Relative Energy and Aperture Estimation of the Five Explosions in North Korea

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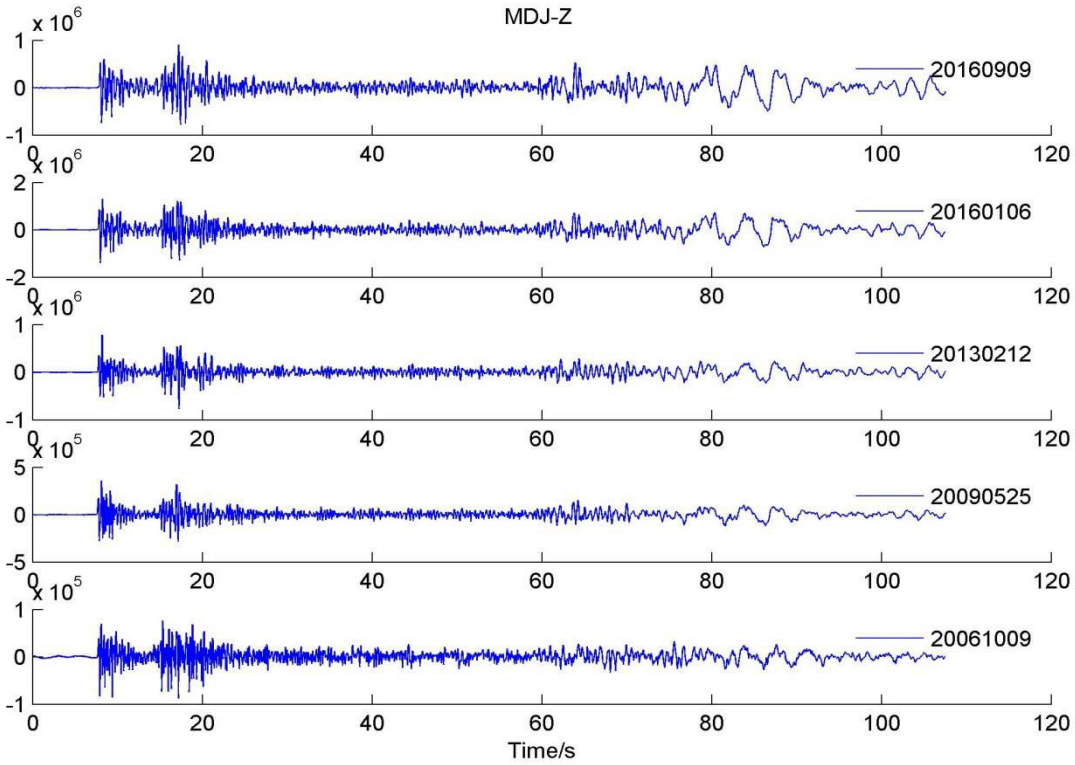
T2.1-08

Outline

- 1. Amplitude and PSD ratio of the five events
- 2. Locations of the latest two events by China Korea Joint Seismic Network
- 3. Estimation of the aperture of the five events
- 4. Conclusions

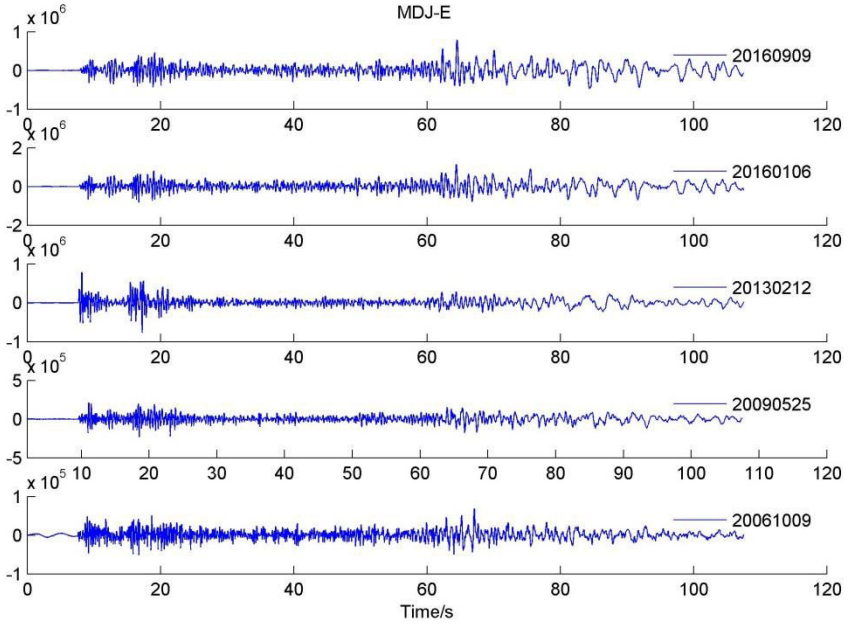
Relative energy of the five events

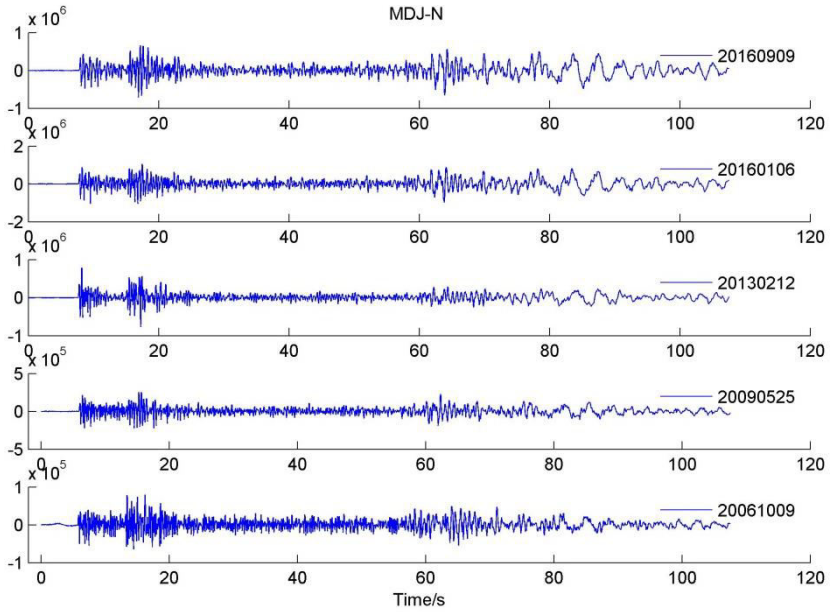
The waveforms of MDJ



MDJ is one of the CDSN (China Digital Seismograph Network) stations, it is located in Heilongjiang Province, the distance to the site is 372km.

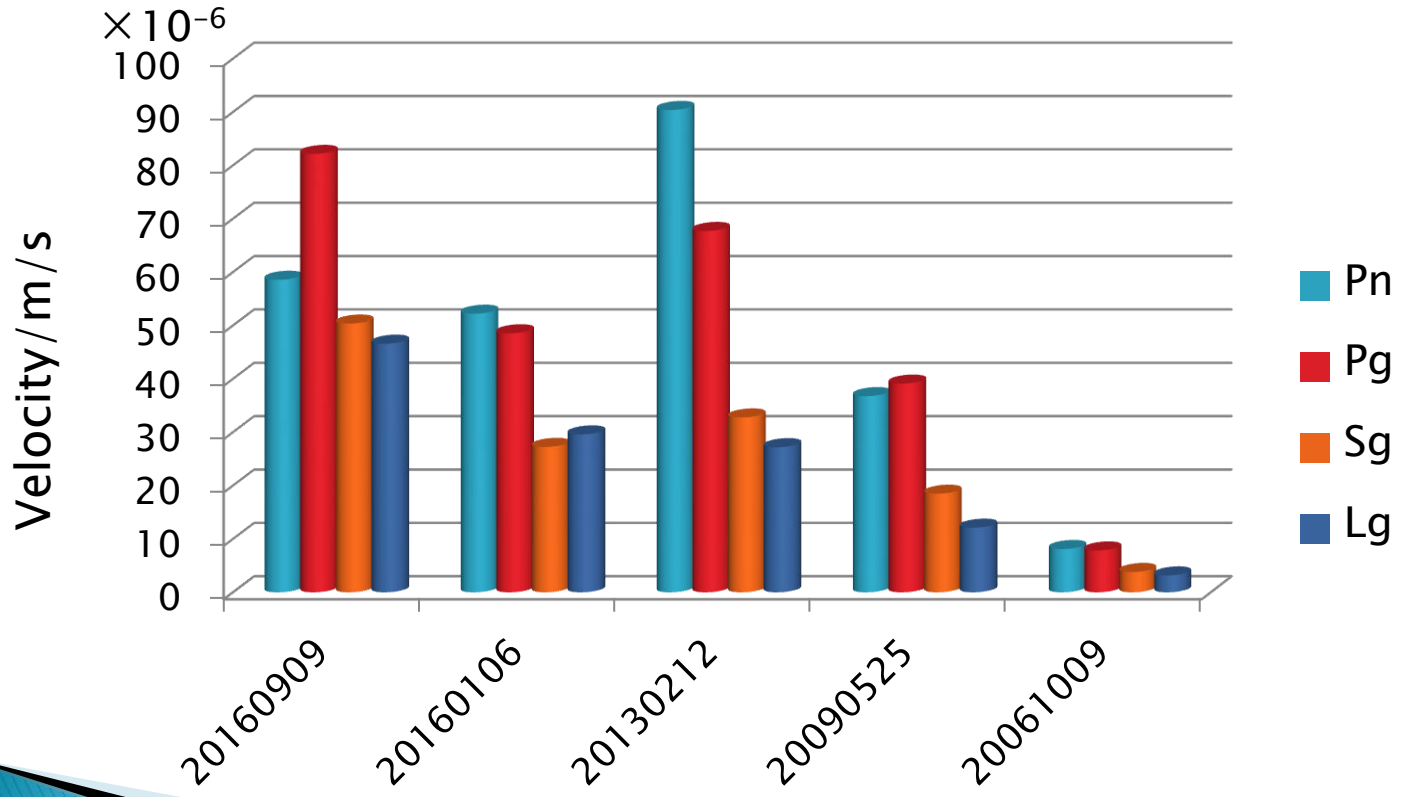
Wavesforms for 5 events recorded by MDJ-E and MDJ-N



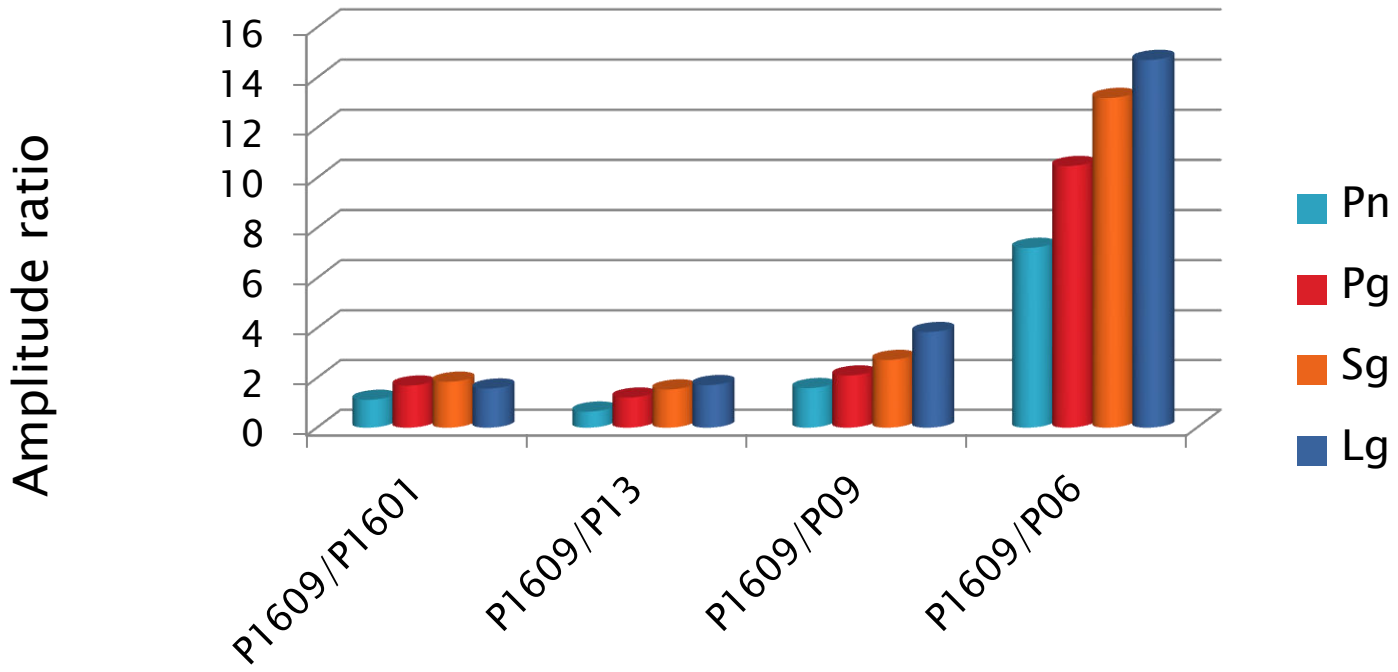


According to the PDE of NEIC, the magnitudes of 5 DPRK events are mb4.3, mb4.7, mb5.1, mb5.3 and mb5.1 respectively.

The amplitude of the Pn、Pg、Sg、and Lg phases recorded in MDJ station



The amplitude ratio between the latest event and the former four events

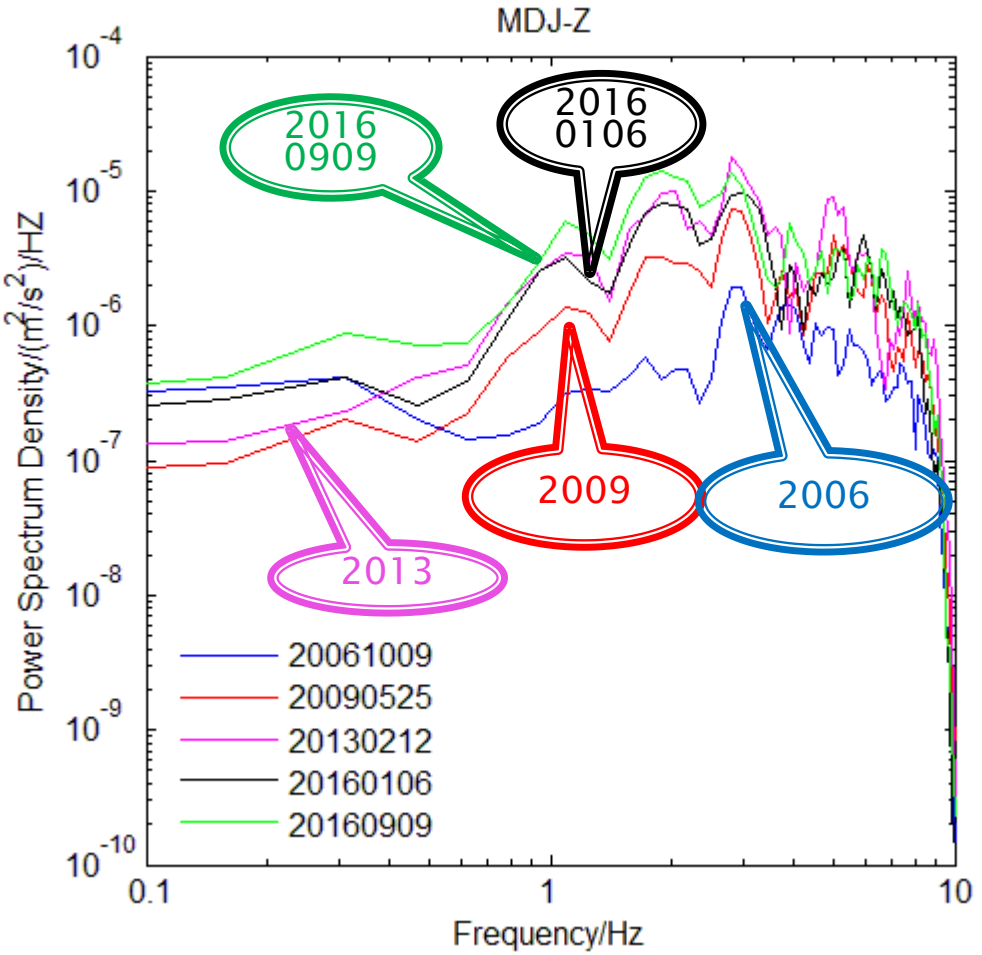


Amplitude ratio table for the events recorded by MDJ station

	A1609/A1601	A1609/A13	A1609/A09	A1609/A06
Pn	1.1218	0.648	1.5932	7.2139
Pg	1.6924	1.2131	2.1005	10.4756
Sg	1.8481	1.5368	2.7251	13.1902
Lg	1.5745	1.7135	3.8472	14.7064
mean	1.56	1.27	2.57	11.4

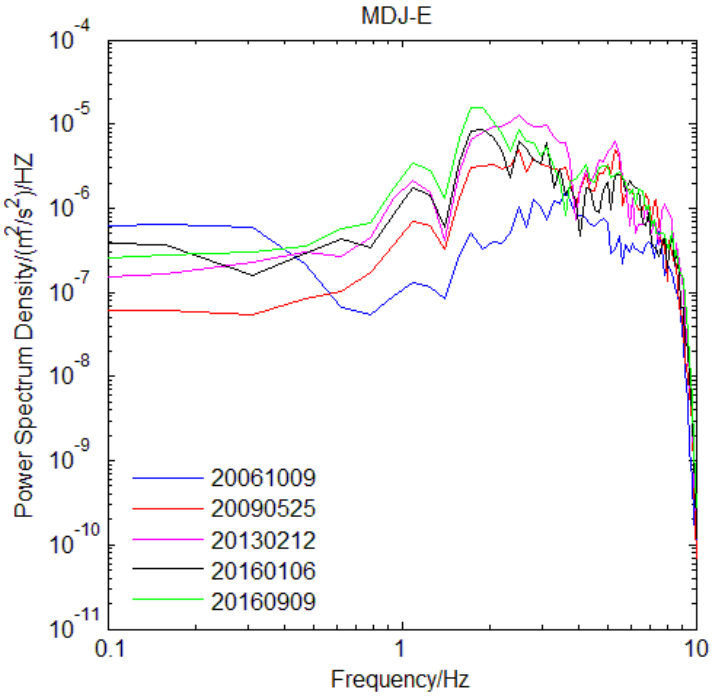
The explosion energy have relation with the magnitude of the explosion, the result of the maximum amplitude ratio between the latest event with the former events give us an estimated result of energy ratio.

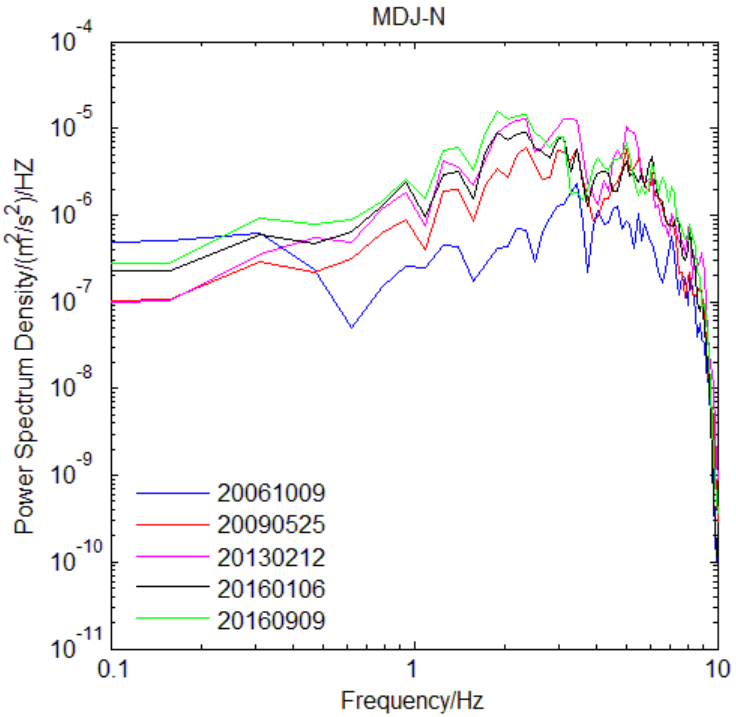
The PSD of the Pg of the five events



The last three events seems to be the similar energy. The green one is the last one, the black one is the January events, and the pink is the events in 2013, so we can see from the picture, that the latest one had the largest energy at the frequency of 0.1-3 Hz, and in the frequency higher than 3 Hz, the latest event had the same energy with the ones in Jan. 2016, in 2013 and even the one in 2009.

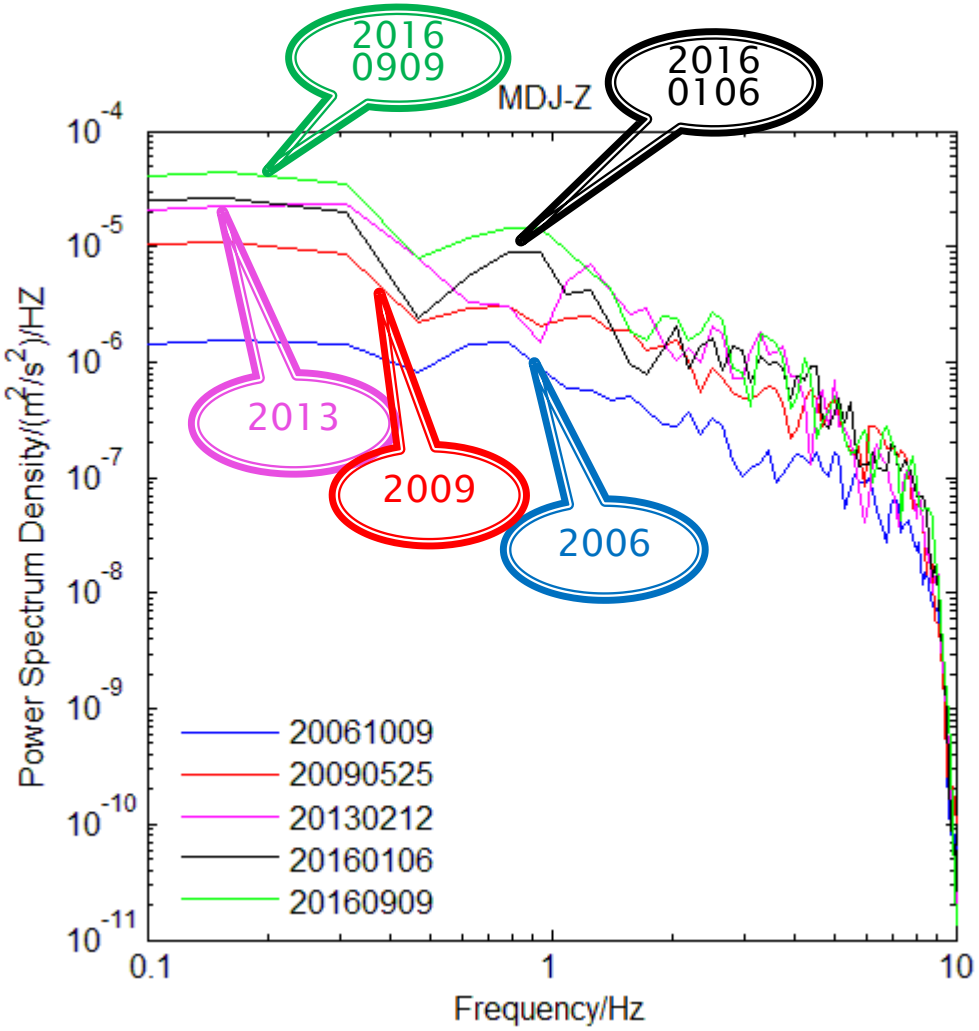
The PSD of the Pg of the five events on horizontal direction





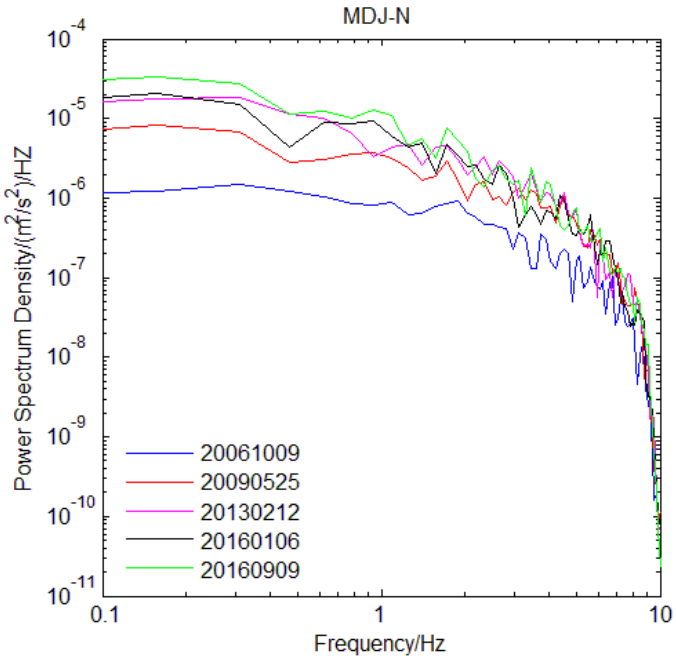
The PSD results of the latest three events are almost equal in high frequency in E-W and in N-S components, the largest one is the event occurred in Sep. 9, 2016 according to the horizontal components.

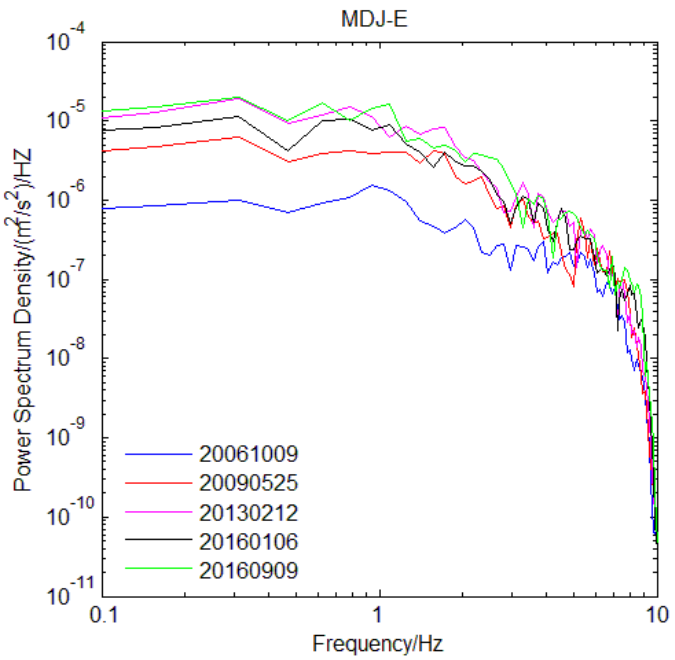
The PSD of the Lg of the five events



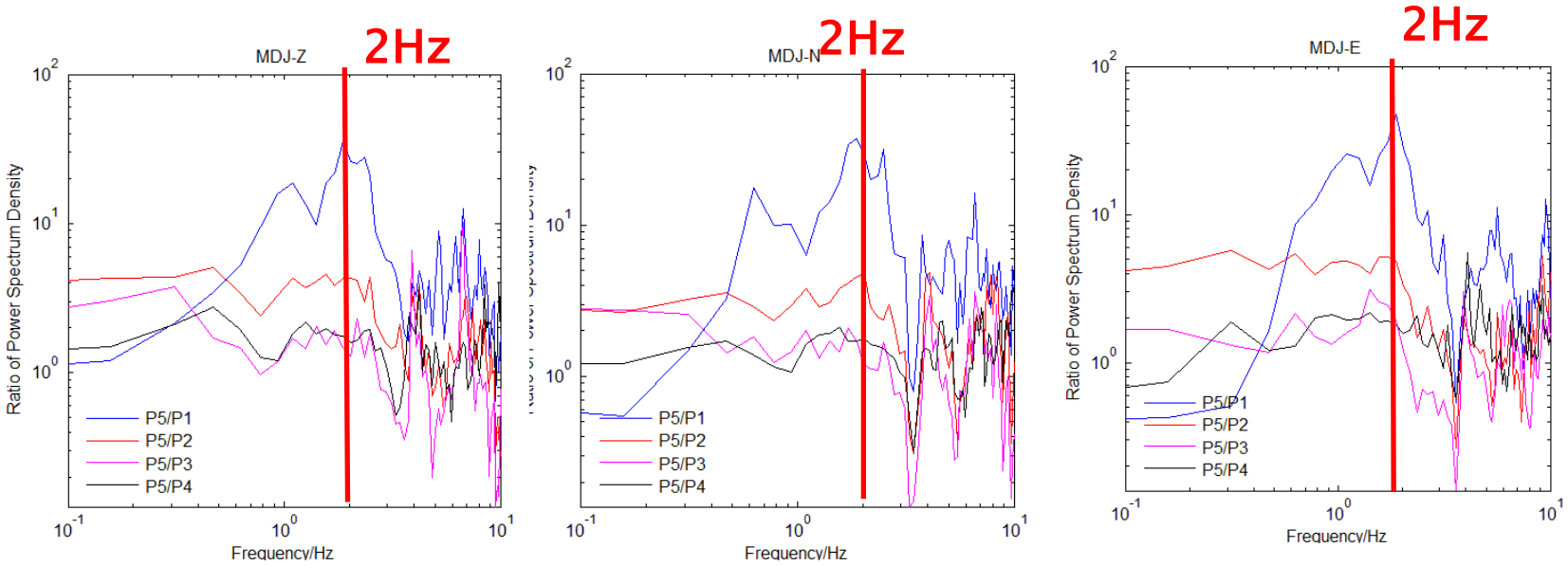
The PSD results of Lg phase supports the results of Pg phase, that the largest event should be the one in Sep. of 2016. It is larger than the event in 2013 and the one occurred in Jan. 2016.

The PSD of the Lg of the five events on horizontal direction





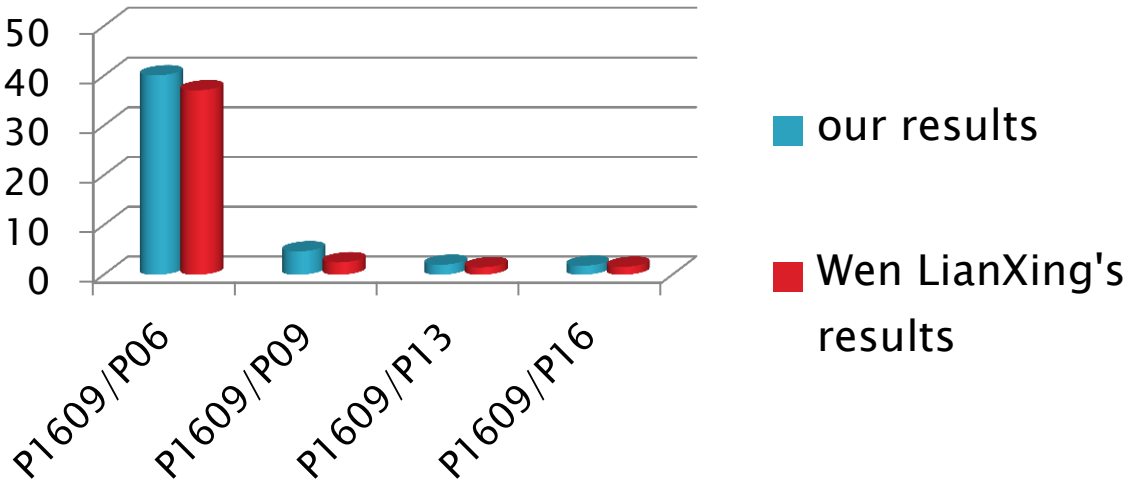
Ratio of the latest events to other four events

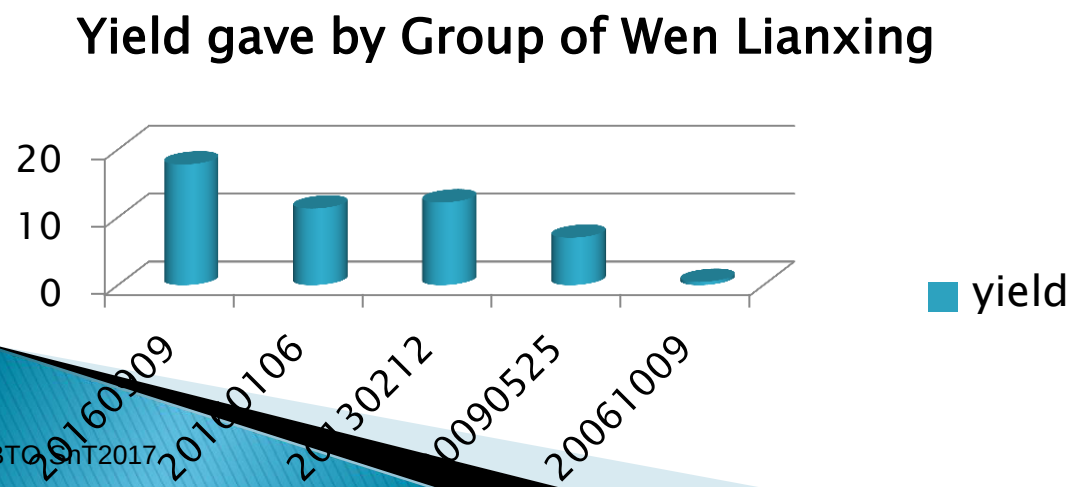


	Z	N	E
P5/P1	35.5	37.4	47.4
P5/P2	4.3	4.8	5.1
P5/P3	2.3	1.2	2.6
P5/P4	1.6	1.8	1.9

At 2 Hz, the average ratio of the event occurred on Sep. 2016 to other four events are 40.1, 4.7, 2.0 and 1.8 respectively.

Energy ratio between the latest event and the former four events

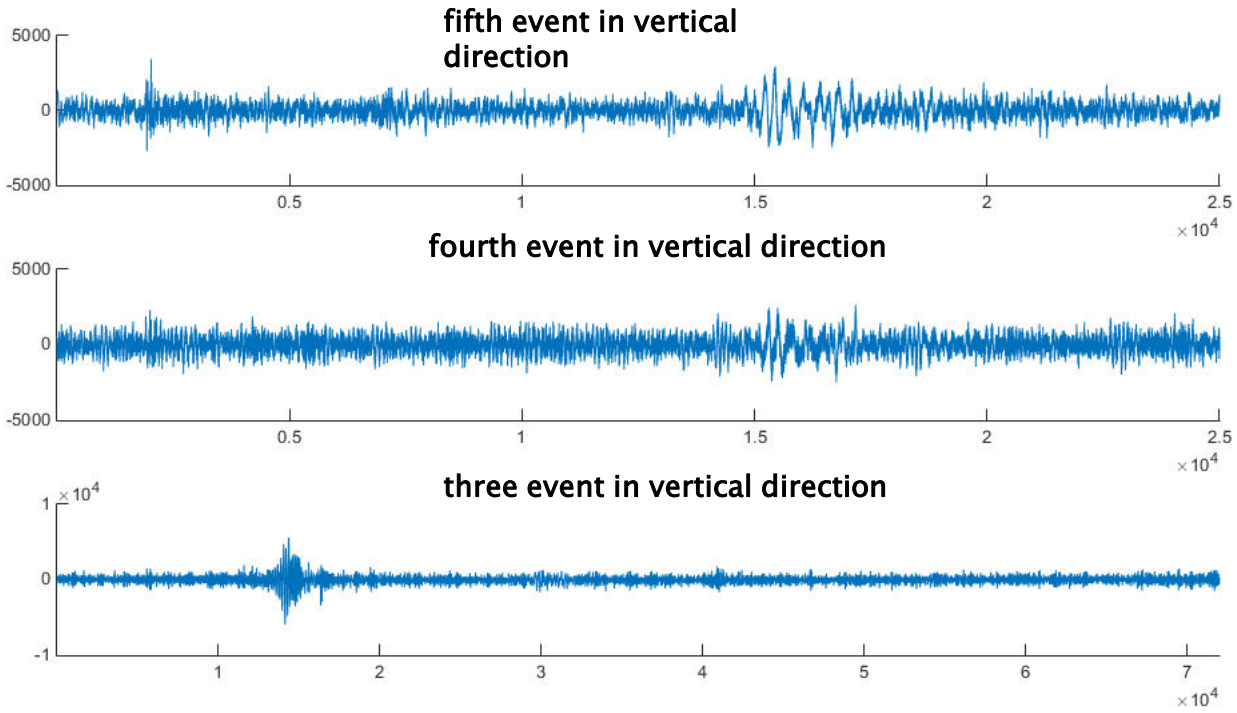




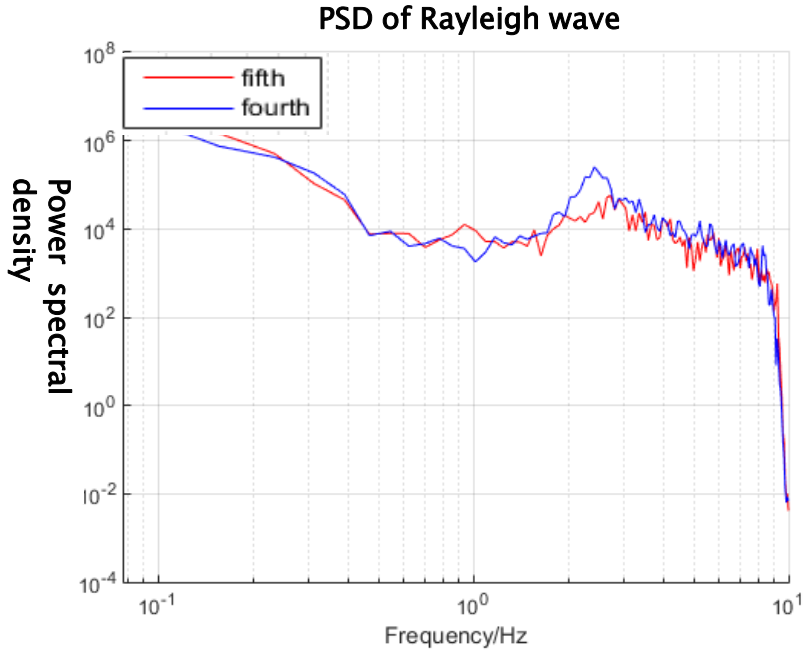
At 2 Hz, the ratio of the event occurred on Sep. 2016 to other four events are 40.1, 4.7, 2.0, 1.8 respectively, which have little difference with the results of Wen Lianxing group, which gaves the yields of 17.8kt, 11.3kt, 12.2kt, 7kt, 0.48kt for the five events, and the ratios are 37.1, 2.5, 1.5, 1.6 respectively.

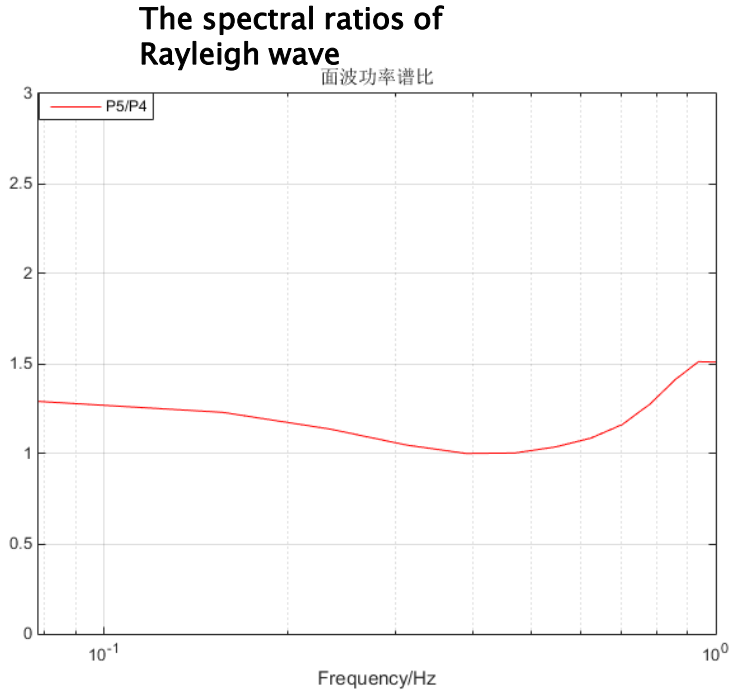
Some result from other Chinese stations

Station: KMI
Δ=3012km



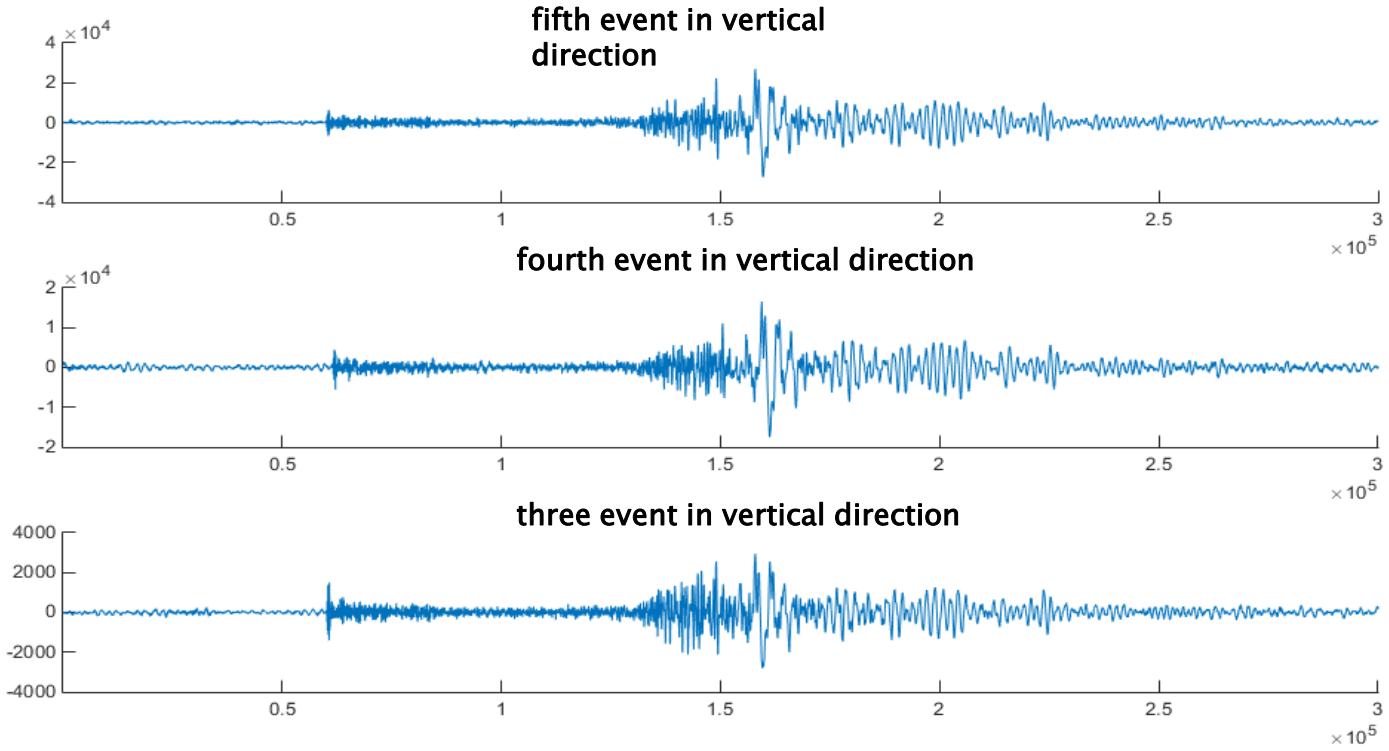
Rayleigh waves can be seeing the fifth and fourth events



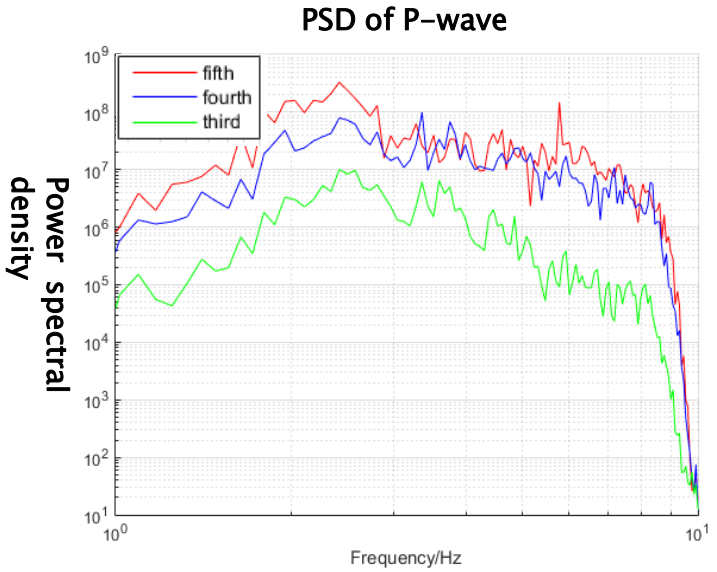


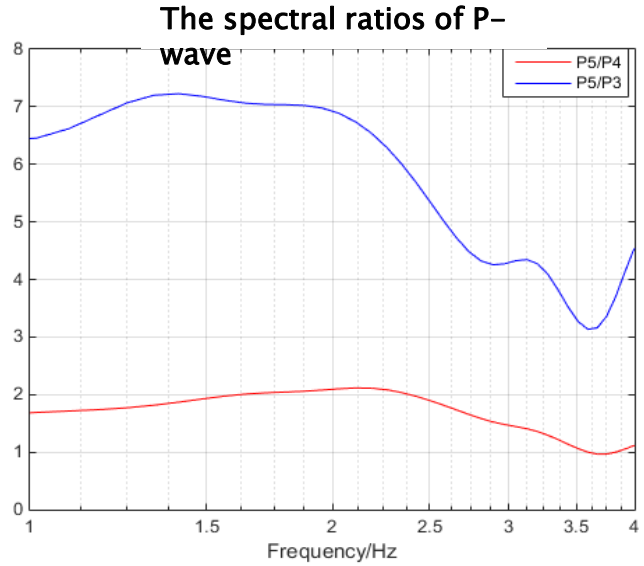
The PSD and mean spectral ratios of Rayleigh in KMI

Station: HIA
Δ=1143km

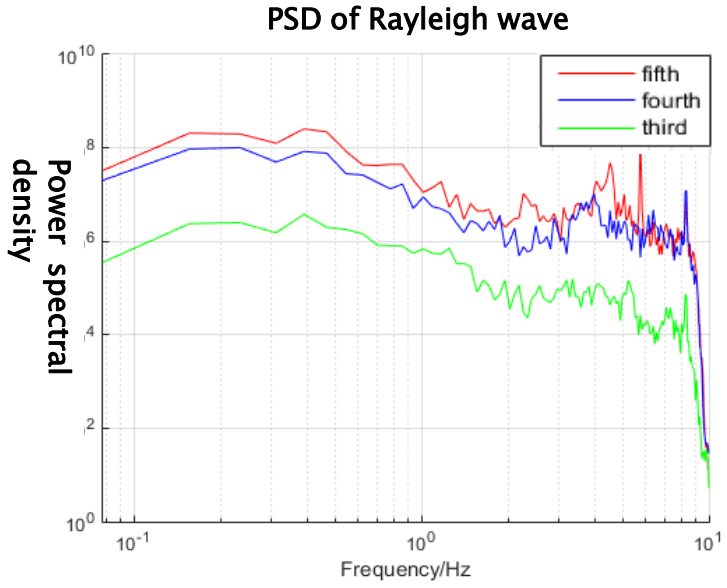


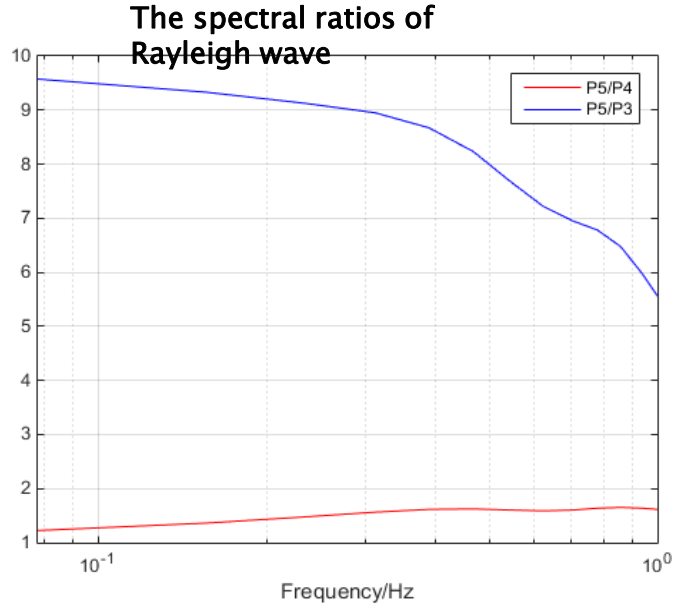
the first two events were completely submerged in the noise at HIA station





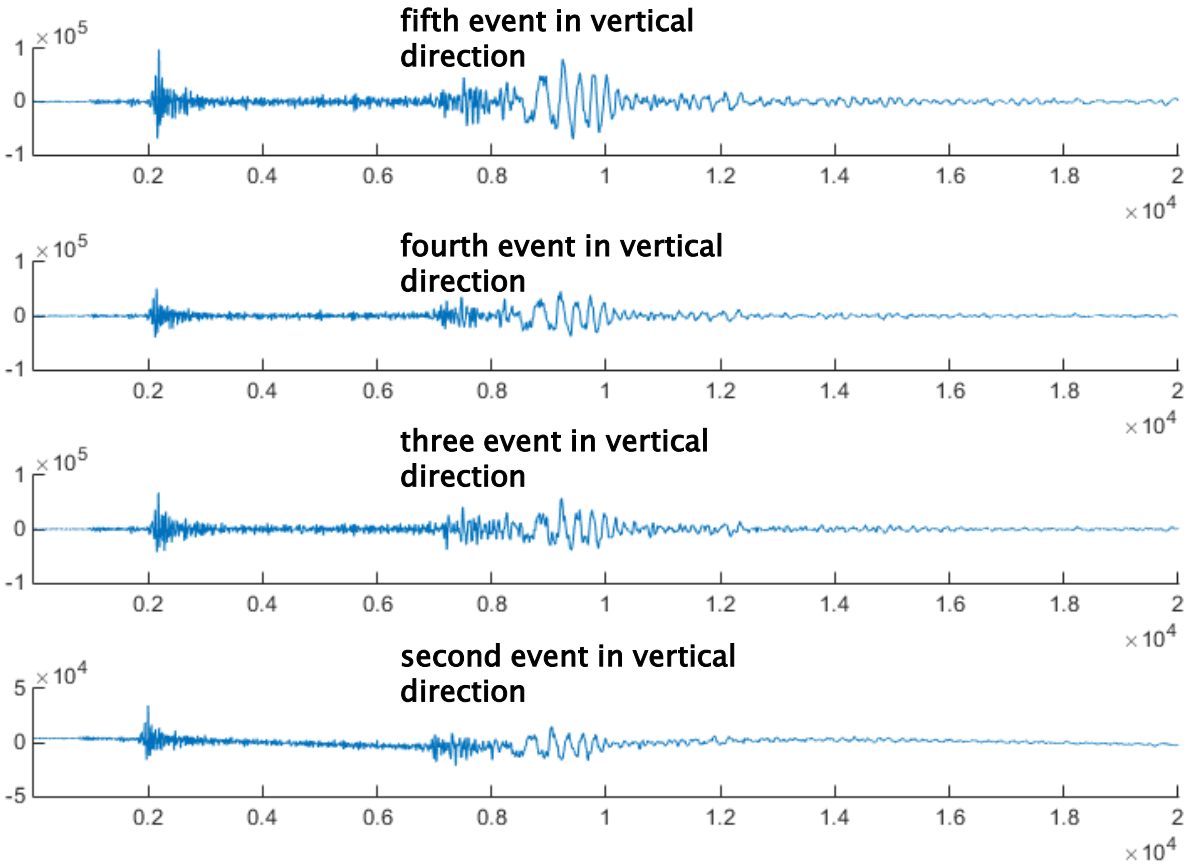
The mean ratios of P-wave are 1.6 and 5.4



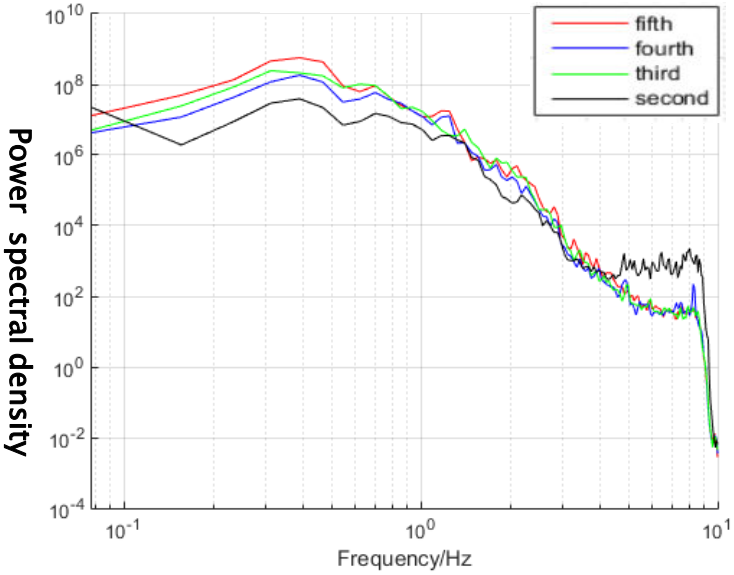


The mean ratios of Rayleigh wave are 1.6 and 5.4

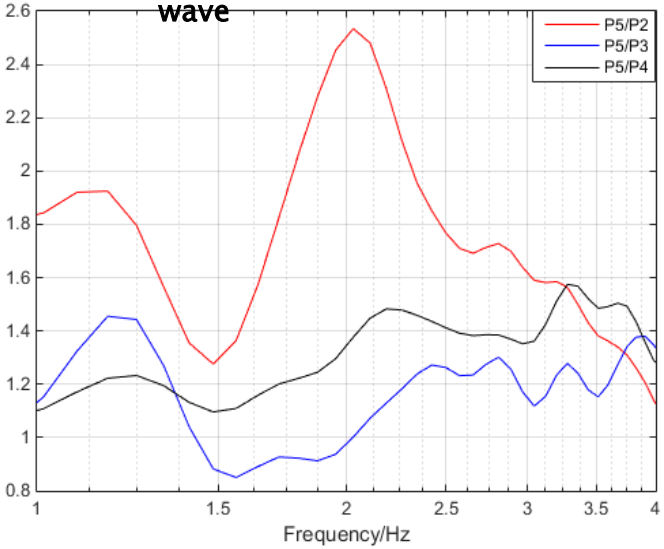
Station: DDO
Δ=410km



PSD of P-wave

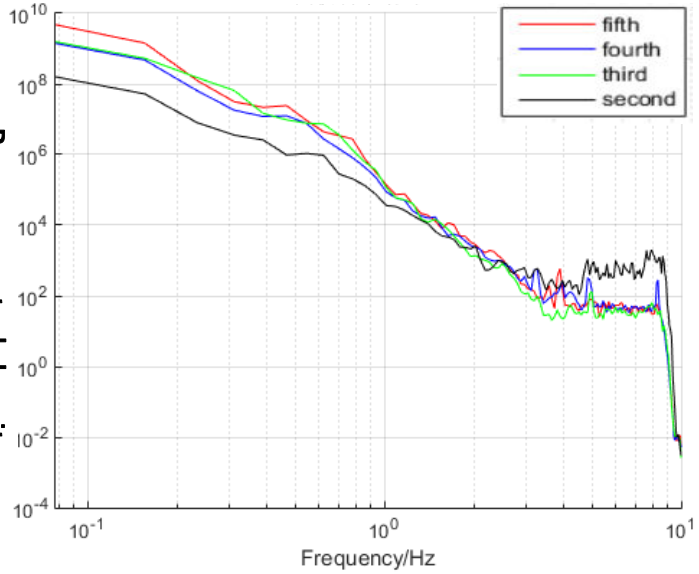


The spectral ratios of P-wave

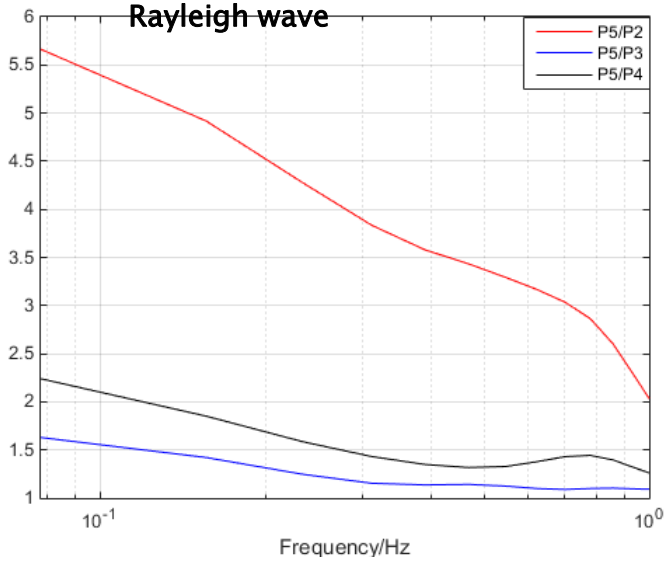


The mean ratios of P-wave are 1.34 、 1.15 and 1.72

PSD of Rayleigh wave

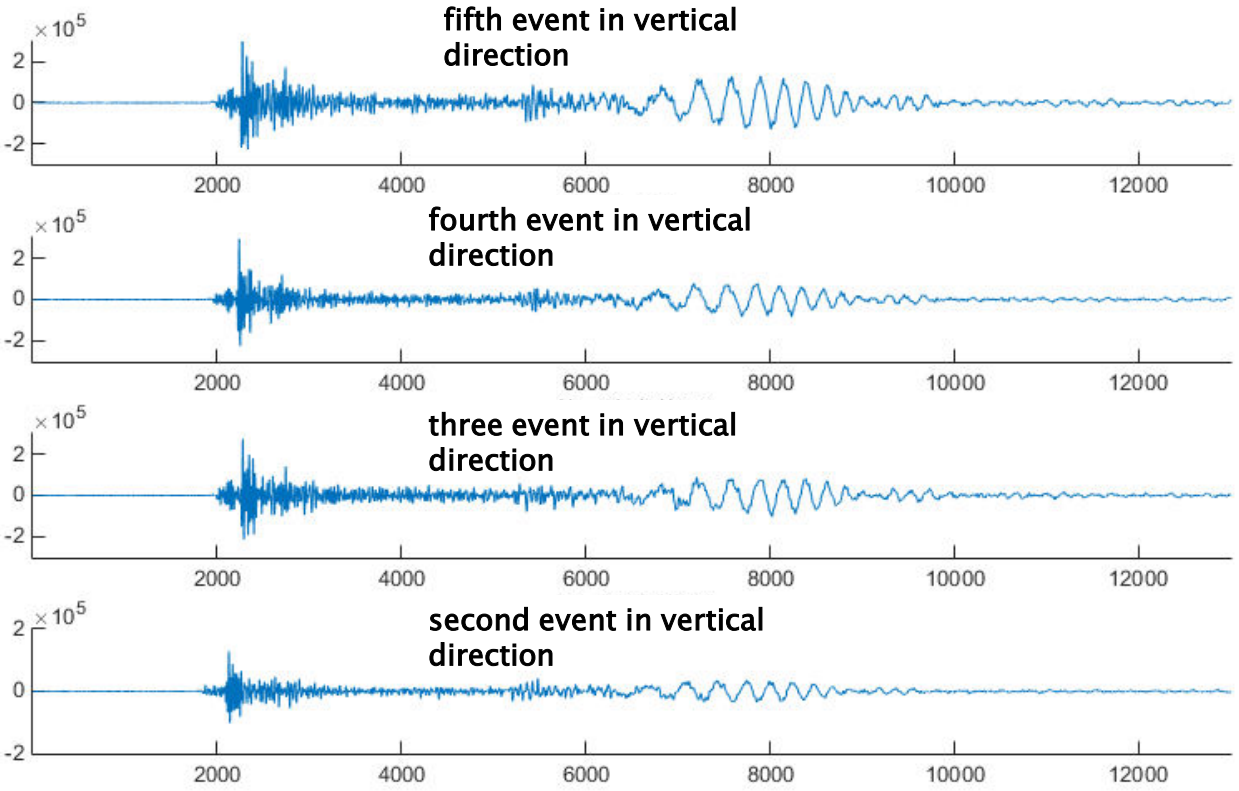


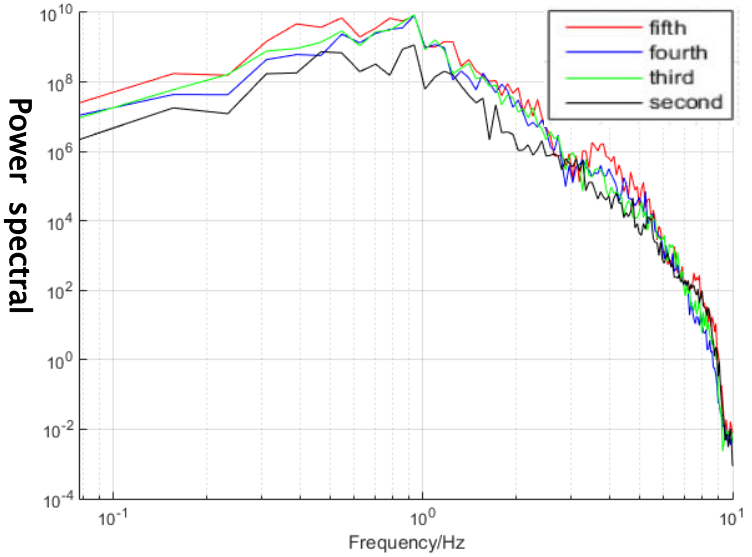
The spectral ratios of Rayleigh wave

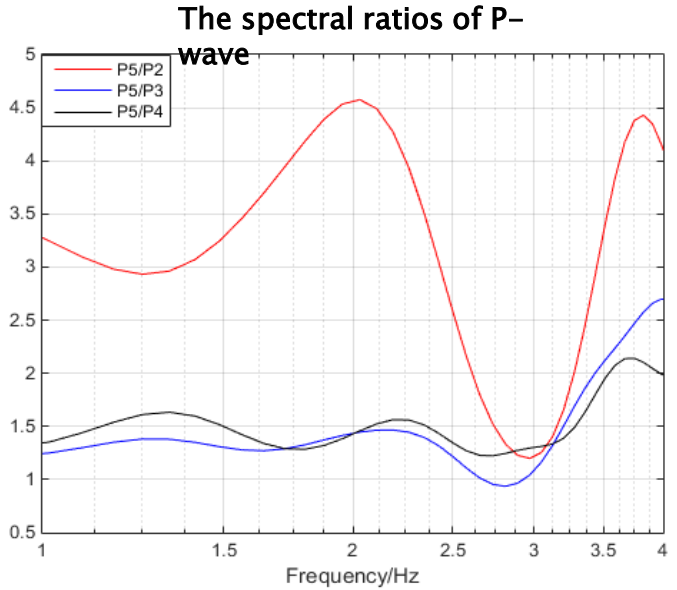


The mean ratios of Rayleigh wave are 1.57 、 1.23 and 3.67

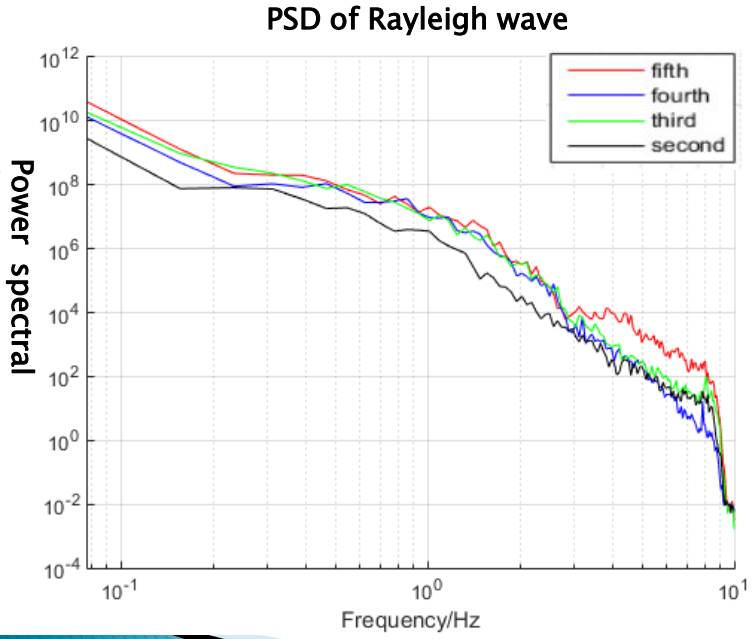
Station: JCT
Δ=247km

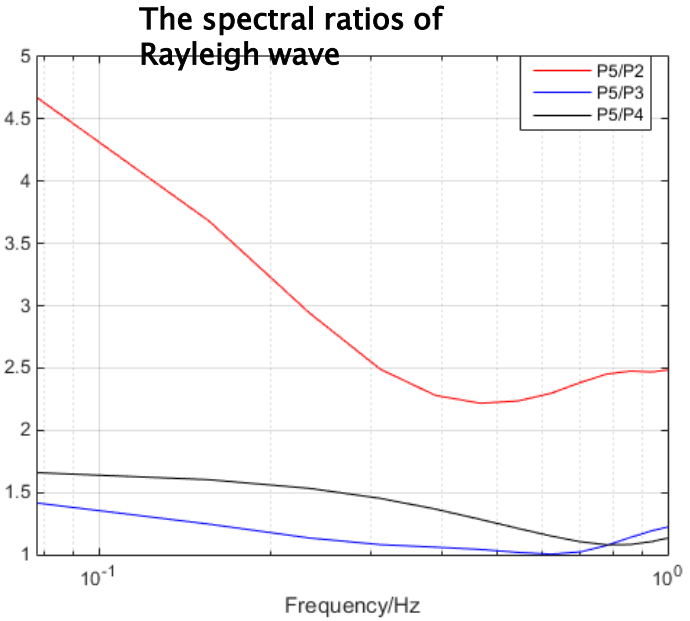






The mean ratios of P-wave are 1.54、1.53 and 3.12

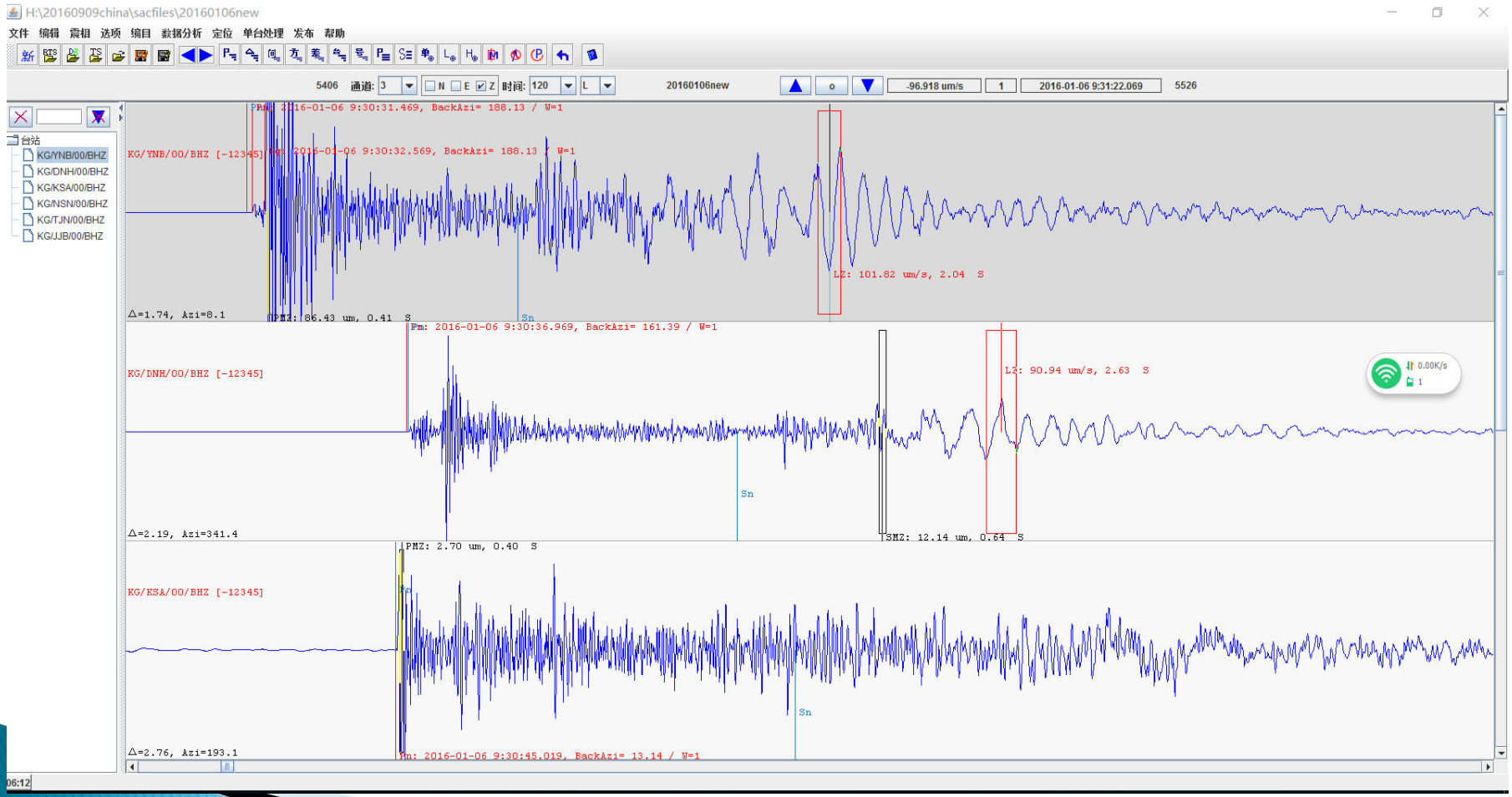


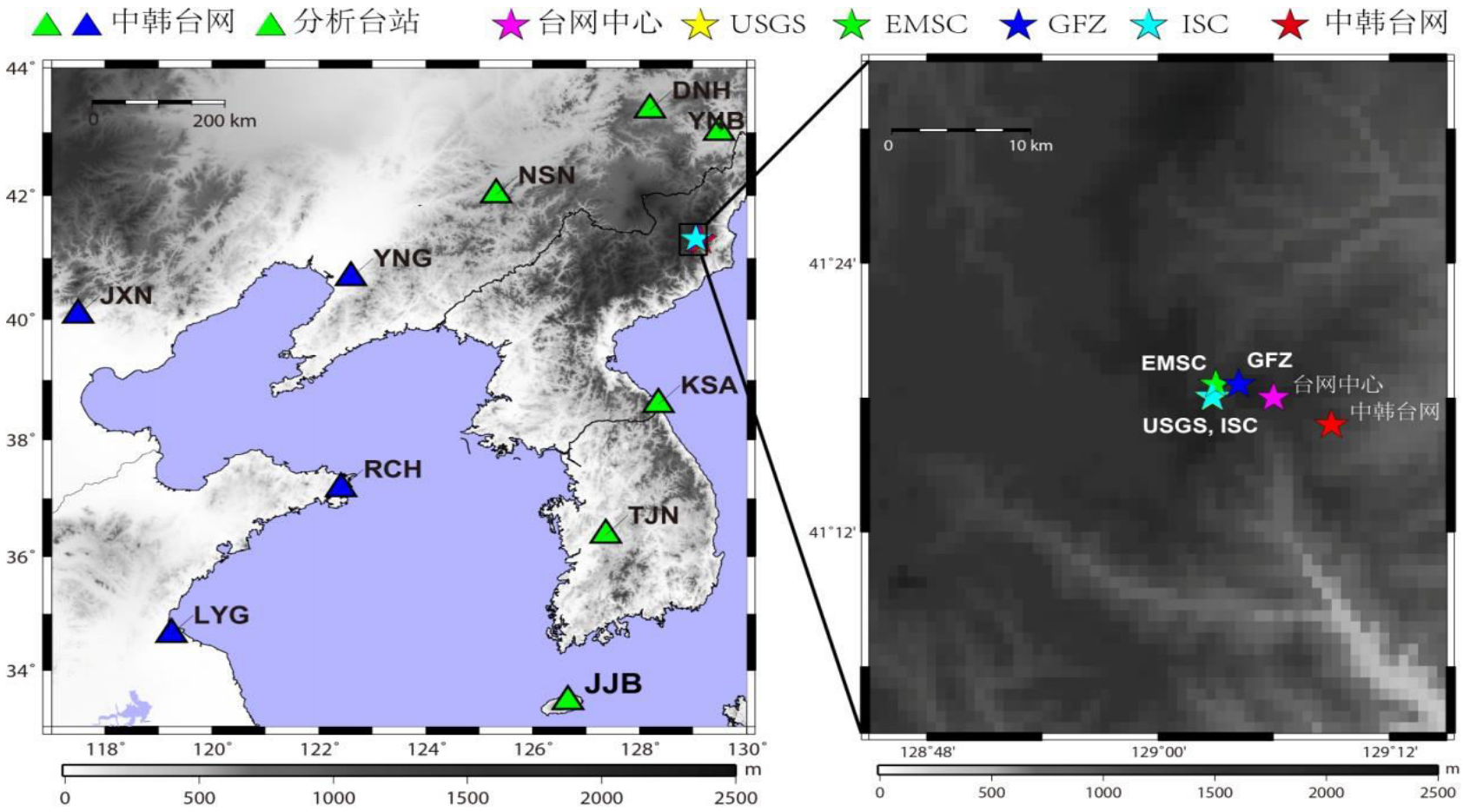


The mean ratios of Rayleigh wave are 1.32、1.16 and 2.93

Location by CKJSN for the events on Jan. 6, 2016 and Sep. 9, 2016

Use hypo81 to locate the event on Jan. 6, 2016 recorded by CKJSN



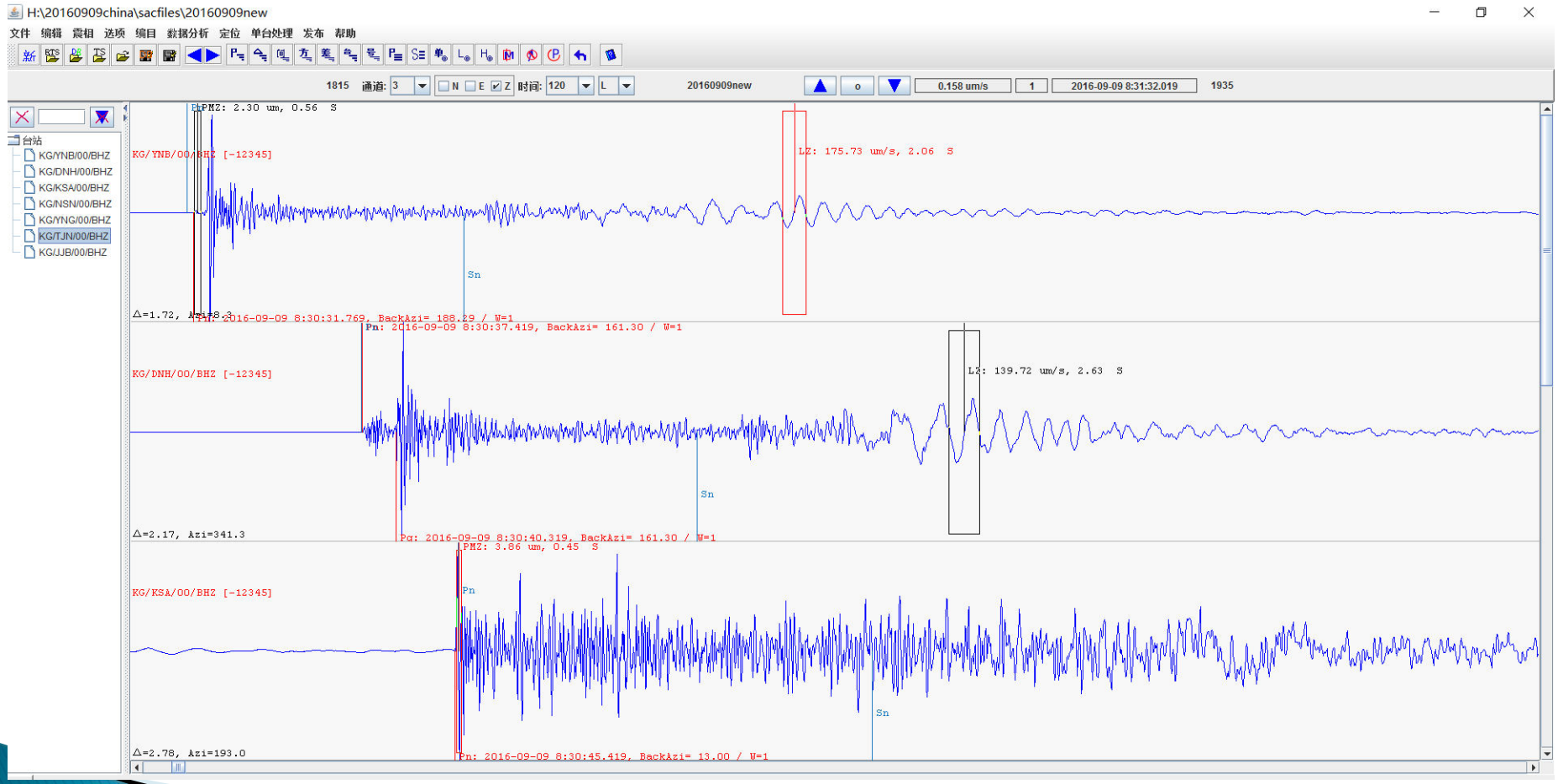


Triangles represent distribution of stations of China Korea Joint Seismic Network. The green triangles represent the stations with locating, the red, pink, blue, green, cyan blue stars represent the results of different organizations.

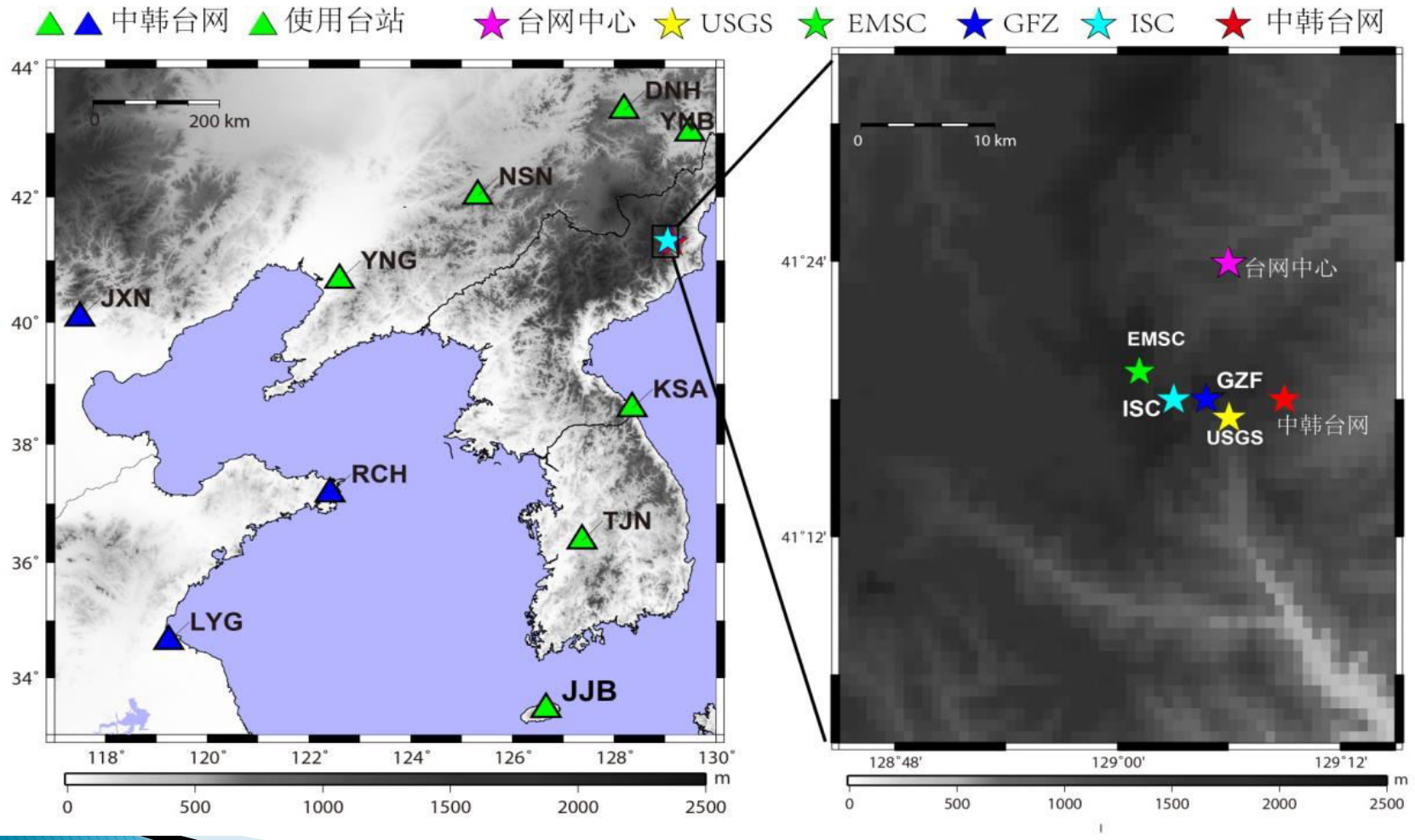
organization	time	Time difference/s	hypocenter	difference/km	Magnitude
CKJSN	09:29:59.57		41.28,129.15		mb5.0
CENC	09:30:01.9	1.93	41.3,129.1	4.7	mb4.9
USGS	09:30:01.48	1.51	41.3,129.05	8.7	mb5.1
ISC	09:30:01.49	1.52	41.3,129.05	8.7	mb4.8
EMSC	09:30:00.7	0.7	41.31,129.05	9.0	mb5.1
GFZ	09:30:01.1	1.13	41.31,129.07	7.5	mb5.1

According to the differences of occurrence time, location, magnitude, we can see that the magnitude of CKSN are similar to the other organizations, the location and occurrence time differences are relatively large.

Use hypo81 to locate the event on Sep. 9, 2016



Triangles represent distribution of stations of China Korea Joint Seismic Network. The green triangles represent the stations with locating, the red, pink, blue, green, cyan blue stars represent the results of different organizations.

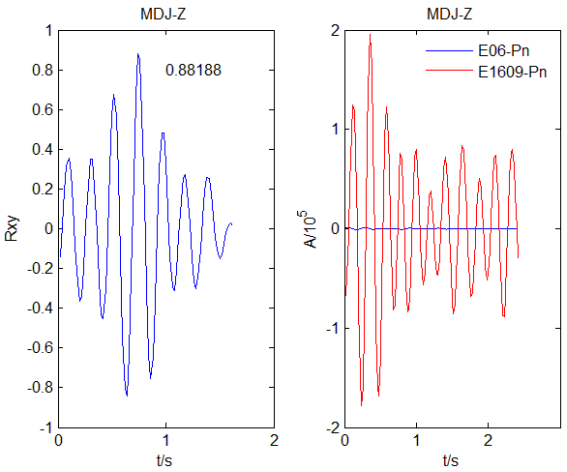


organization	time	Time difference/s	hypocenter	difference/km	Magnitude
CKJSN	08:30:00.07		41.28,129.15		Mb5.0
CENC	08:30:00.5	0.43	41.4,129.1	11.9	Mb5.0
USGS	08:30:01	0.93	41.29,129.09	5.1	mb5.3
ISC	08:30:00.87	0.17	41.30,129.05	8.4	Mb5.1
EMSC	08:30:01.1	1.03	41.32,129.02	11.1	mb5.3
GFZ	08:30:01.5	1.43	41.3,129.08	5.8	mb5.3

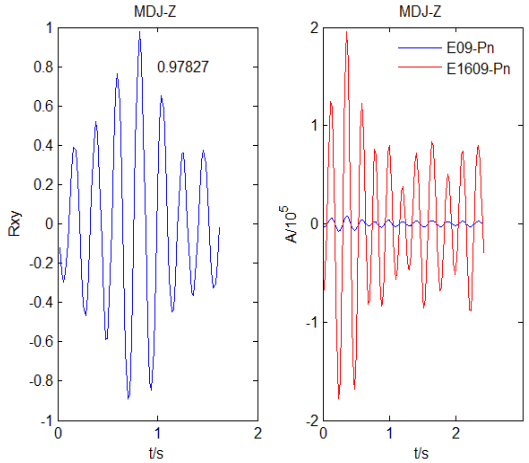
According to the differences of occurrence time, location, magnitude, we can see that the occurrence time and magnitude of CKJSN are similar to the result of ISC.

Eestimation of the aperture of the five events

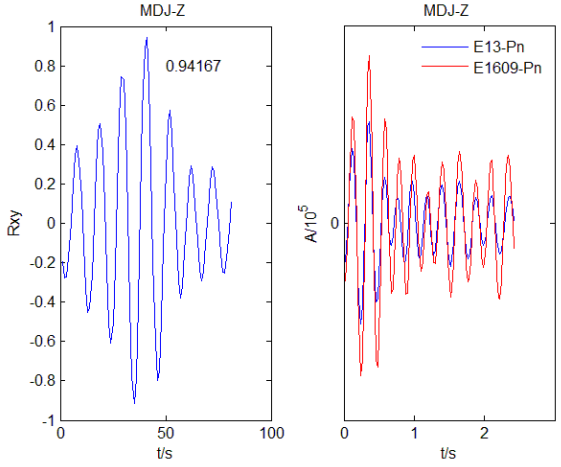
The efficiencies between the latest event and the four events recorded in MDJ



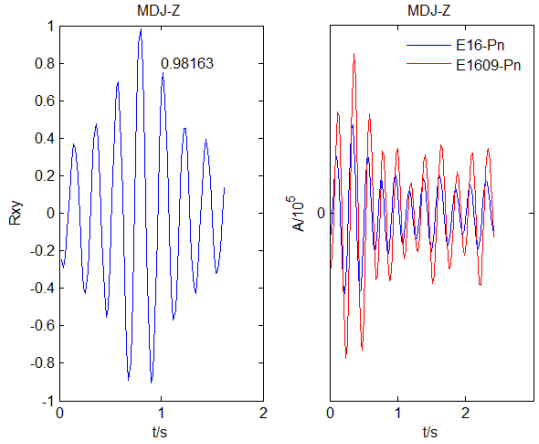
MDJ-Z 2006-201609



MDJ-Z 2009-201609



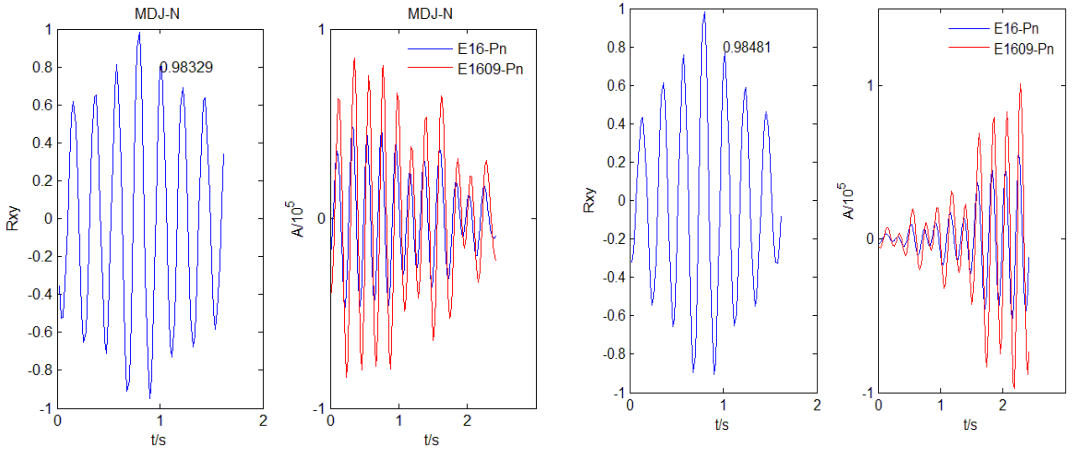
MDJ-Z 2013-201609



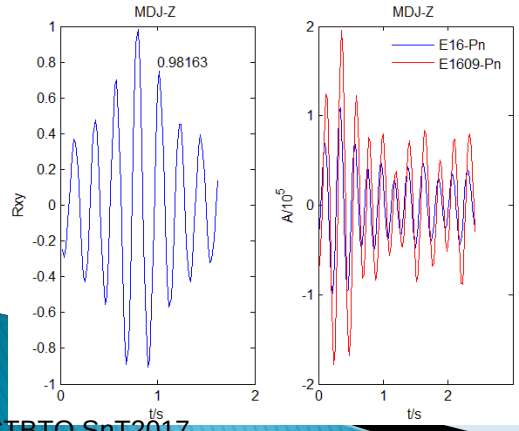
MDJ-Z 201601-201609

According to the calculation, the maximum coefficients between E1609 and E06, E09, E13, E1601 are 0.88, 0.98, 0.94, 0.98 in vertical component. In the left pictures, the first one is the coefficients of two events and the second picture is the head waveforms of the two events

There are high coefficients between event in Jan. 2016 and the event in Sep. 2016



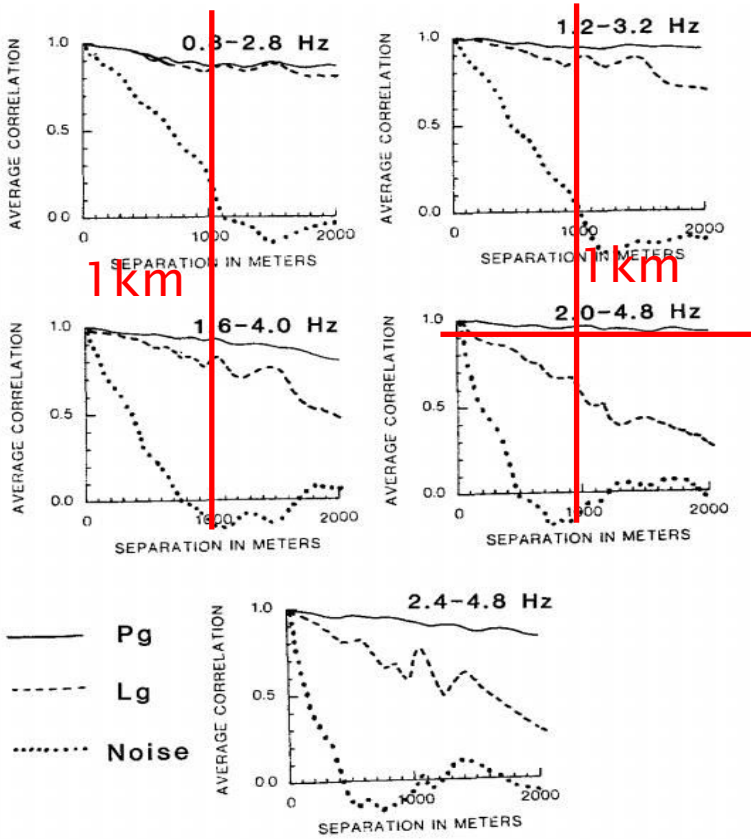
MDJ-N 201601-201609 MDJ-E 201601-201609

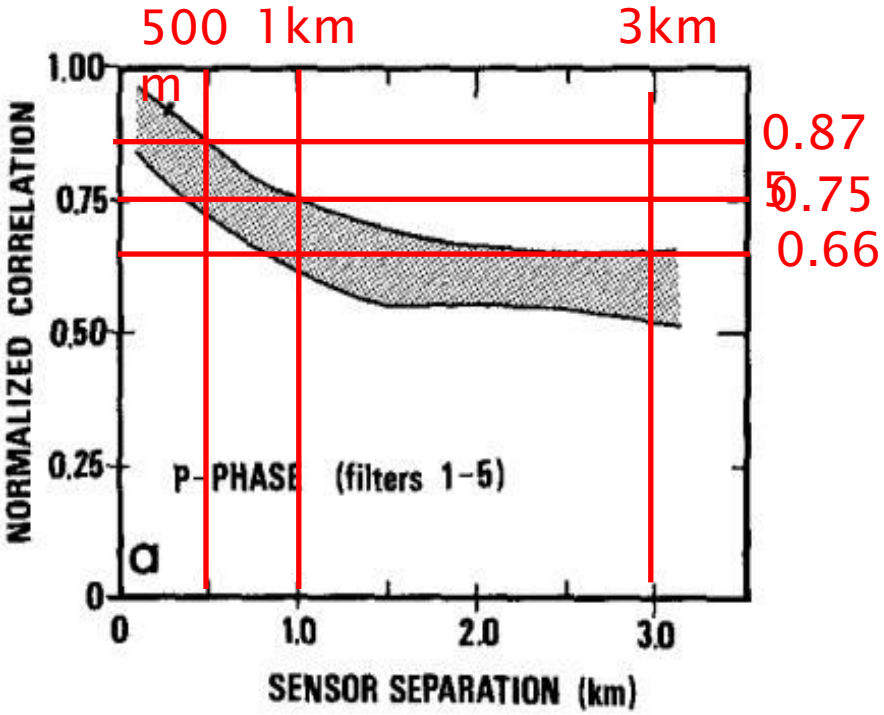


201601-201609

According to the calculation, the maximum coefficients of E1609 and E1601 are 0.98, 0.98, 0.98 in Z, N, E components. In the picture, the first one is the coefficients of two events and the second image is the head waveforms of the two events

Relations between distance and coefficients





- The coefficients of five explosions showed that they are highly correlated, which indicate that the aperture of the five explosions are small, according to S. F. Ingate (1985) and F. Ringdal (1982).

Conclusion

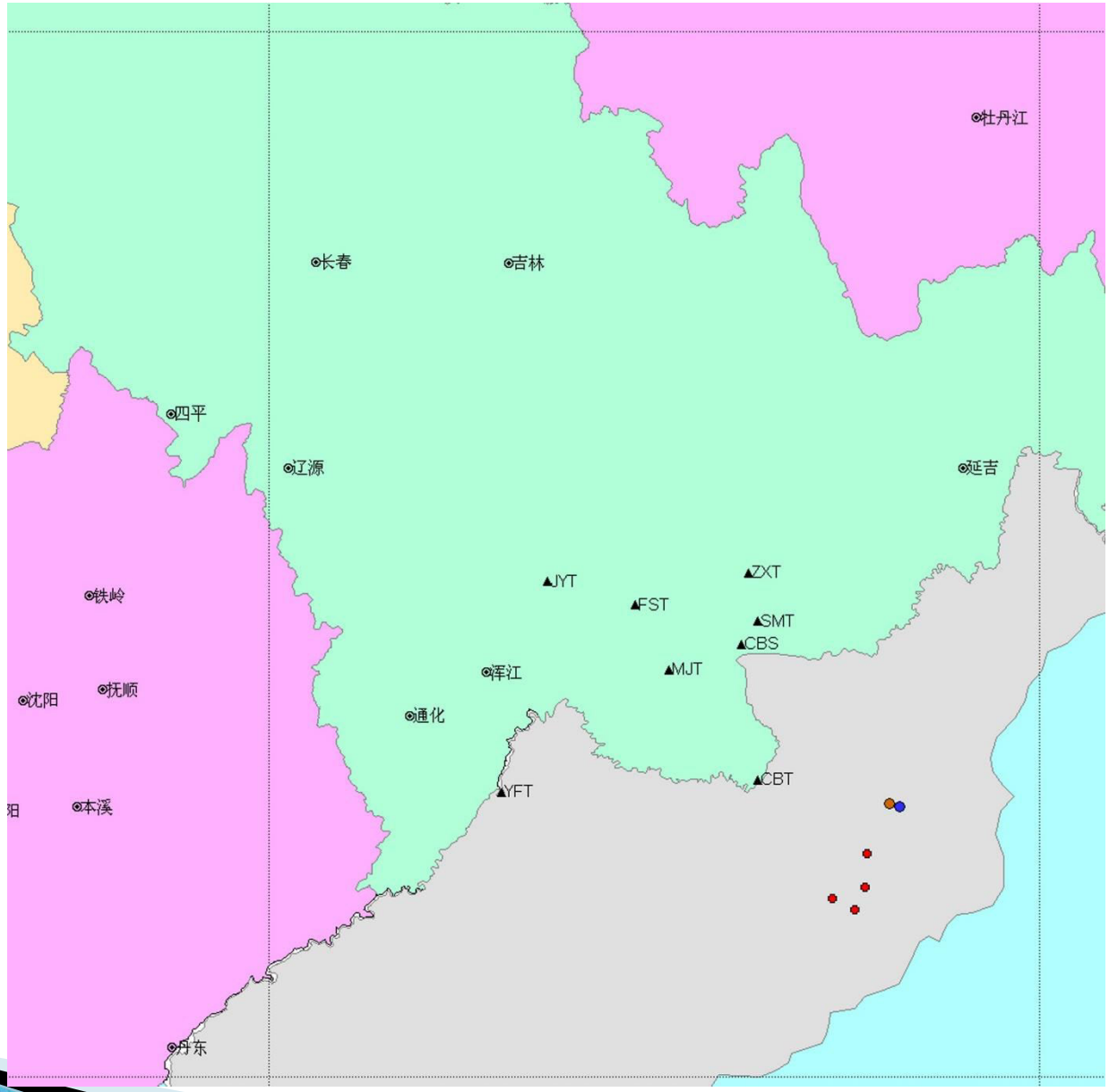
- According to MDJ station, the amplitude ratio of latest explosion to the former explosions are 11.4, 2.57, 1.27 and 1.56 respectively.

- At 2 Hz, the PSD ratio of the event occurred on Sep. 2016 to other four events are 40.1, 4.7, 2.0 and 1.8 respectively, which have little difference with the results of Wen Lianxing of USTC, who gave the yields of 17.8kt, 11.3kt, 12.2kt, 7kt, 0.48kt for the five events, and the ratios are 37.1, 2.5, 1.5 and 1.6 respectively.

- China Korea Joint Seismic Network has an advantage that the stations are close to the site, but the station distribution is not good enough. And the location result can be as a reference.

- With the high coefficients between the latest explosion and former four explosions, according to the results of the correlation between the coefficients and distances, we estimate that the aperture of the five explosions is not large, no larger than 3km, and the distance between the latest explosion and the event occurred on Jan. 6, 2016 is within 500 - 1000m.

Thanks


牡丹江
长春
吉林
四平
辽源
延吉
铁岭
JYT
ZXT
FST
SMT
CBS
MJT
浑江
沈阳
抚顺
通化
CBT
YFT
本溪
丹东