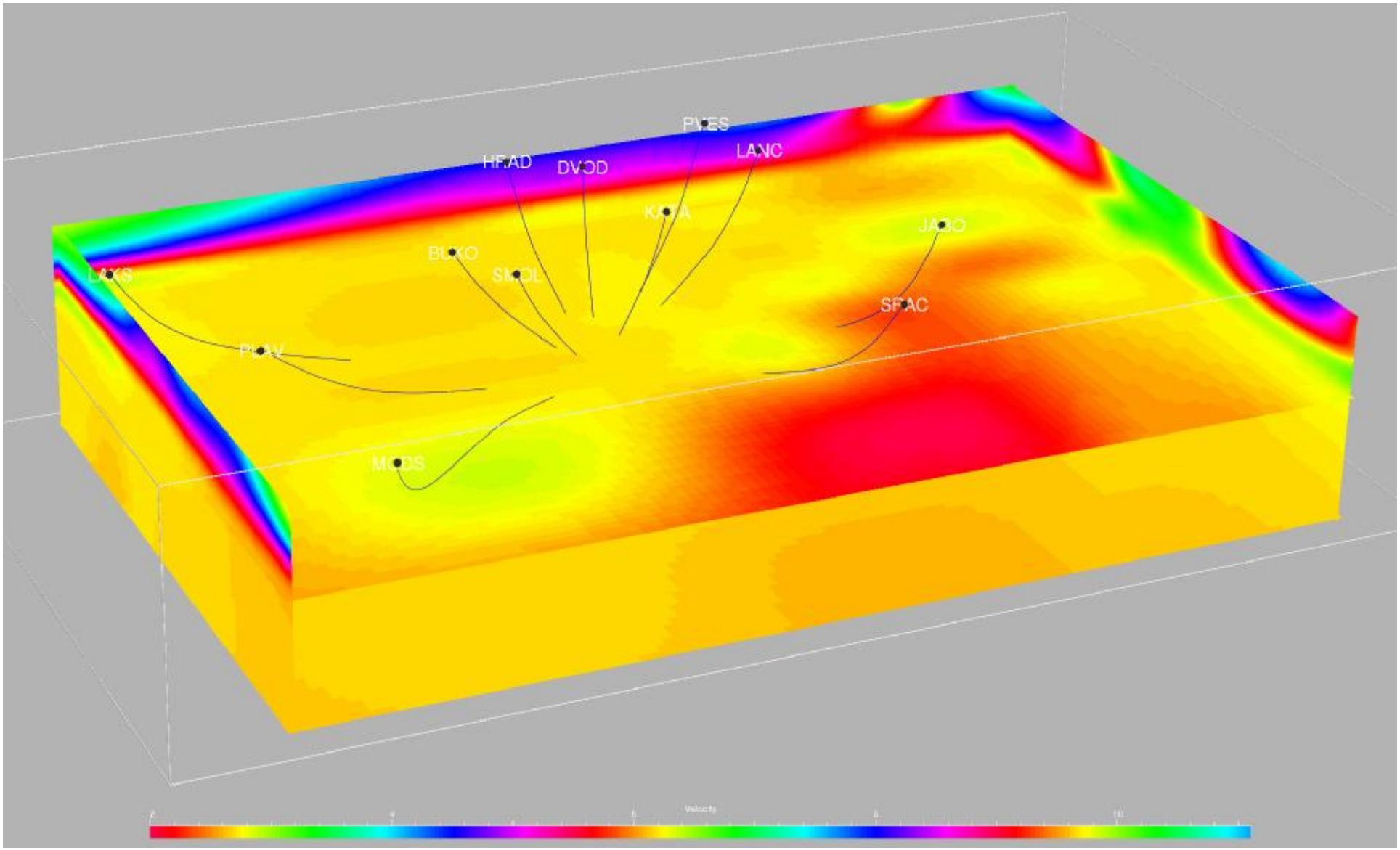

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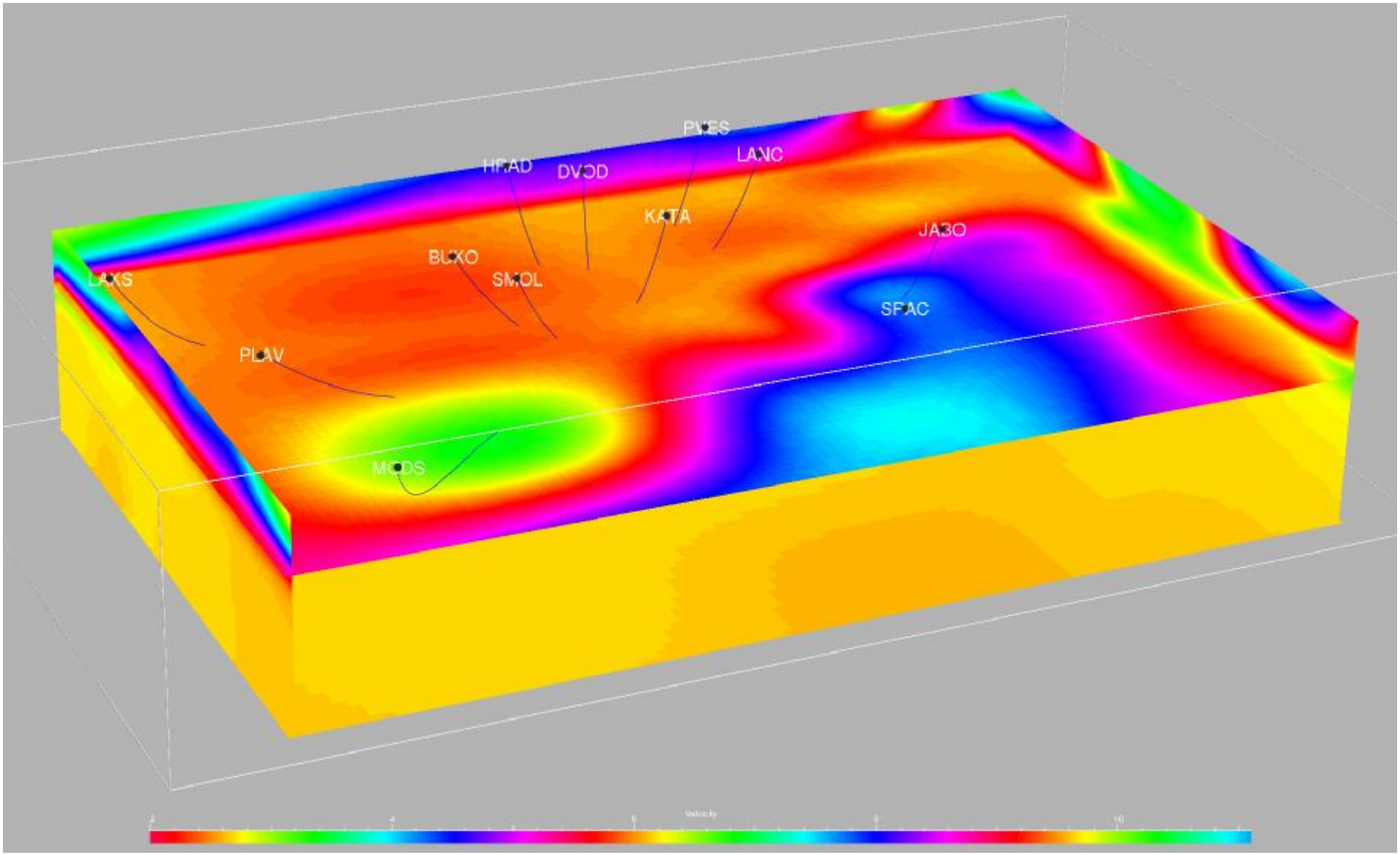

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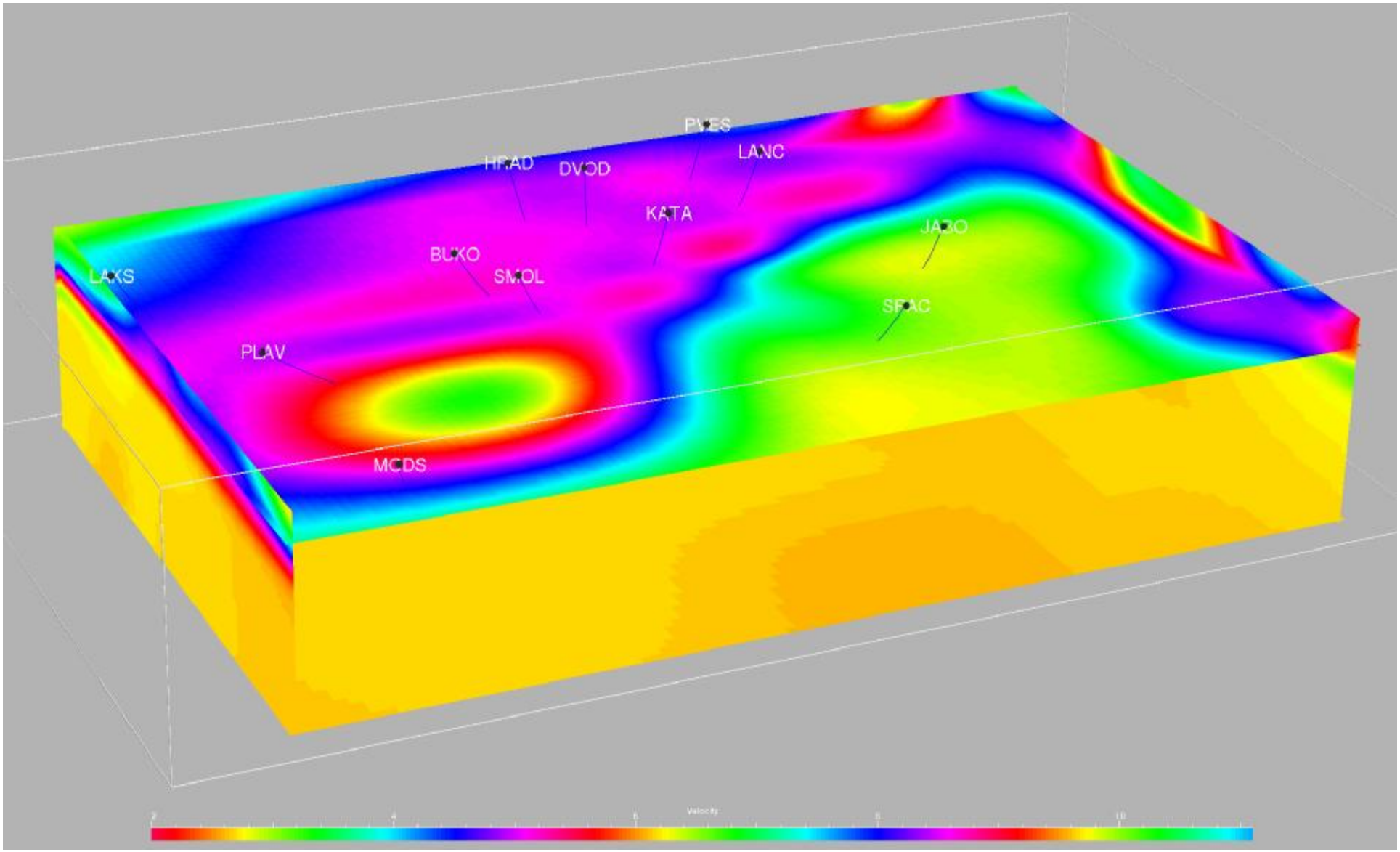

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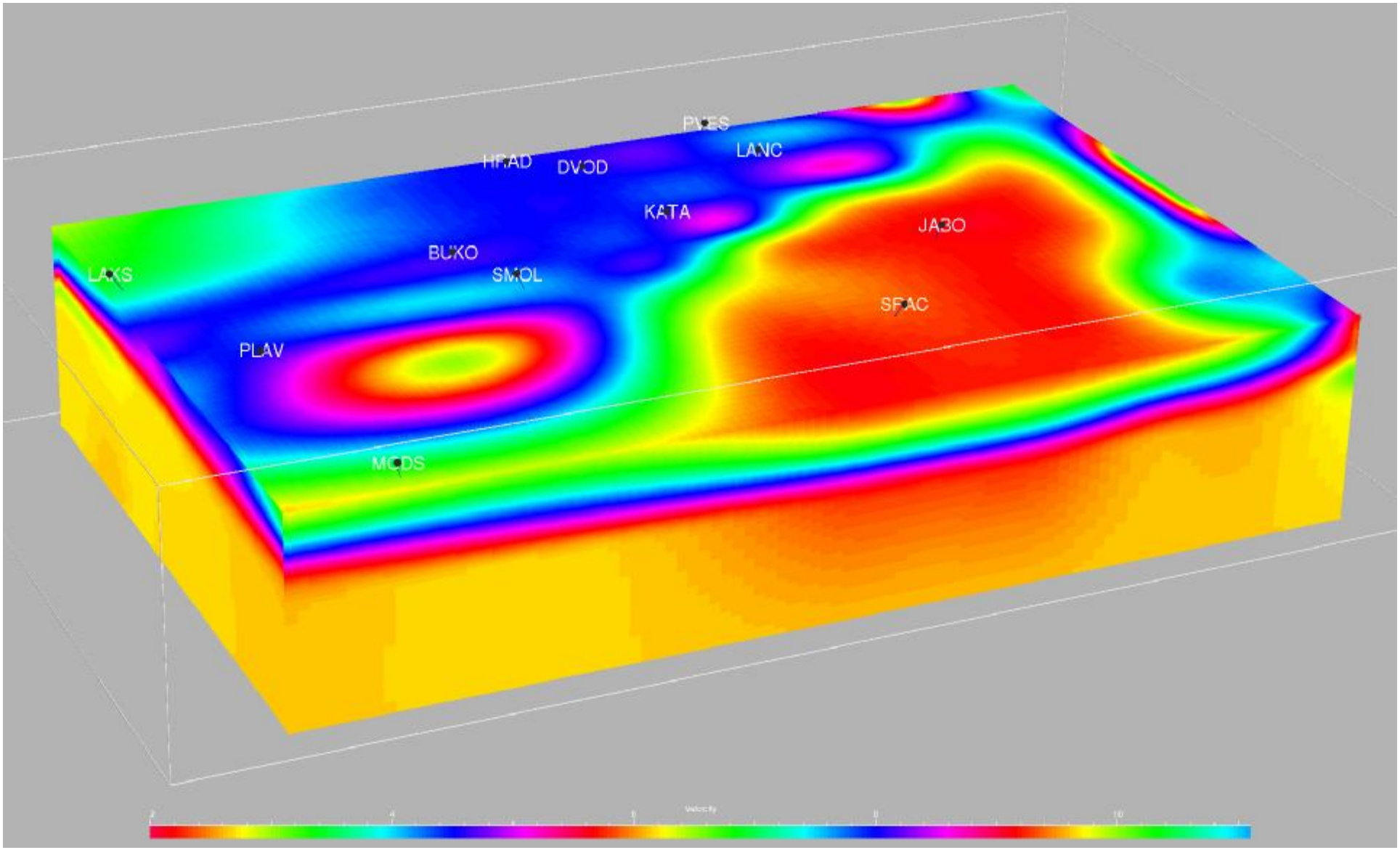


Synthetic test of moment tensor inversion

- synthetic test designed to mimic the configuration of the Malé Karpaty network

- synthetic seismograms calculated in the 3-D model

- MT inversion performed in both 3-D and 1-D models

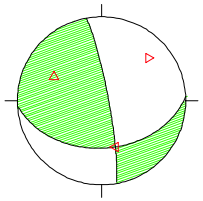
- MT inversion performed wit P&S wave data, with P wave data, and with vertical component of P wave data only

- MT inversion performed also for the data with 10% and 20% of noise

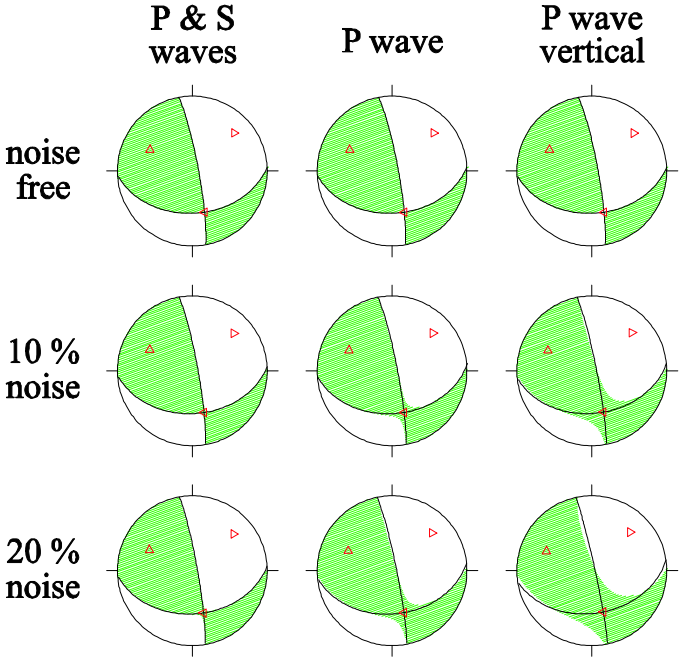
Synthetic test of moment tensor inversion

Source model

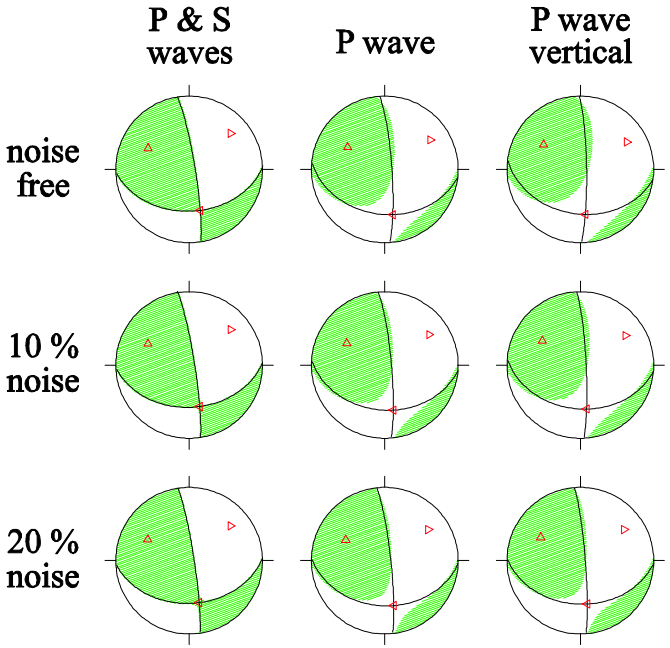
- pure double couple (DC)
- black lines - nodal lines of the DC part
- triangle up – tension axis
- triangle right - pressure axis
- triangle left - N axis
- green zone - compressions



Results of MT inversion in 3-D model



Results of MT inversion in 1-D model



=> orientation of DC part of the mechanism was retrieved well also for 1-D model and noisy input data

Synthetic test of moment tensor inversion

3-D model	P & S waves	P wave	P wave vertical
noise free	DC 100.0% V 0.0% CLVD 0.0%	DC 99.7% V 0.0% CLVD(T) 0.3%	DC 99.4% V 0.0% CLVD(T) 0.6%
10% noise	DC 97.2% V(imp) 0.8% CLVD(P) 2.0%	DC 91.6% V(imp) 1.3% CLVD(P) 7.1%	DC 77.5% V(imp) 1.4% CLVD(P) 21.1%
20% noise	DC 94.3% V(imp) 1.6% CLVD(P) 4.1%	DC 82.8% V(imp) 2.7% CLVD(P) 14.5%	DC 55.9% V(imp) 2.8% CLVD(P) 41.3%

1-D model	P & S waves	P wave	P wave vertical
noise free	DC 91.4% V(exp) 2.9% CLVD(T) 5.7%	DC 51.7% V(exp) 4.4% CLVD(T) 49.9%	DC 34.6% V(exp) 5.6% CLVD(T) 59.8%
10% noise	DC 93.9% V(exp) 2.2% CLVD(T) 3.9%	DC 61.3% V(exp) 3.4% CLVD(T) 35.3%	DC 49.5% V(exp) 4.8% CLVD(T) 45.7%
20% noise	DC 96.5% V(exp) 1.5% CLVD(T) 1.9%	DC 72.5% V(exp) 2.4% CLVD(T) 25.1%	DC 68.4% V(exp) 3.7% CLVD(T) 27.9%

MT = DC + nonDC

MT = DC + V + CLVD

Synthetic test of moment tensor inversion

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- results for 3-D noise free good => station coverage is good

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- for 3-D: - more noise => more data required
  - less data => quality of the data is more important

Synthetic test of moment tensor inversion

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- for 1-D: - DC vs. non-DC content was distorted unless both P & S wave amplitudes were inverted

Synthetic test of moment tensor inversion

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MT = DC + V + CLVD

- results for 3-D noise free good => station coverage is good

- for 3-D:
  - more noise => more data required
  - less data => quality of the data is more important

- for 1-D:
  - DC vs. non-DC content was distorted unless both P & S wave amplitudes were inverted
  - effect of incorrect velocity model overrides the effect of noise largely: we observe bigger distortion for noise free data than for data contaminated by noise

Synthetic test of moment tensor inversion – new in 2013

- synthetic test designed to mimic the configuration of the Malé Karpaty network

- synthetic seismograms calculated in the 3-D model

- MT inversion performed in both 3-D and 1-D models

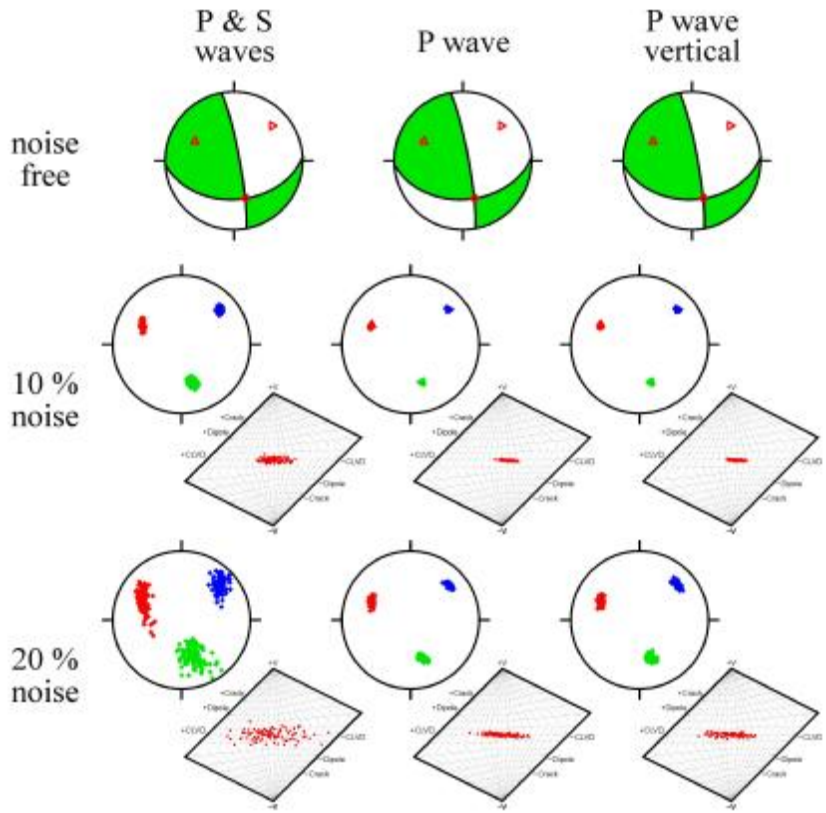
- MT inversion performed wit P&S wave data, with P wave data, and with vertical component of P wave data only

- MT inversion performed also for the data with 10% and 20% of noise

- 100 data sets are generated for each level of noise

Synthetic test of moment tensor inversion – new in 2013

Results of MT inversion in 3-D model



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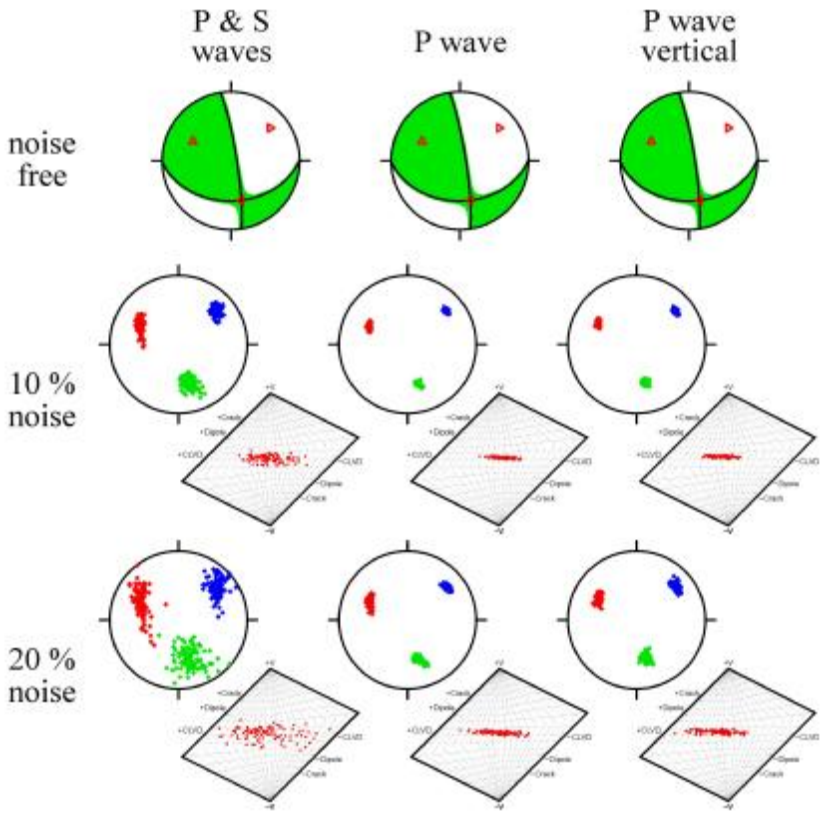


Synthetic test of moment tensor inversion – new in 2013

3-D model	P & S waves	P wave	P wave vertical
noise free	DC 100.0% V 0.0% CLVD 0.0%	DC 100.0% V 0.0% CLVD 0.0%	DC 100.0% V 0.0% CLVD 0.0%
10% noise	DC 88.0±7.6% V -0.7±2.7% CLVD -1.7±12.1%	DC 90.1±6.2% V -1.5±0.8% CLVD -7.7±6.7%	DC 88.4±6.4% V -1.2±1.0% CLVD -9.7±7.1%
20% noise	DC 70.6±18.2% V 0.0±7.3% CLVD 2.6±29.1%	DC 84.4±10.7% V 0.2±2.0% CLVD 0.9±17.3%	DC 82.4±11.1% V 0.1±2.5% CLVD 0.1±18.9%

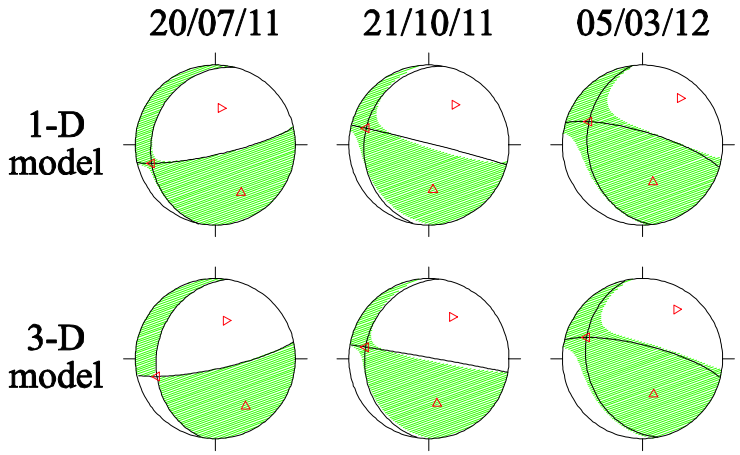
1-D model	P & S waves	P wave	P wave vertical
noise free	DC 94.7% V 3.6% CLVD 1.7%	DC 94.7% V 3.6% CLVD 1.7%	DC 94.7% V 3.6% CLVD 1.7%
10% noise	DC 77.8±12.7% V 1.3±5.0% CLVD 1.4±21.7%	DC 86.9±7.5% V 2.5±1.4% CLVD -4.8±12.2%	DC 83.0±10.8% V 4.1±1.5% CLVD 9.6±13.5%
20% noise	DC 64.3±19.9% V 1.6±9.2% CLVD 6.6±33.5%	DC 79.5±12.7% V 3.6±2.3% CLVD 2.4±20.7%	DC 72.5±18.6% V 5.0±2.4% CLVD 17.6±22.8%

- strange results of better solution for more noisy data disappeared

Dobrá Voda sample events => 2012

Date	Origin time	Latitude	Longitude	Depth	M_L
20.7.2011	18:30:58,0	48.620	17.870	16.0	2.1
21.10.2011	15:58:39,3	48.530	17.170	8.0	2.5
5.3.2012	22:56:57,1	48.550	17.186	14.0	3.1

	20/07/11	21/10/11	05/03/12
1-D model	DC 95.9% V(imp) 0.5% CLVD(P) 3.6%	DC 64.2% V(imp) 8.2% CLVD(P) 27.6%	DC 75.9% V(exp) 6.2% CLVD(P) 17.9%
3-D model	DC 99.5% V(imp) 0.1% CLVD(P) 0.4%	DC 75.2% V(imp) 6.9% CLVD(P) 17.9%	DC 86.9% V(exp) 7.1% CLVD(P) 6.0%



- 3 real events inverted for moment tensors
- results indicate the dominance of the DC components, the non-DC part remaining low

Dobrá Voda sample events

full MT and pure DC inversions, probability F-test

Dobrá Voda sample events
full MT and pure DC inversions, probability F-test

unconstrained full MT inversion:
- search for full moment tensor describing the source
- linear inversion
- 6 degrees of freedom

pure DC inversion:
- search for a pure double couple source
- nonlinear inversion
- 4 degrees of freedom (dip, strike, rake, scalar moment)

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The noise in the data, mismodeling of the Green's function, and other uncertainties of the MT inversion manifest themselves mostly in the non-DC part of the MT solution =>
=> need to estimate the significance of the non-DC components retrieved in the MT inversion

Dobrá Voda sample events
full MT and pure DC inversions, probability F-test

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probability F-test:
- quantifies the confidence of the MT model with respect to the pure DC one by comparing the fits achieved by unconstrained MT and pure DC models
- 100% => the same confidence of MT and DC solutions
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5 real events inverted for MT and DC source models

Dobrá Voda sample events => 2013

Date	Origin time	Latitude	Longitude	Depth	M_L
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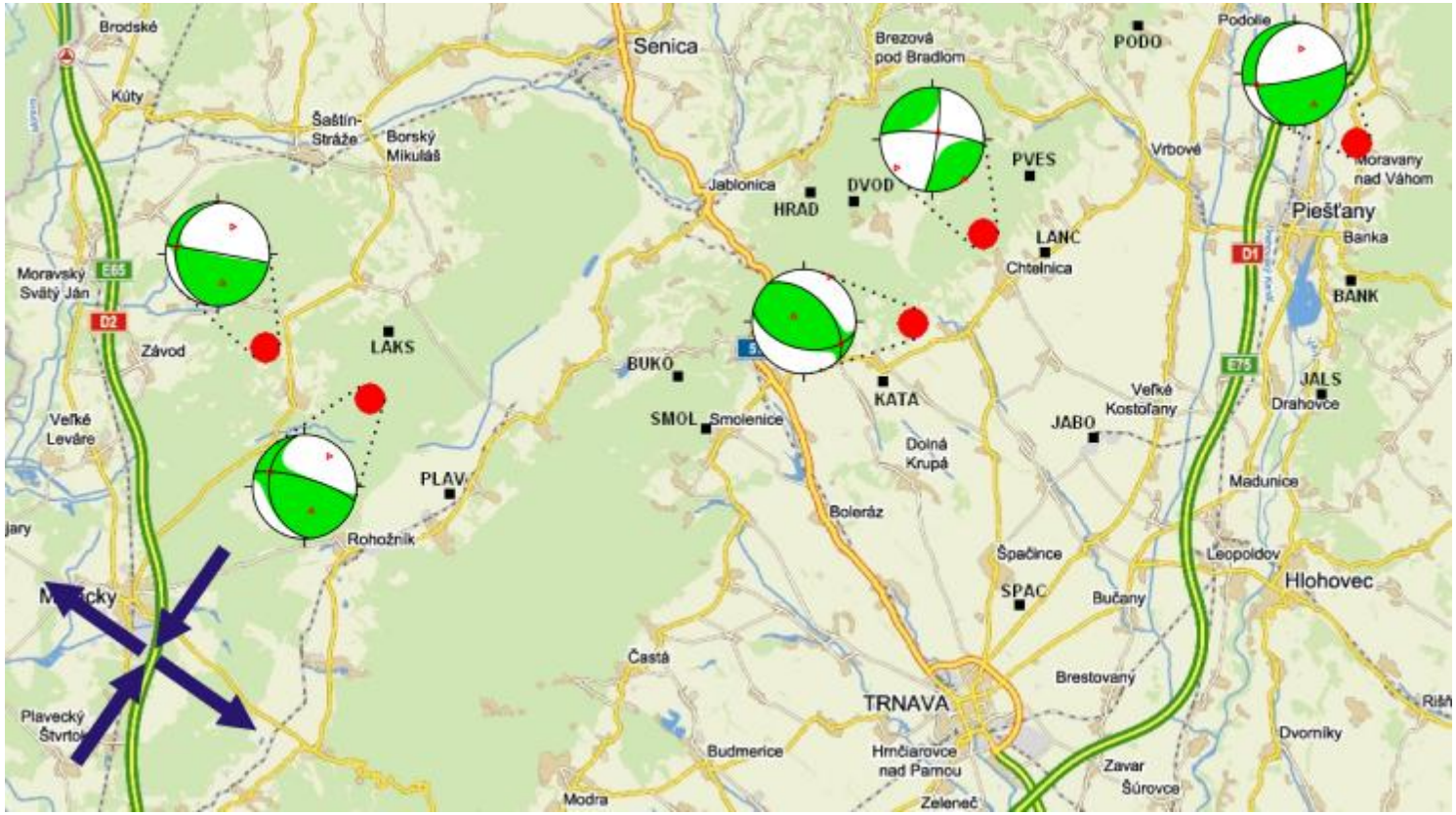
18.11.2012	21:23:31,0	48.582	17.605	5.2	1.9
16.3.2013	09:38:38,9	48.540	17.569	9.8	1.5



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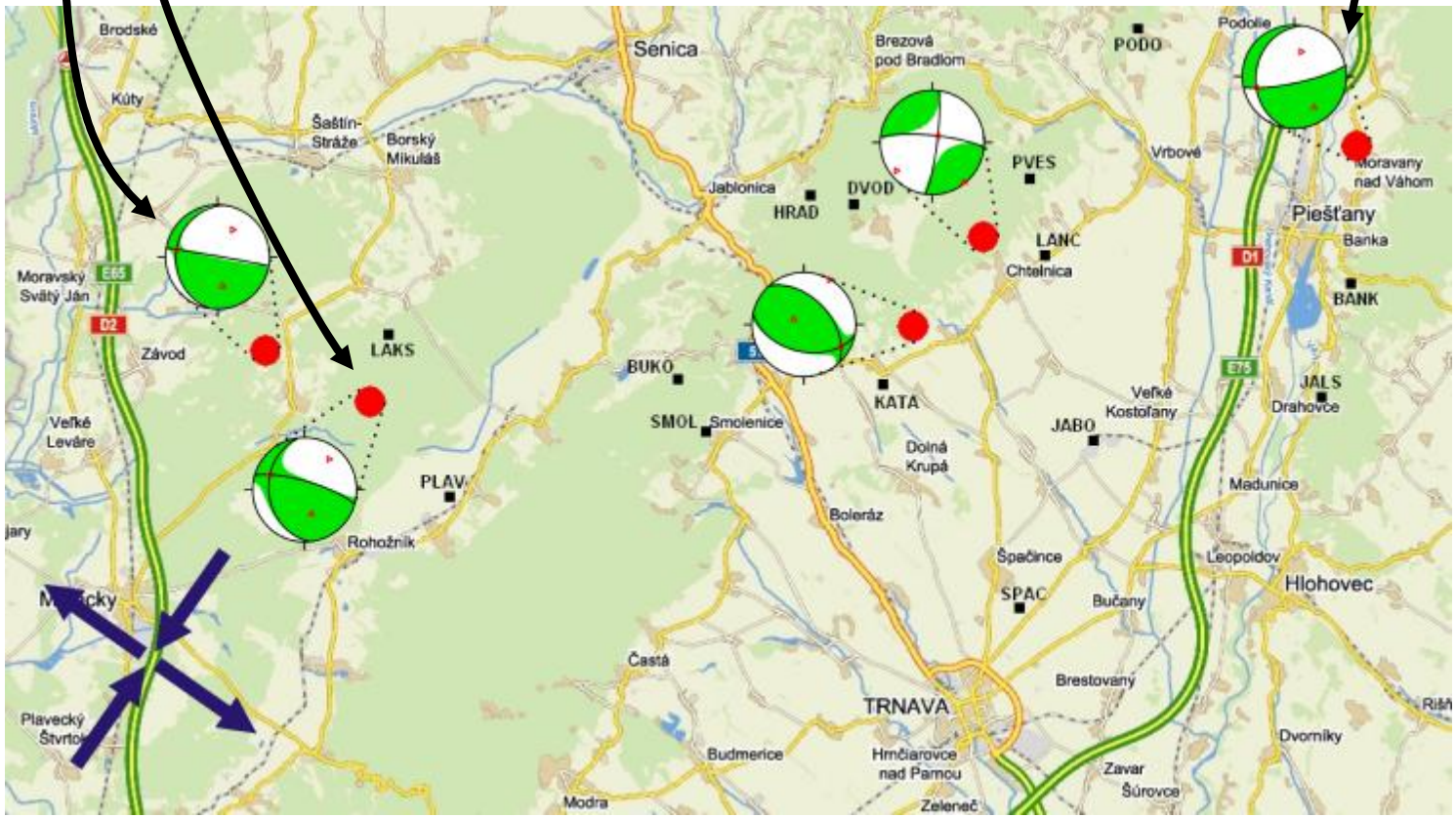
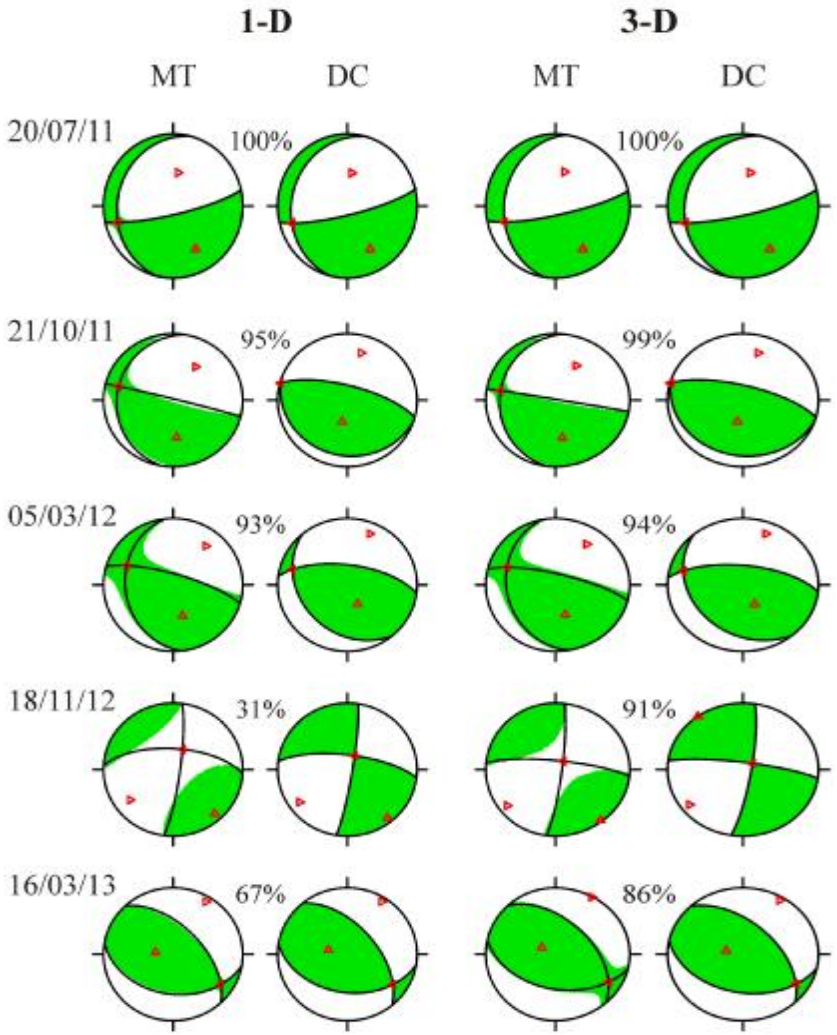
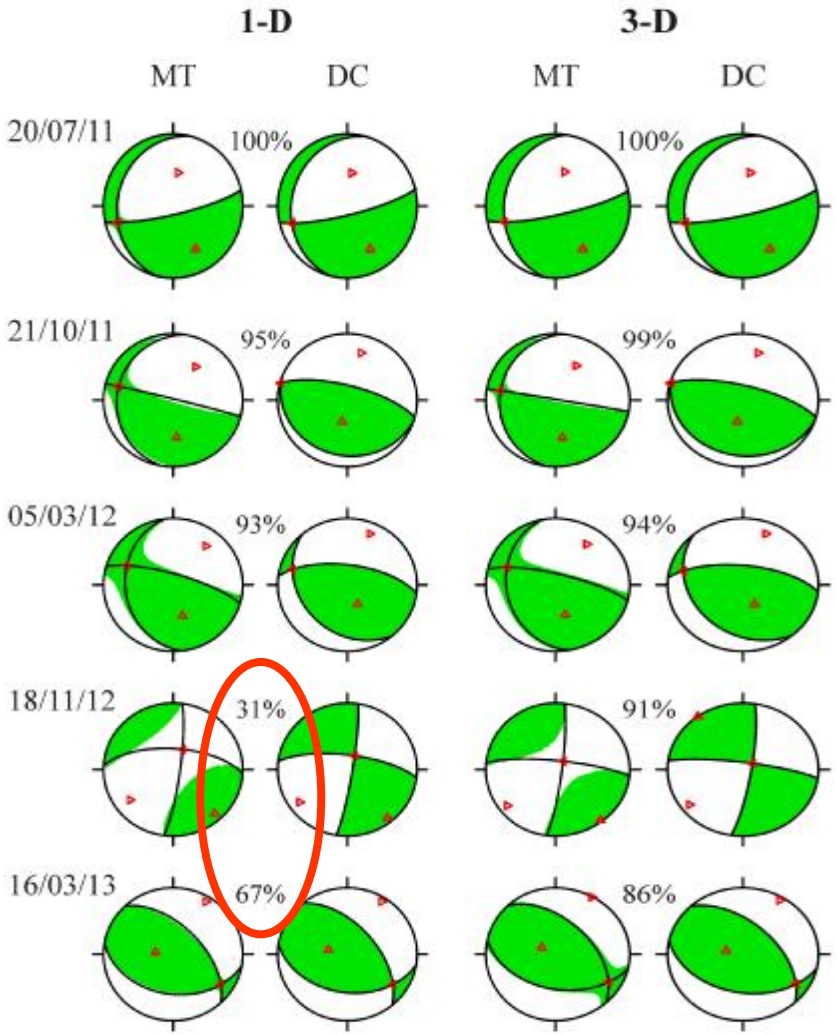


Dobrá Voda sample events => 2013



	1-D model	3-D model
20/07/11	DC 95.9% V -0.5% CLVD -3.6%	DC 99.5% V -0.1% CLVD 0.4%
21/10/11	DC 64.2% V -8.2% CLVD-27.6%	DC 75.2% V -6.9% CLVD-17.9%
05/03/12	DC 75.9% V 6.2% CLVD-17.9%	DC 86.9% V 7.1% CLVD -6.0%
18/11/12	DC 23.6% V -10.1% CLVD 66.3%	DC 59.4% V -3.4% CLVD 37.2%
16/03/13	DC 77.8% V -6.9% CLVD-15.3%	DC 88.5% V 2.5% CLVD 9.0%

Dobrá Voda sample events => 2013



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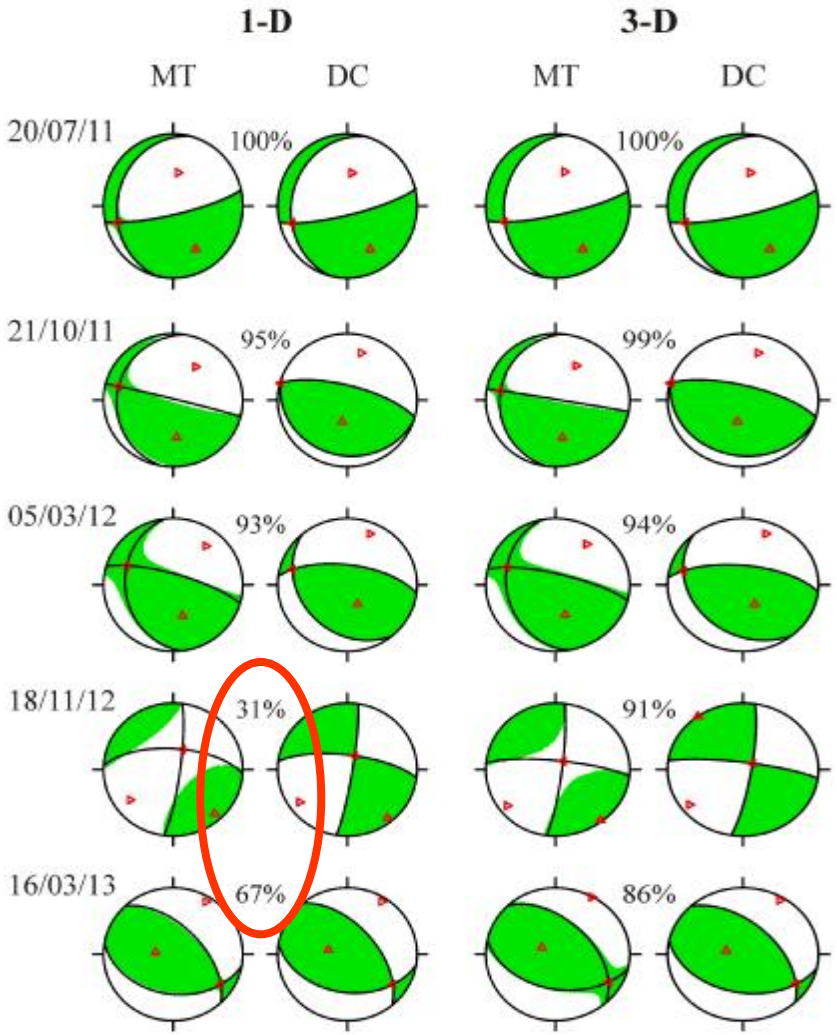
16/03/13	DC 77.8% V -6.9% CLVD-15.3%	DC 88.5% V 2.5% CLVD 9.0%

Dobrá Voda sample events => 2013

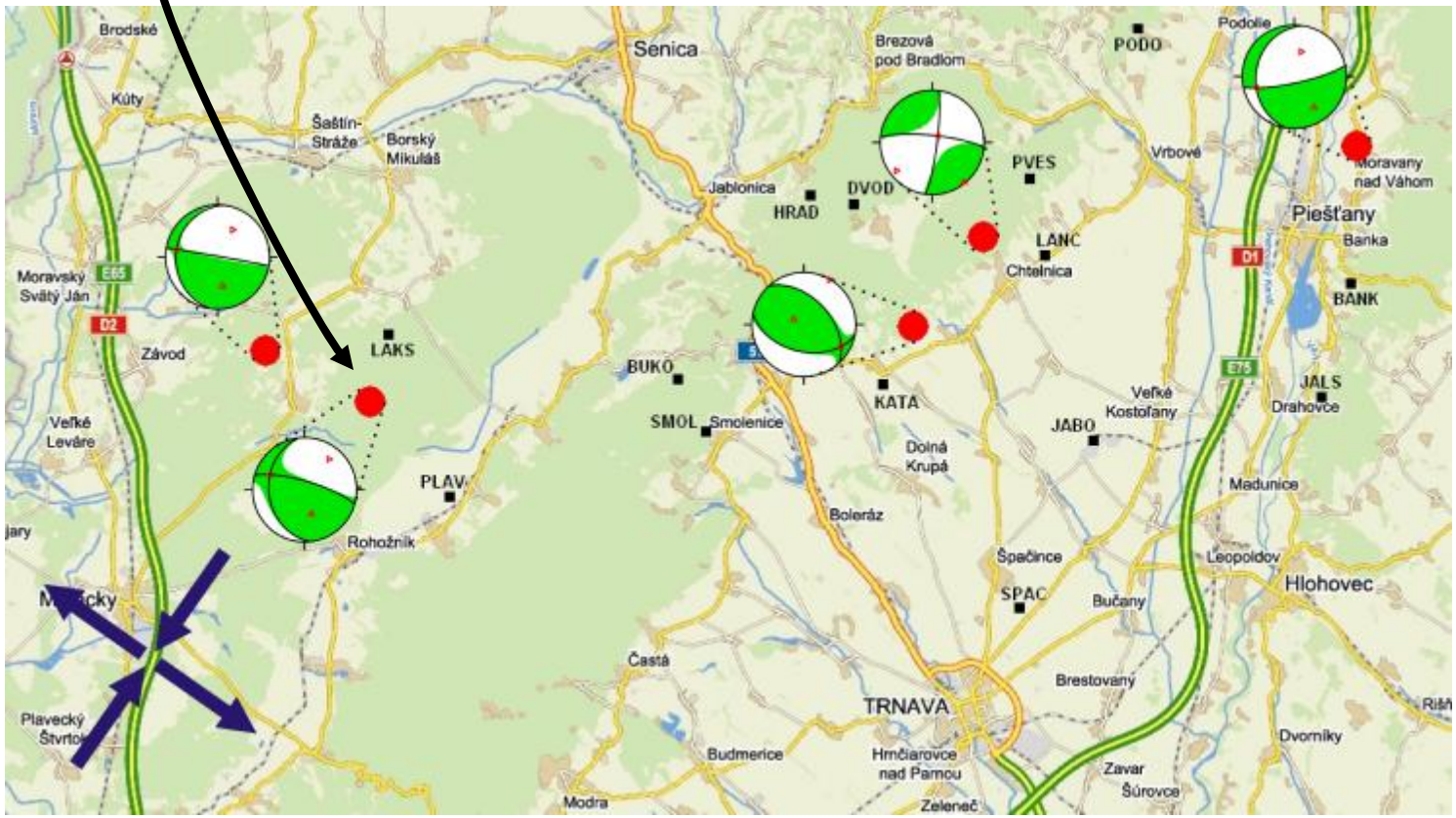


	1-D model	3-D model
20/07/11	DC 95.9% V -0.5% CLVD -3.6%	DC 99.5% V -0.1% CLVD 0.4%
21/10/11	DC 64.2% V -8.2% CLVD-27.6%	DC 75.2% V -6.9% CLVD-17.9%
05/03/12	DC 75.9% V 6.2% CLVD-17.9%	DC 86.9% V 7.1% CLVD -6.0%
18/11/12	DC 23.6% V -10.1% CLVD 66.3%	DC 59.4% V -3.4% CLVD 37.2%
16/03/13	DC 77.8% V -6.9% CLVD-15.3%	DC 88.5% V 2.5% CLVD 9.0%

=> using of 3-D model in MT inversion enables more reliable estimation of the DC versus non-DC components of the moment tensor

Analysis of the depth of the location of the strongest event

Date	Origin time	Latitude	Longitude	Depth	M_L
20.7.2011	18:30:58,0	48.620	17.870	16.0	2.1
21.10.2011	15:58:39,3	48.530	17.170	8.0	2.5
5.3.2012	22:56:57,1	48.550	17.186	14.0	3.1
18.11.2012	21:23:31,0	48.582	17.605	5.2	1.9
16.3.2013	09:38:38,9	48.540	17.569	9.8	1.5



Analysis of the depth of the location of the strongest event

- location from national network => 5 km depth
- location from local network => 14 km depth

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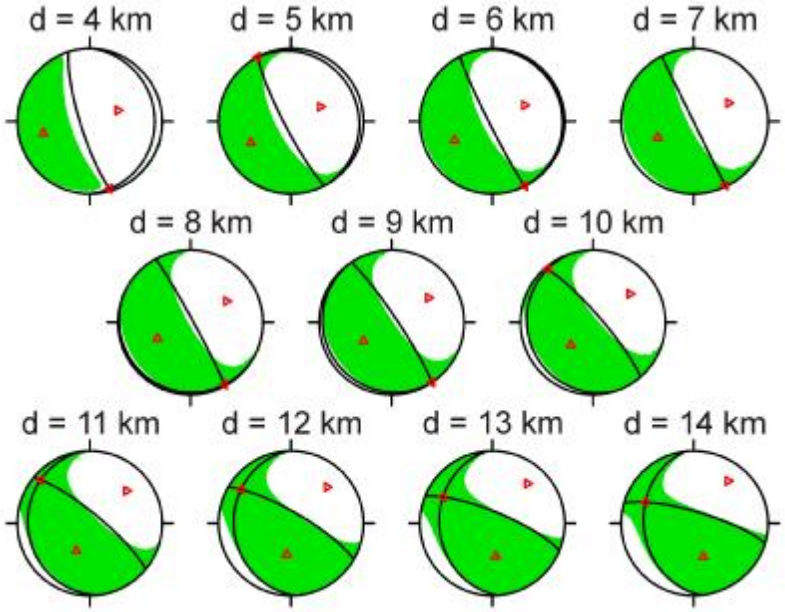

depth [km]	NRMS	strike [°]	dip [°]	rake [°]	DC [%]	V [%]	CLVD [%]
4	0.398	163/1	79/11	-94/-72	42.2	-19.9	-37.9
5	0.330	153/329	82/8	-90/-93	44.7	-15.9	-39.4
6	0.284	155/336	86/4	-90/-89	52.6	-12.6	-34.8
7	0.252	154/64	90/2	-92/0	57.9	-10.0	-32.1
8	0.229	331/119	4/87	57/92	61.0	-7.5	-31.5
9	0.215	145/326	6/84	89/90	61.3	-4.8	-33.9
10	0.205	162/319	10/81	112/86	61.1	-1.9	-37.0
11	0.199	173/310	16/79	133/79	62.1	1.0	-36.9
12	0.196	177/300	22/77	145/72	66.1	3.8	-30.1
13	0.195	176/292	28/77	151/66	75.2	6.1	-18.7
14	0.194	174/286	32/77	154/61	86.9	7.1	-6.0

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- location from national network => 5 km depth
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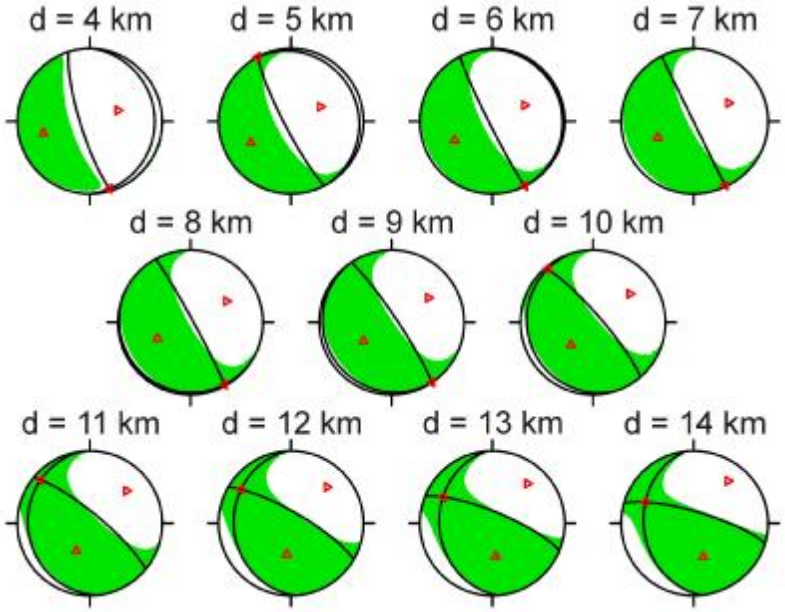

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=> with increasing depth DC content increases and NRMS decreases

Acknowledgments

- ProgSeis for providing the seismic data

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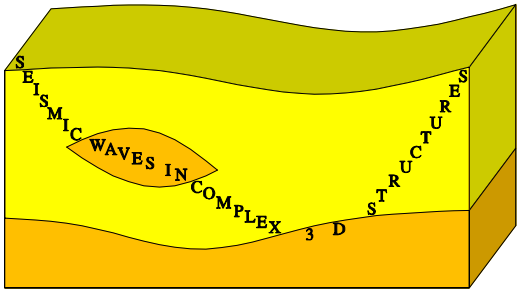
- members of the consortium “Seismic Waves in Complex 3-D Structures'‘ for the support



http://sw3d.cz