PROCEEDINGS, 13th Indonesia International GEOTHERMAL Convention & Exhibition 2013
Assembly Hall - Jakarta Convention Center Indonesia, June 12 – 14, 2013

# PRELIMINARY STUDY HYDROTHERMAL ACTIVITY USING MICROSEISMIC PORTABLE IN THE GEOTHERMAL POTENTIAL AREA, CASE STUDY : MT. LAMONGAN, EAST JAVA INDONESIA

Widya Utama[1*], Tri Martha Kusuma P[1)], Agus Suprianto[2)], Makky S. Jaya[3)]

[1)]Institute of Technology Sepuluh Nopember, Surabaya – Indonesia
[2)] Gadjah Mada University, Yogyakarta – Indonesia
[3)] GFZ Helmholtz Center, ICGR Postdam - Germany
*e-mail: widya@geofisika.its.ac.id

## ABSTRACT

Microseismic a passive seismic method in the geophysics exploration. An application of the method to identify the hydrothermal dynamics in the subsurface. Hydrothermal is a oscillating fluid in the pore spaces of rock caused by volcanic activity. The hydrothermal movement in the subsurface correlated with geothermal potential area. Hydrothermal dynamics have low frequency between 1 to 6 Hz. Preliminary study about intensity of seismicity very important to design of microseismic acquisition with using more sensitive geophone to ground motion detection caused by hydrothermal activity. This preliminary study was conducted using a portable microseismic have range frequency between 4.5 Hz until 120 Hz. This research has been conducted on the geothermal potential area of Mount Lamongan, East Java, Indonesia. Five stations were installed with multiplet acquisition for 5 days in the around of Mt. Lamongan to delineate the active seismic zone. Active seismic zone for acquisition design of microseismic with broadband to record local event from hydrothermal dynamics. Microseismic data processing to determine frequency of local events using EEMD method. Noise comes from nature source such as vibration of the local meteorological conditions, urban, ocean waves, and other events that could lead to oscillation. Recapitulation of the frequency of local events used to delineate seismically active area for microseismic data acquisition design using broadband sensors.

Keywords : Microseismic, Hydrothermal, EEMD, Mt. Lamongan, broadband.

## INTRODUCTION

Mount Lamongan is one of the geothermal potential of East Java. Exploration activities continued until now conducted by the Department of Energy and Mineral Resources of East Java in cooperation with ITS and the GFZ German. Activities and exploratory research is an attempt being made to complete the data as geothermal mining working zoning of East Java. Subsurface mapping to determine the position of geothermal reservoirs using geophysical methods. Geophysical method used is microseismic.

The interaction between the rock (hot source rock) with subsurface fluid (usually water) resulted in a micro-scale movement. Movement of hydrothermal fluids can be identified using the microseismic or microtremor. Short signal period with a frequency of 1-6 Hz brief is characteristic signals from hydrothermal movement.

Sanger et al. (2009) said that the spectrum (vertical component) in the reservoir stronger than non-reservoir area. To determine presence of hydrothermal dynamics based on signal of microseismic, anthropogenic noise reduction process becomes very important. The method to separate the desired signal with unwanted signals is Ensemble Empirical Mode Decomposition (EEMD). The EEMD method a development of Empirical Mode Decomposition (EMD) method by Zhaohua Wu and Norden E. Huang (2009), Jiang and Zhang (2010) to eliminate the mixin mode.

Microseismic signals have been filtered will be election events indicate hydrothermal dynamics. The event selection based on event at the same time (arrival time of P-wave), at least three stations (minimum). Hydrothermal monitoring using microseismic was installed in the geothermal potential area of Mt. Lamongan, East Java using DSS Cube 4.5 Hz, the microseismic tools developed by GFZ Germany.

## GEOTHERMAL POTENTIAL AREA OF MT. LAMONGAN

Mount Lamongan, a small 1631-m-high stratovolcano located between the massive Tengger and Iyang-Argapura volcanic complexes, is surrounded by numerous maars and cinder cones. Geothermal energy potential is indicated by the appearance of hot springs in the district Tiris. The hot springs out from cracks at rock andesite breccie. In the vicinity of hot springs in general found the reddish yellow precipitate and a bit smelly sulfur, precipitated iron is an essential element that came out with hot water and oxidation that shows colors like corrosion.

Based on the geological conditions and the characteristics of hot springs that came out in the river Tancak is interpreted that the hot springs in the area exit outflow as with hot water flow from the slopes of Mt. Argopuro (from the east). Survey area is interpreted to form a horseshoe basin of peak Mt. Argopuro and open towards the north-west (towards the exit of the manifestation of the hot springs).

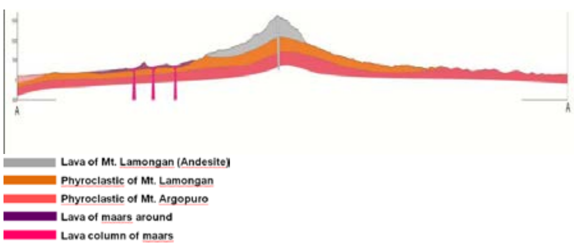
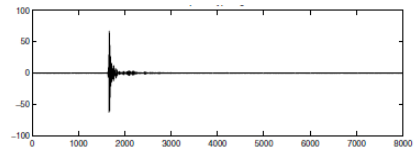



*Figure 1: Geological geothermal cross section of Mt. Lamongan, East Java (Widya,2012)*

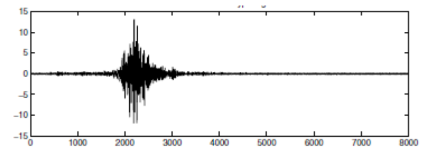
Morphologically, the study area is a valley between Mt. Argopuro and Mt. Lamongan. Rock composed of constituent can be grouped into five, namely : Geni pyroclastic rock unit, Lava mountain Lamongan Old pyroclastic rock unit of Mt. Lamongan, Lamongan Mountain Breccia Unit, Mount Argopuro Breccie Unit and Tarub sandstone unit. Figure 1 is a tentative initial estimates of the geological survey. So geophysical studies are needed to delineate the active seismic zone such as fault dip direction and position of geothermal energy sources Tiris.

## MICROSEISMIC SOURCE MECHANISM

Geophones measure ground motion relative to the inertial mass, so that the resulting electrical signal proportional to the speed of the wave. There are two types of microseismic recorded signal are a impuls and successive signals. The impulse type have very sharp peaks with very short propagation time. While the type of successive signals have wave propagation travel time longer than the impulse signals (Angus, 2005).



(a)



(b)

*Figure 2: signal type of microseismic recorded data (a) Impulse signal type (b) Successive signal type.*

Noise is a term used to indicate the ambient vibration of the ground caused by natural sources such as tide, sea water waves on the beach, wind turbulence, wind effects on trees or buildings, industrial machinery, automobiles, trains, traces of human or animal , and so forth. Gutenberg (1958) categorize ambient noise based on frequency. Low frequency (<1 Hz) derived from nature form ocean and meteorological conditions or large global scale. Intermediate frequency (1 to 5 Hz) sourced from local meteorological conditions and urban scales and higher frequencies associated with the originating nature source (Sylvette Bonefoy-Clauded, 2006). Hydrothermal oscillations in the rocks pore spaces due to high pressures and high temperatures have low frequencies <5 Hz. Event duration time is shorter than tectonic event. The time delay between the P and S waves are less than 10 second. Sometimes very difficult to determine the arrival time of P wave and S wave caused by phase difference not clear.

## NOISE REDUCTION USING EEMD METHOD

Random noise reduction is the most important for seismic data processing, interpretation and inversion. Recording seismic data in a signals is generally consists of secondary signals (which is expected) and noise (the primary source from nature) described by the equation :

$$x(t) = s(t) + n(t) \qquad (1)$$

$x(t)$, $s(t)$, and $n(t)$ are the recorded signal, the expected signal and noise, signal in the time domain $(t)$. Noise reduction process to obtain the desired signal is very important in this study. In this study, the method EEMD (Ensemble empirical mode decomposition) is used to reduce noise in the data recording.

EMD decompose the seismic signal into some oscillatory components called Intrinsic Mode Function (IMF). Each component of the IMF has different frequency. This decomposition has assumption that the data consists of intrinsic oscillations various models. The intrinsic mode (linear or non-linear) will have the same number of extreme be symmetrical against the local average.

Huang et al. (2009) said that EMD can not overcome the problems caused by the mixing mode signal interruption. To solve this problem, Huang et al. (2009) superposing signal with add white noise to avoid mixing mode. This process is Ensemble Empirical Mode Decomposition (EEMD) method. EEMD method can describe by simple mathematical equations in the equation (2). According to Wu and Huang (2009) and Chang (2010) steps to start analysis with the addition of white noise in time domain $w(t)$.

White noise $w(t)$ is the random number with zero mean, and standard deviation of a single variant. Here are the steps EEMD method (Ensemble empirical mode decomposition):

1. Addition of white noise $w(t)$ to signal.

$$X(t) = x(t) + w(t)R \qquad (2)$$

   R is a standard devition ratio parameter between amplitude noise added to the data $x(t)$.
2. Data decomposition with addition of white noise to the *n* component of the IMF. EEMD applied to $X(t)$ to decompose the data $x(t)$ to produce several intrinsic mode fuction (IMF) ($c_1$ until $c_n$).
3. Repeat steps 1 and 2 with the addition of white noise $w_j(t)$ to the signal $x(t)$ but with different white noise series each time. The process will stop when the value of the $SD_k$ is smaller than the limit set by the interpreter.

$$SD_k = \sum_{i=0}^{T}\left[\frac{|h_{1(k-1)}(t)-h_{1k}(t)|^2}{h_{1(k-1)}(t)^2}\right] \qquad (3)$$

4. Obtain the (ensemble) means ofcorresponding IMFs of the decompositions as the final result.

$$c_i = \frac{1}{N}\sum_{j=1}^{N} c_{ij} \qquad (4)$$

$$r_n = \frac{1}{N}\sum_{j=1}^{N} r_{jn} \qquad (5)$$

R value (standard deviation ratio) and N value depends interpreter. Wu and Chang (2009) recommend 0.2 for R and a few hundred for N value, for good results in some cases. Jeng and Chen (2011) using 0.1 for amplitude noise R, and 50 for N was applied to the GPR and seismic signals, due to the high frequency content of the data and a large amount of data. While Lin and Jeng (2010) was applied 0.5 for R and 100 for the N for VLF data processing, results the process dominated by low-frequency signals.

## ANALYSIS AND DISCUSSION

### Delineation Area Based on Microseismic Event Recording

Data processing to delineate interest area based on microseismic intentisty used vertical component. Data recording for 24 hours around Mount Lamongan. Preliminary studies for the seismic intensity recording data used 5 station configuration.

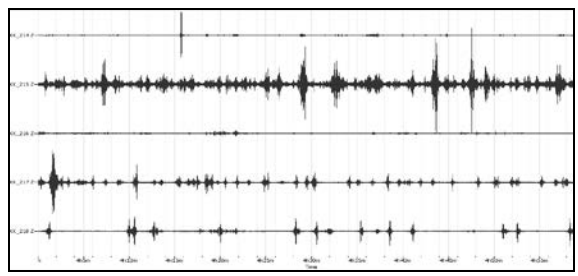


*Figure 3 : Microseismic recording data for 1 hour.*

It is difficult to determine the local event of a data record in Figure 3. To eliminate noise from the data must to reduction process using EEMD method. The main signal will be decomposed into several IMF with different frequency values at each IMF component (Figure 4).

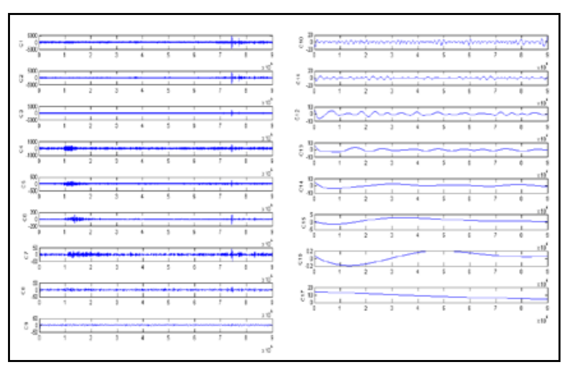


*Figure 4: Signal decompose using EEMD method to noise reduction.*

C1 in Figure 4 is the input signal, C2 to C17 is the main signal (C1) decomposition into several IMF components. C6 is the best component is assumed to be free of noise due to several events can be well defined and do not change the phase of the previous components. Classification and determination of local event based on the similarity of P wave arrival time each event that pounce on the data (Figure 5).

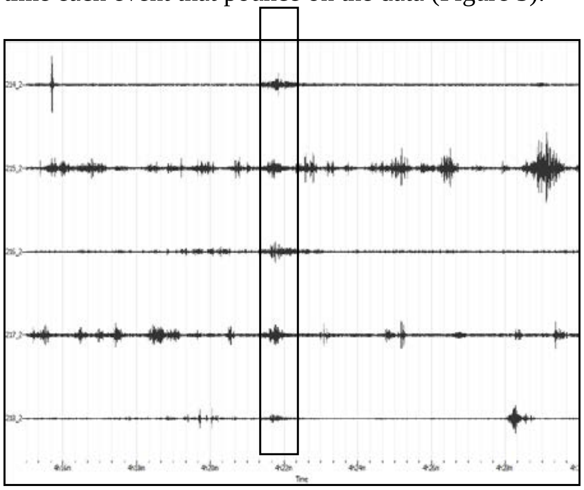


*Figure 5 : Event classification based on P wave arrival time.*

Event time delay between stations ranged between 0.3 - 0.5 second. The time delay caused by the distance of each station and subsurface geological conditions. Each event in the each station analyzed to determine the frequency spectrum of a local event (Fig. 5).

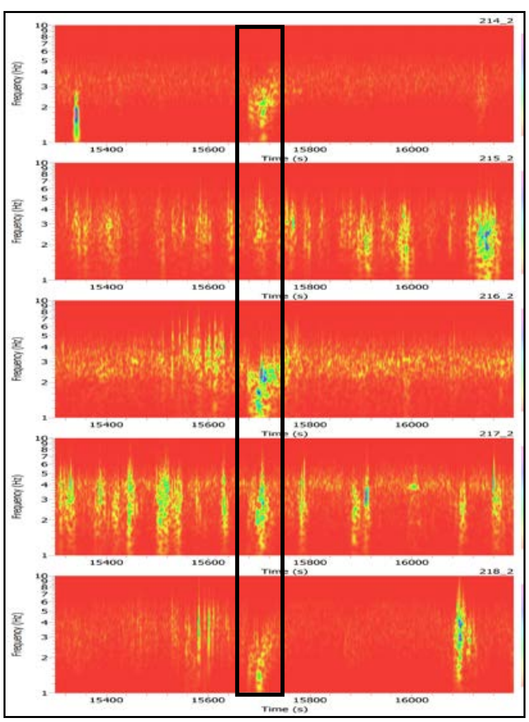


*Figure 6 : Amplitude spectrum analysis microseismic signals.*

There are nine (9) local events recorded during 24 hours in the Mount Lamongan. The local event has frequency range between 1.66 Hz to 4.20 or <5 Hz (low frequency).

*Table 1: Frequency range of hydrothermal dynamic in Mount Lamongan.*

| Time | Frequency (Hz) | | | | |
|---|---|---|---|---|---|
| Station | 214 | 215 | 216 | 217 | 218 |
| 04:21:15 | 2.82 | 3.03 | 3.30 | 4.85 | 1.54 |
| 06:01:33 | 1.66 | 2.44 | 2.38 | 2.35 | 1.51 |
| 08:03:49 | - | - | 2.53 | 2.38 | 3.18 |
| 08:10:37 | - | 2.11 | 2.59 | 2.27 | 2.06 |
| 09:09:31 | 4.20 | 4.35 | - | 4.05 | - |
| 10:23:53 | - | - | 2.44 | 3.68 | 2.79 |
| 14:36:05 | 2.11 | - | 2.75 | 2.22 | 3.07 |
| 14:47:43 | 2.44 | - | 2.24 | 2.56 | 2.50 |
| 15:33:56 | 2.16 | 2.19 | 2.89 | 1.89 | 2.04 |

Seismic active areas are in the north and west of Mount Lamongan or stations 216, 217, and 218 can local record the even better than other station (214 and 215). Stations 218 and 217 can record either because of the location near manifestations (hot spring). So that fluid dynamics can be recorded properly. Stations 216 recording the dynamics of hydrothermal activity in the cyder cone (intrusion) which is in the west of Mount Lamongan. So, the active area in the north and west as interest area to install microseismic with broadband sensors.

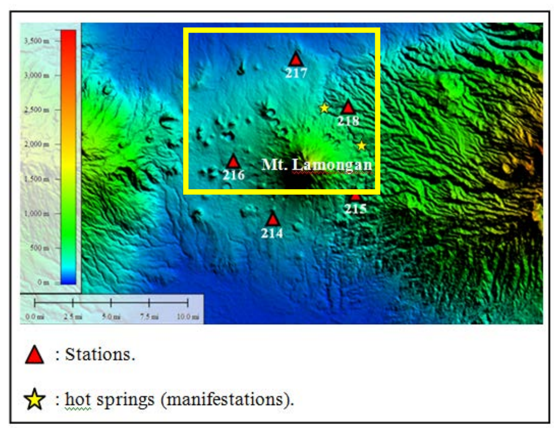



*Figure 7: Delineation area based on microseismic intensity recording data for 24 hour in the Mt. Lamongan Around.*

Yellow box in Figure 7 is the area to do the recording microseismic with broadband sensor. Data recording can be done for at least 3 months (minimum) to obtain good data. The sensors place must far away from road or highway because it can leading more noise.

**Installation Design for Microseismic Broadband Sensor**

In order to map and monitor the location of earthquake microhydraulic fracture in Mt. Lamongan are correlated with active region here, the installation and monitoring is done using a grid of geophones on the Mt. Lamongan. We use the 3C geophones or three component of seismometer to record seismic energy; include 16 short period geophones and 4 broadband geophones. Short period seismometer sensors buried in the soil at a depth of 50 cm.

The contact between the seismometer and soil was using a concrete or plugged directly into the ground. The micro seismic sensors buried in the ground with the purpose of the sensor can vibrate in tune with the ground vibrations. Schematic diagram of a short period sensor station is shown in Figure 8 and the documentation of one short period microseismic station is shown in Figure 9.

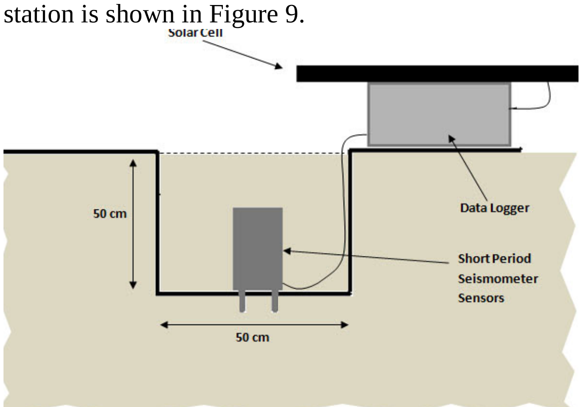



*Figure 9. Schematic diagram of Short Period micro-seismic monitoring station*

The area that covered by the installation of 20 microseismic monitoring stations are 23x32 km$^2$, by conducting using a grid configuration. The distance between the sensor grids is approximately 5 kilometers. On the other case, the installation of short period microseismic section. Broadband seismometer sensors planted in the ground in a place like bunker at a depth of 1 meter and diameter bunker between 80 to 100 cm. The schematic diagram of installation of broadband sensor station is shown in Figure 10.

In addition to three channels of input from geophone, the microprocessor receiving timing and positional data from GPS receiver is collecting. Seismic sensor and GPS data send the data to control center and data logger. The measurements data will be downloaded periodically. This station is powered bu 12V dry cell batteries, charged by a 100 WP solar panel. Coverage measurement of a set of stations that have been installed in the Mt. Lamongan is not just microearthquake in this region, but also local earthquake and regional earthquake.

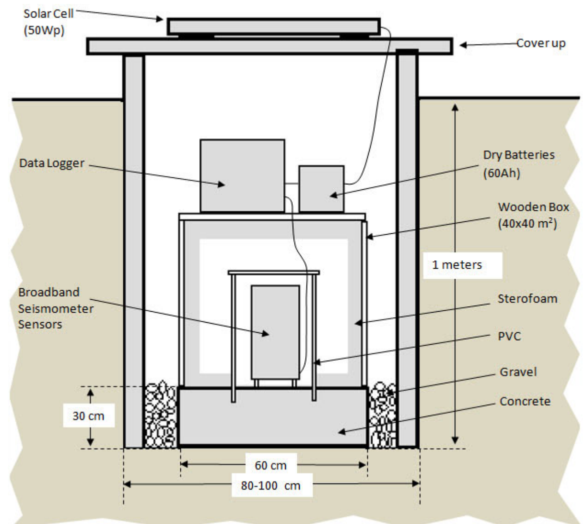



*Figure 10. Schematic diagrams of broad band micro-seismic monitoring station*

## CONCLUSION

Installation micro-seismic station in Mt. Lamongan has successfully done. We have presented a design of microseismic station monitoring. The station includes 20 geophones, 16 short period geophones and 4 broadband geophones, signal processing, data logger and power supply. The seismic information received by a controlled center and data logger and downloaded periodically. The seismic data recording displayed on 3-C data's visualization.

EEMD method (Ensemble Empirical Mode Decomposition) can reduce noise by dividing the original signal into several IMF components. This method used to noise reduction on the recording microseismic signals to obtain estimated signal from the reservoir. This is reinforced with the frequency range of 1-5 Hz to ensure that the event comes from the reservoir fluid dynamics. Station 217 is able to record stations intense hydrothermal movement. In addition to station 217, 218 and 216 have more intensity recording hydrothermal dynamics than 214 stations and 215. Seismic active caused by hydrothermal dynamic in the north of Mount Lamongan.

## REFRENCES

A. Baig., and T. Urbancic, 2010, Microseismic moment tensors: A path to understanding frac growth: The Leading Edge, 29, 320–324

Angus Errington, B.L.F Daku, David Dodds, AmfinnPrugger. (2005). "*Characterization of The Energy Spectral Density for A Potash*

*Mine", Proceedings of the IEEE Canadian Conference on Electrical & Computer Engineering*, p. 246-250.

D. Saputra., 2012, Rumah warga retak akibat gempa Gunung Lamongan,Available: http://www. http://www.antaranews.com/berita/300961/rumah-warga-retak-akibat-gempa-gunung-lamongan , accessed on 25 April 2013.

E.L. Majer., (Without year), White Paper: Induced Seismicity and Enhanced Geothermal Systems, Available: http://storage.globalcitizen.net/data/topic/knowledge/uploads/20090303101852579.pdf,accessed on 1 April 2013.

H. Cahyono., 2011, Geokimia Gas Fumarol Gunung Lamongan,Available: http://www. http://harry-geochem.blogspot.com/2011/07/geokimia-gunung-lamongan-maret-2011.html accessed 25 April, 2013.

J. Metahelumual., 1990, Gunung Lamongan. Berita Berkala Vulkanologi, Edisi Khusus No. 125

Jiang Zhang, Ruqiang Yan, Robert X Gao, Zhihua Feng. (2010). "Performance Enhancement of Ensemble Empirical Mode Decomposition". *Mechanical System and Signal Processing 24*, p. 2104-2123.

L.S. Eisner., A.Williams-Stroud, P. Hill., Duncan, and M. Thornton,2010, Beyond the dots in the box: Microseismicity-constrained fracture models for reservoir simulation: The Leading Edge, 29, 326–333.

P. M. Duncan and E. Leo., 2010, Reservoir characterization using surface microseismic monitoring, Geophysics, Vol.75, No.5, pp.139-146.

Po-Hong Wu. (2004), "Time-Frequency Analysis and Wave Transform Term Paper Tutorial Hilbert Huang Transform for Climate Analysis", *Graduate Institute of Communication Engineering.* National Taiwan University.

R.W. Van Bemmelen, 1949. The Geology of Indonesia, Government Printing Office, The Hague.

Suharsono and T. Suwarti, 1992, Peta Geologi Lembar Probolinggo, Jawa, Pusat Penelitian dan Pengembang.an Geologi Indonesia

Sylvette Bonnefoy-Claudet, Fabrice Cotton, Pierre-Yves Bard. (2006), "The Nature of Noise Wavefield and Its Application for Site Effects Studies A Literature Review", *Earth-Science Reviews 79*. ELSEVIER . p. 205-227.

T. Simkin, and L. Siebert.,1994. Volcanoes of the World, 2nd ed, Geoscience press, Tucson.

W. Pettitt., J.R. Montes., B. Hemmings., and E. Hughes., 2009, Using Continuous Microseismic Records for Hydrofracture Diagnostics and Mechanics, SEG International Exposition and Annual Meeting,Houston.

Wei Chen, Shangxu Wang, Zhen Zhang, Xiaoyu Chuai. 2012. "Noise Reduction Based on Wavelet Threshold Filtering and Ensemble Empirical Mode Decomposition", *SEG Annual Meeting* : Las Vegas. p.1-5.

Zhaohua Wu, Norden E. Huang. 2009. "Esemble Empirical Mode Decomposition : A Noise-Assited Data Analysis Method". *Advances in Adaptive Data Analysis Vol. 1 No. 1*. p. 1-41.

http://www.volcano.si.edu/world/volcano.cfm?vnum=0603-32=