Back-propagation analysis for hypocenter location

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ABSTRACT

Back propagation analysis，implemented in two approaches，has been based on the incident propagation directions derived from 3C data by hodogram analysis with weighted least squares, the resulting nearest points of mutual raypaths, and the statistical clustering optimization of nearest points with Student's *t* distribution. The hodogram of each trace is based on MER (modified energy ratio) picking of the first arrival time on noise attenuated data.

METHODS

1. **Hodogram analysis for propagation directions:** It employs the weighed least squares technology, a noise attenuation approach, and the modified energy ratio (MER) analysis

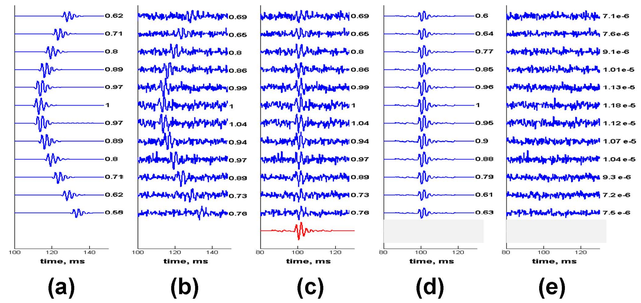

FIG. 1. Noise attenuation tested with synthetic data . (a) true arrivals, (b) noisy traces (SNR=3), (c) trace alignment and stacking after bandpass filtering (bp-filter), MER windowing and matched filtering (Mm-stack), (d) signal components after noise signal separation (NSS), and (e) noise components after NSS.

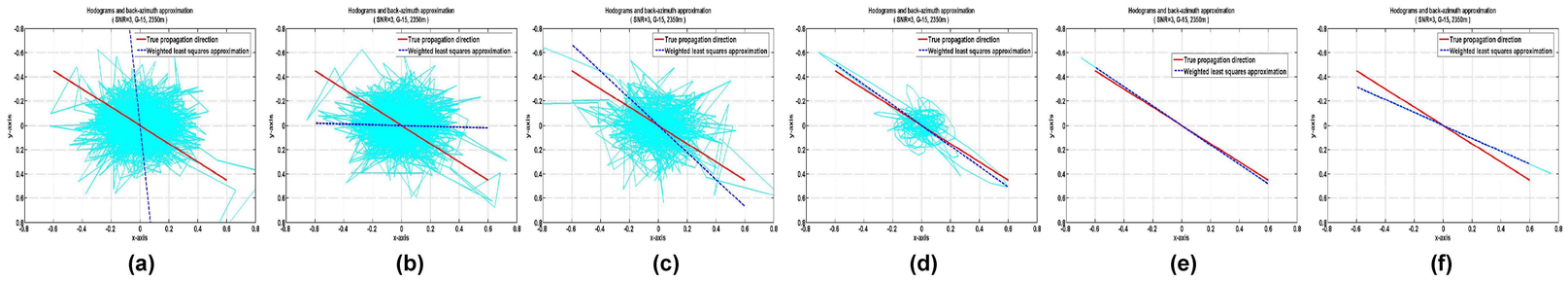

FIG.2. Hodogram orientation (blue dash line) by the weighted least squares technique on (a) raw data with Gaussian noise (SNR=3), and noise attenuation effects with (b) bp-filter (c) Mm-stack (d) Mm-stack and NSS (e) bp-filter and NSS, and (f) bp-filter, Mm-stack, and NSS. The red line indicates the true incident propagation.

2. **Back-propagation analysis**: It employs the nearest approach to two spatial lines and the Student's *t* distribution.

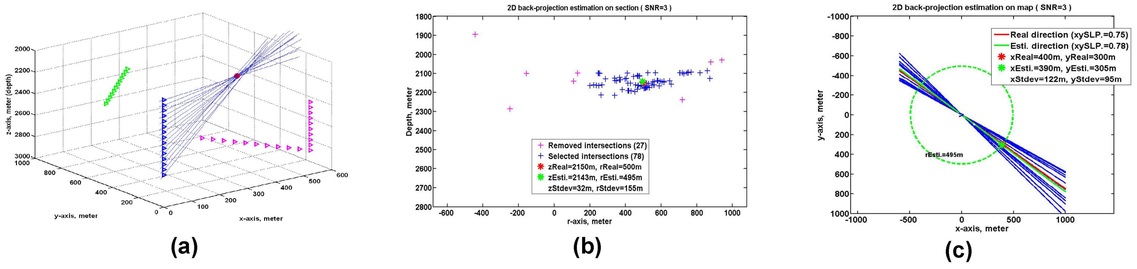

FIG.4. The 2D approach illustration (a) raypaths from a single vertical well in a perspective view, (b) back-propagation analysis on the radial section, (c) back-propagation analysis on the map.

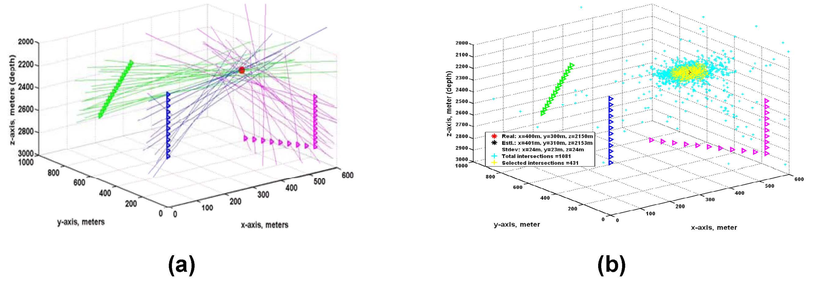

FIG.3. The 3D approach applied to (a) raypaths from 3-wells (color-coded triangles) monitoring a single microseism (red dot) , (b) back-propagation analysis in 3D approach.

3. **The location uncertainties with both 2D and 3D approaches:**

This back-propagation method exhibits low location uncertainties in both 2D and 3D approaches under sufficient experimental testing (total of 600 and 180 cases for 2D and 3D respectively) as shown in Table 1 and Table 2.

Table 1: Statistics of location uncertainty for the 2D approach of back-propagation analysis

SNR	Δz (m)	x_s (m)	y_s (m)	z_s (m)
10	10	390 ± 28	292 ± 22	2148 ± 7
10	25	398 ± 13	298 ± 10	2151 ± 3
10	50	401 ± 8	310 ± 7	2149 ± 4
3	10	264 ± 58	195 ± 43	2122 ± 14
3	25	386 ± 37	286 ± 30	2151 ± 12
3	50	410 ± 27	301 ± 23	2152 ± 15
True	Location :	400 m	300 m	2150 m

Table 2: Statistics of location uncertainty for the 3D approach of back-propagation analysis

SNR	Δz (m)	x_s (m)	y_s (m)	z_s (m)
10	10	400 ± 1.5	299 ± 2.2	2150 ± 2.1
10	25	400 ± 1.9	299 ± 1.7	2150 ± 1.7
10	50	400 ± 2.5	300 ± 2.4	2150 ± 2.3
3	10	400 ± 9.0	294 ± 6.4	2153 ± 8.2
3	25	405 ± 5.0	295 ± 6.6	2155 ± 5.7
3	50	405 ± 7.7	299 ± 8.9	2158 ± 7.8
True	Location :	400 m	300 m	2150 m

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