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The earthquake monitoring study by using electromagnetic signals observed by the first CSELF network

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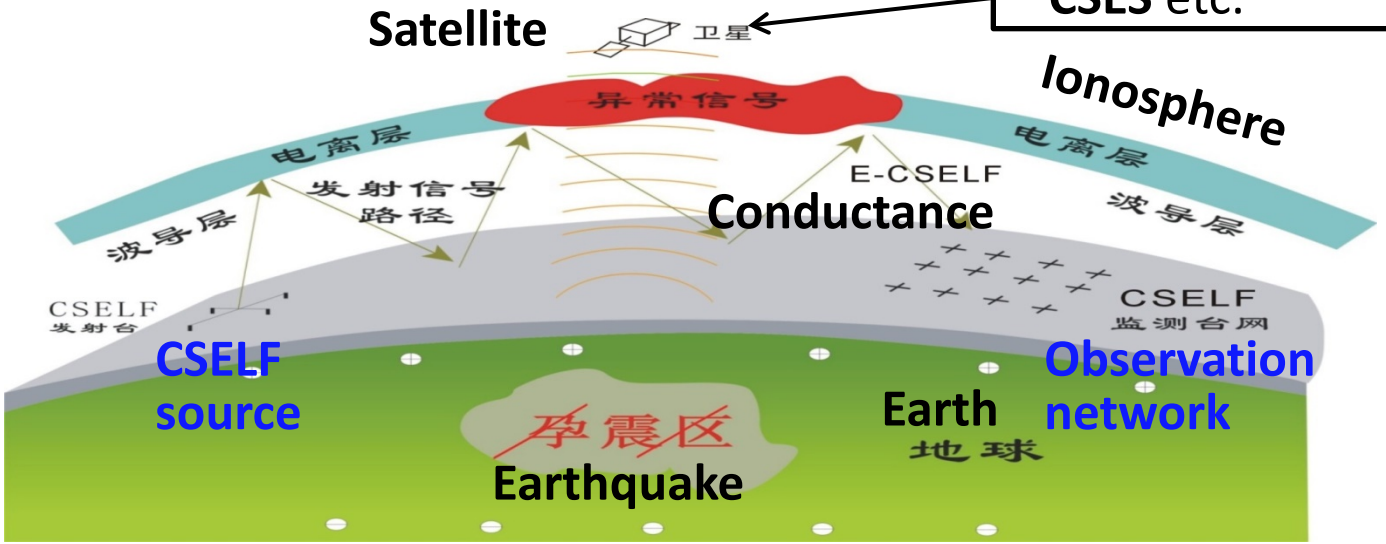
Detecting Seismic Anomalies from Satellite and Ground Data with Multiple Parameters

Purpose

1. Develop new methods to analyze the satellite data, including SWARM, CSES (to be launched in August 16,2017) etc. for detecting EM anomalies.
2. Experimental study on the earthquake monitoring and prediction using CSELF observatory network.
3. Comparing study between the data observed by satellite and ground data for artificial and natural EM signals.
4. Comprehensive study for the possible regular law of the anomaly caused by earthquake.

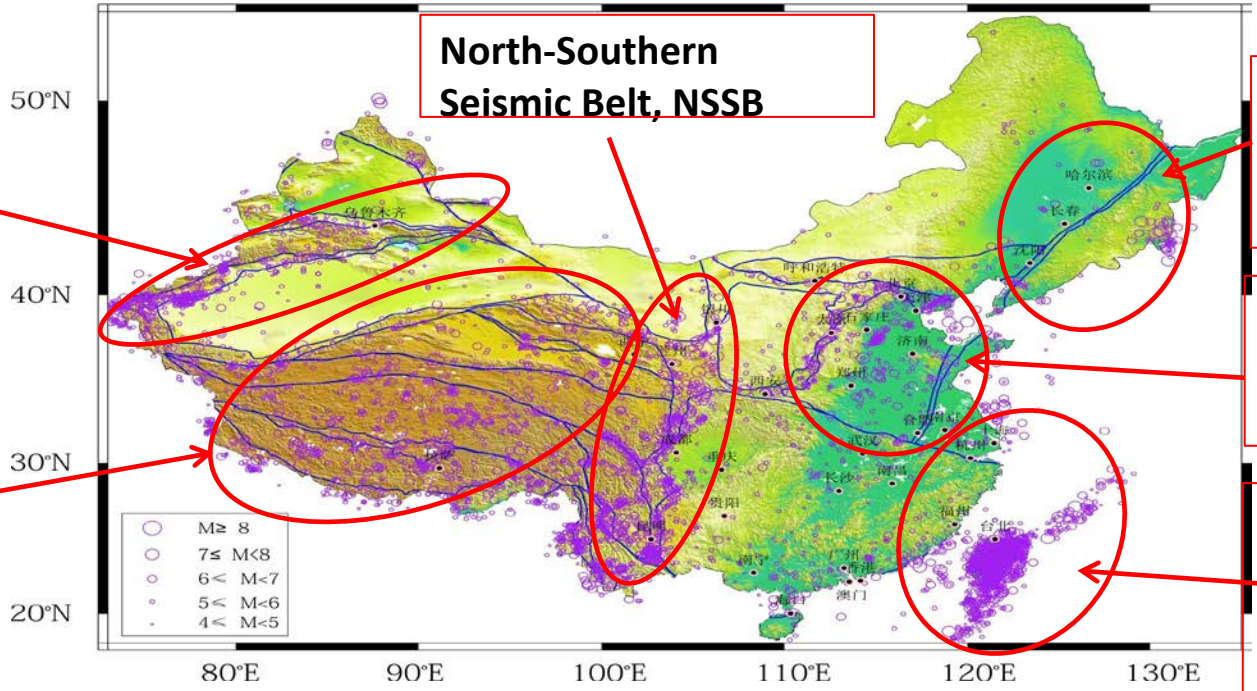
The present tendency of earthquake monitoring: to develop stereoscopic observation

DEMETER，SWARM, CSES etc.



Both of electromagnetic fields transmitted by powered source and natural source are received by the ground CSELF （Control Source Extremely Low Frequency） observation network and satellites at same time for monitoring anomalies caused by earthquake.

There are 6 seismically active belts in China



TienShan Seismic Belt, TSSB

North-Southern Seismic Belt, NSSB

North-East China Seismic Belt, NESB

North China Seismic Belt, NCSB

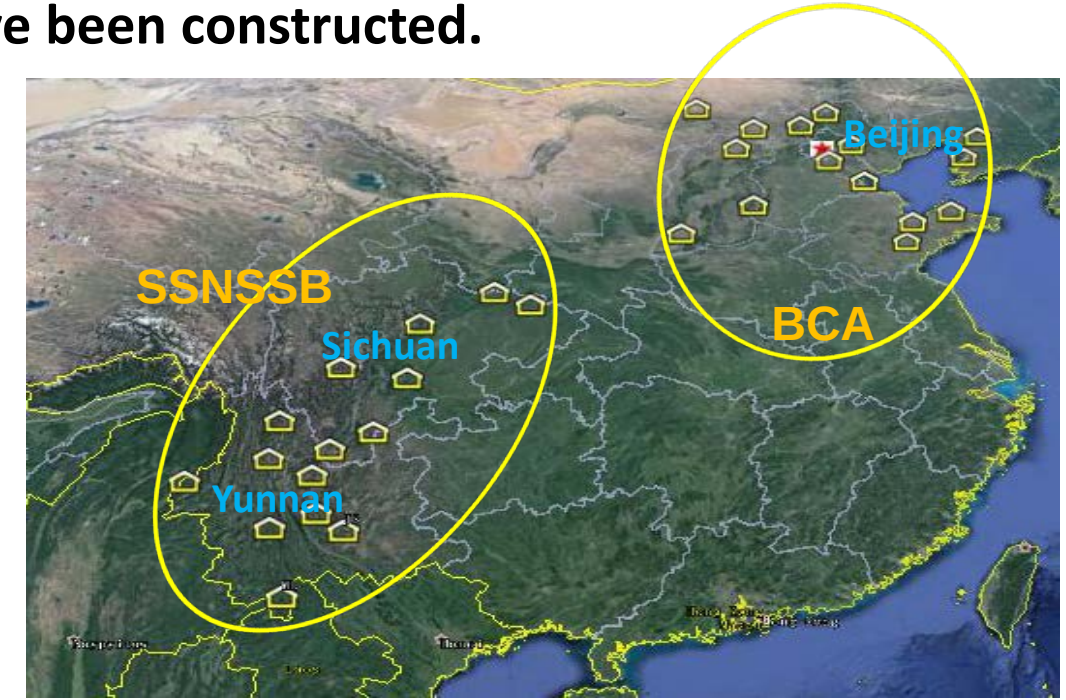
Himalayan Tibet Seismic Belt, HTSB

South-East Coastal Seismic Belt, SESB

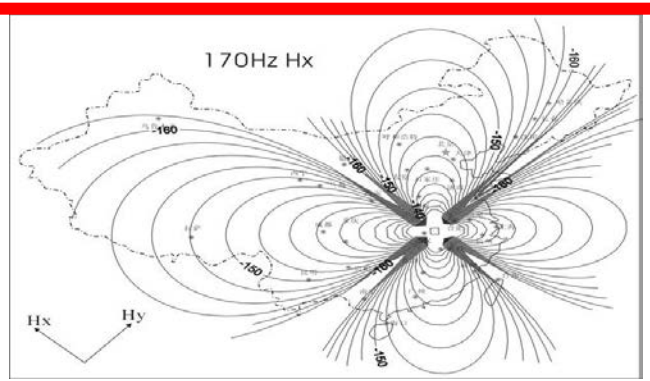
The 20 shocks (M≥5) or 4 shocks (M≥6) occurred for each year averagely. Two shocks (M≥7) for each 3 years. The 25 shocks (M≥8) occurred since 1300 A.D. totally. Earthquakes locate in the block boundaries with severe tectonic deformation. There are six strong earthquake belts (rigions) locate in the block boundary or severe deformed regions.

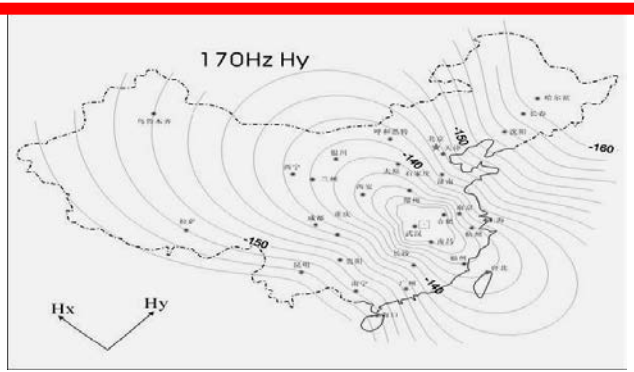
Two networks including 30 CSELF stations in Beijing Capital Area (BCA) and Southern Section of North-South Seismic Belt (SSNSSB, in Yunnan and Sichuan province) have been constructed.

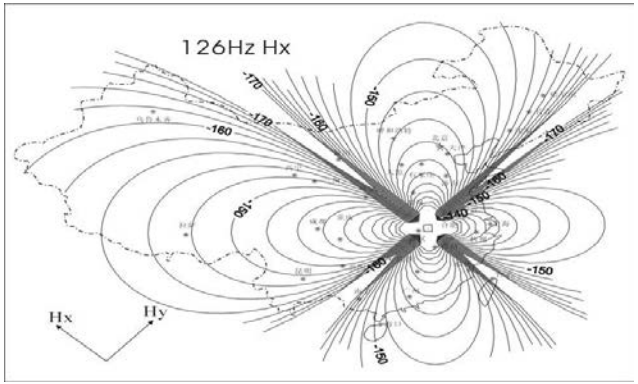
CSELF observation network receives both the artificial EM field (300~0.1Hz) and natural EM signal (1000~0.001Hz) . The observed data on the surface can be used not only in earthquake prediction study but also compared with the data from satellite.

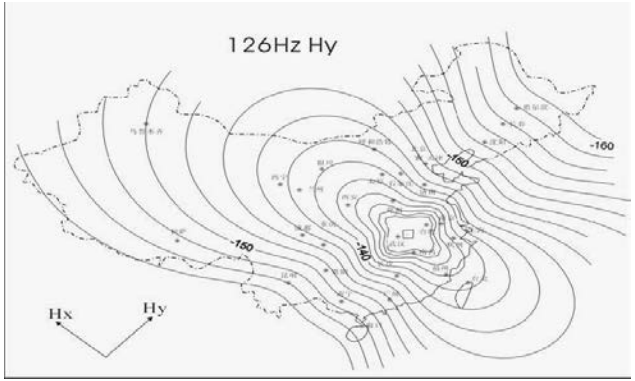


Powered artificial EM field can cover China and the vicinage





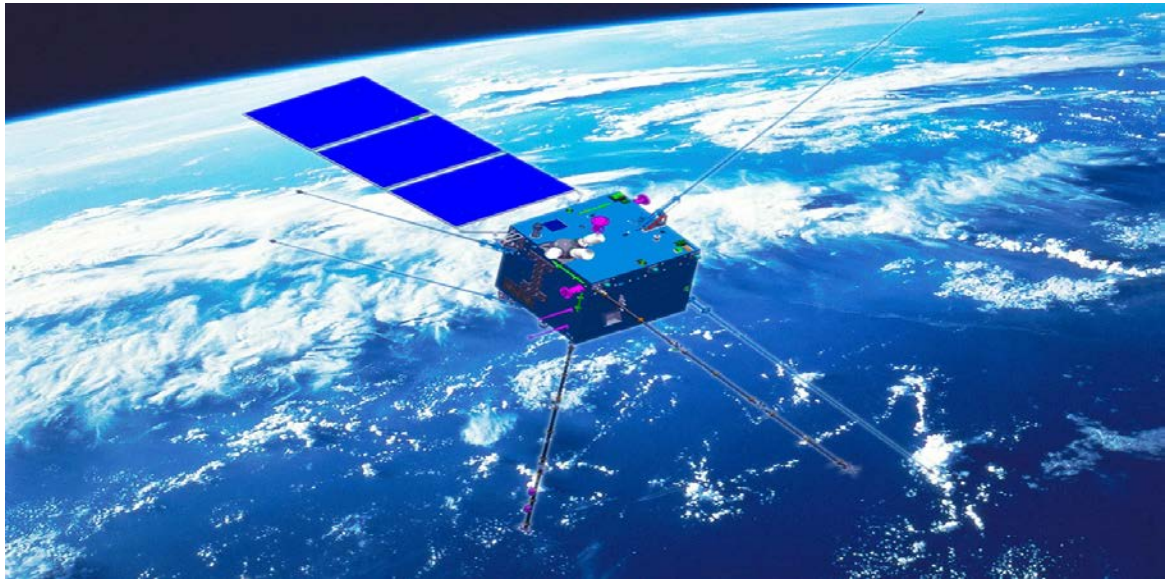




（Zhuo and Zhao）

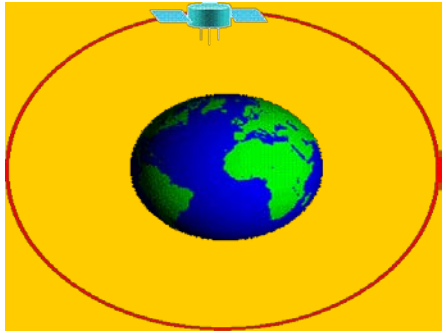
China Seismic Electromagnetic Satellite(CSES) will be launched in 2017.

Payload on board include ①three components of electrical field; ②three coil magnetic sensors; ③flux gate magnetometer; ④ vector magnetometer; ⑤ plasma analyzer; ⑥pangmuir probe; ⑦TEC; ⑧high-energy particle detector

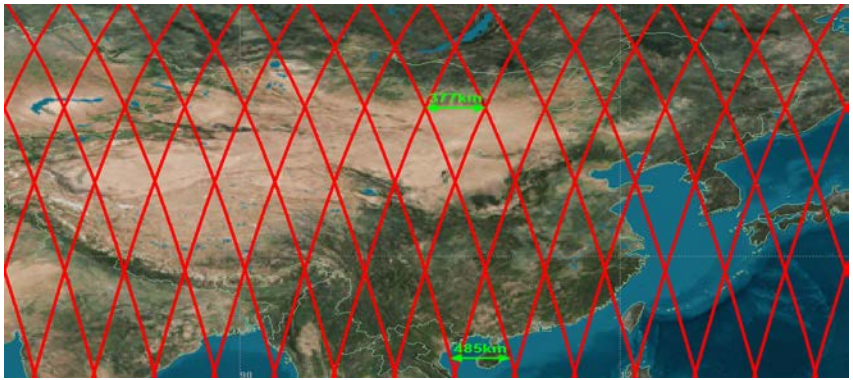


Orbit Parameters

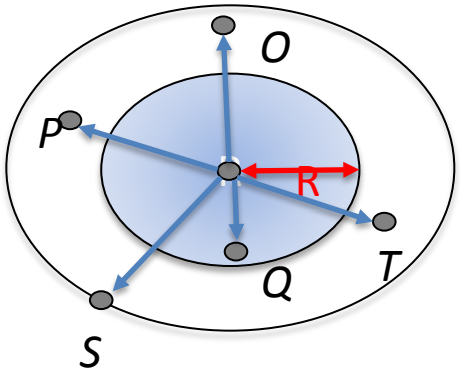
Based on the EM monitoring requirements and the operational experience of existing EM satellites.



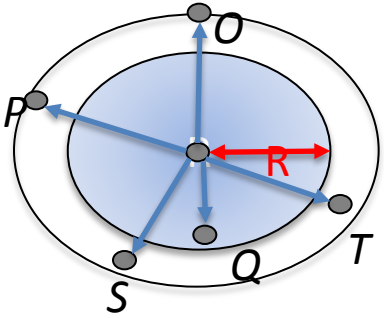
Style of orbit	Sun synchronous orbit
Altitude (km)	507
Inclination (deg)	97.4°
Period (min)	94.6
Local time of descending node	14:00pm
Revisiting period (day)	5



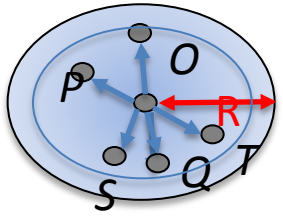
Result 1: Application of new developed methods to analyse Swarm satellite data for Ludian earthquake (M=6.5)，Yunnan province in China occurred on 3 August 2014



Strong anomaly



Weak anomaly

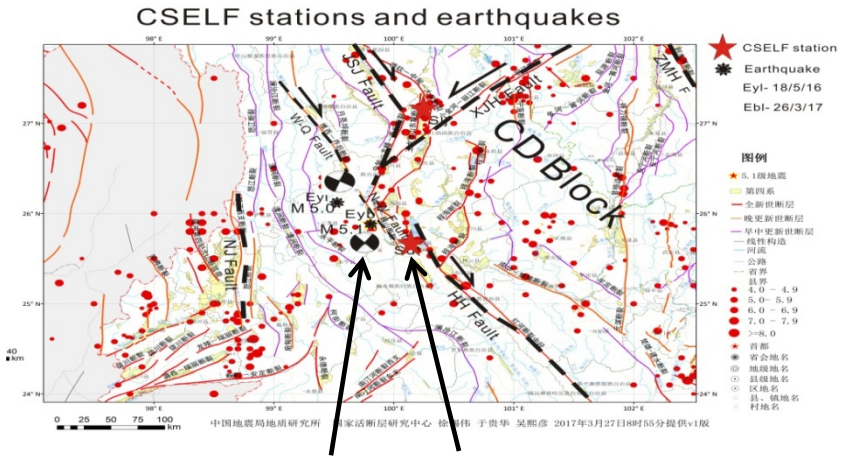


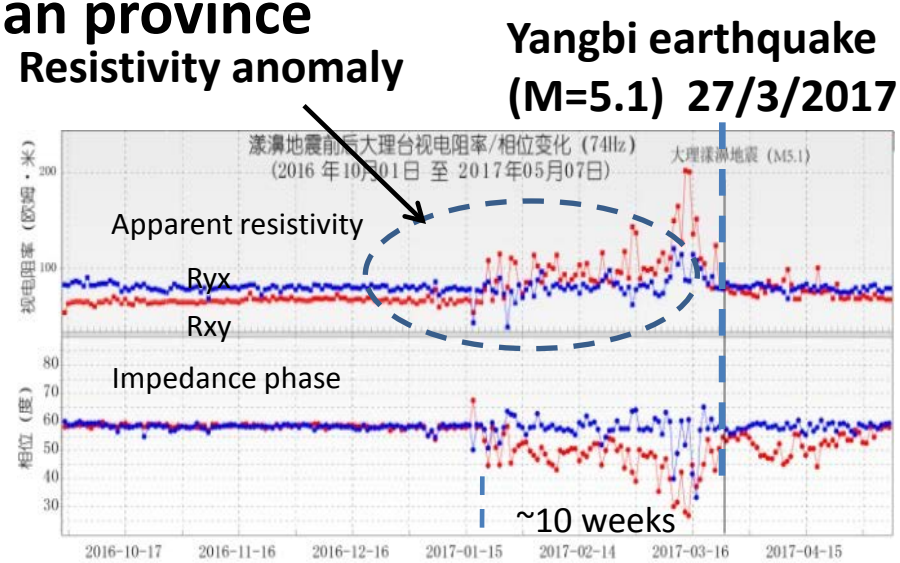
Non anomaly

The E or M field background (non-earthquake data, solid circle in blue color) is obtained by using new methods from 10 month data observed by the SWARM satellites A, B and C.

The anomaly outside the blue circle with bigger value can be recognized more easier compared with the other obtained by using previous methods.

Result 2: Resistivity anomaly is observed before Yangbi earthquake at Dali station in Yunnan province





The anomalies of electromagnetic fields, resistivity and phase appeared a few weeks or a few days before the earthquake, which are relative to the tectonics and possibly caused by piezoelectric, piezomagnetic affect and/or dynamic-electric effect.

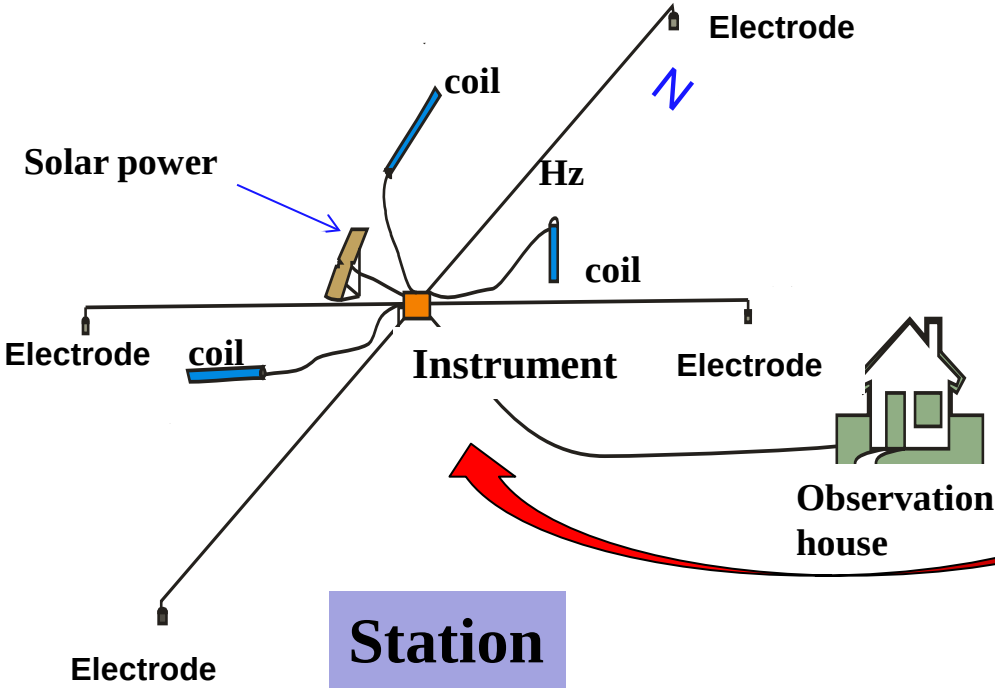
Content

1. Measurement system and recording mode at CSELF station
2. Advantages using artificial signal measurement
3. Relationship of EM anomaly with earthquake event
4. Discussion and prospect

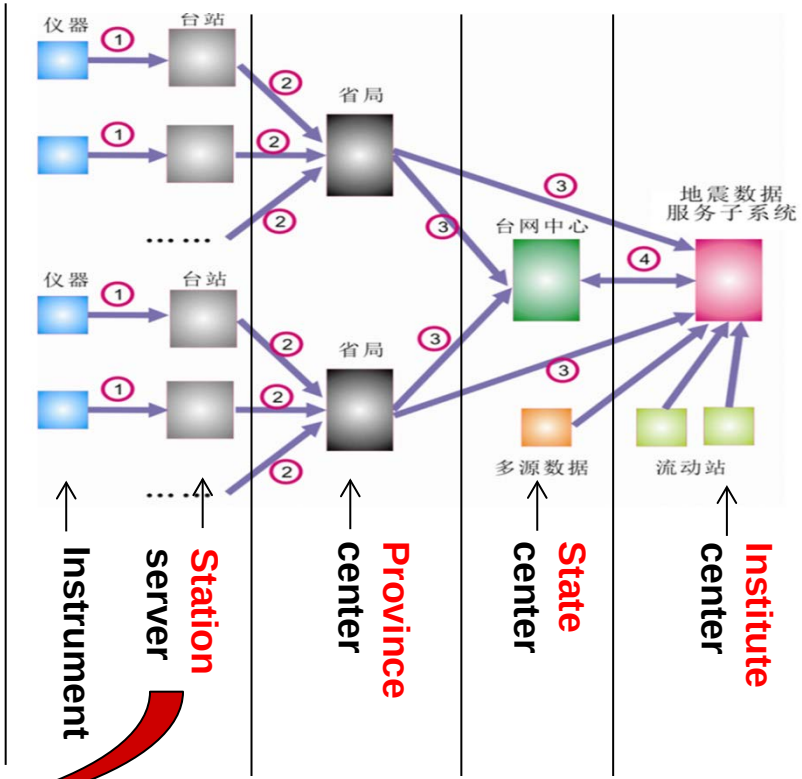
CSELF measurement system and data flow

Five EM field components are measured

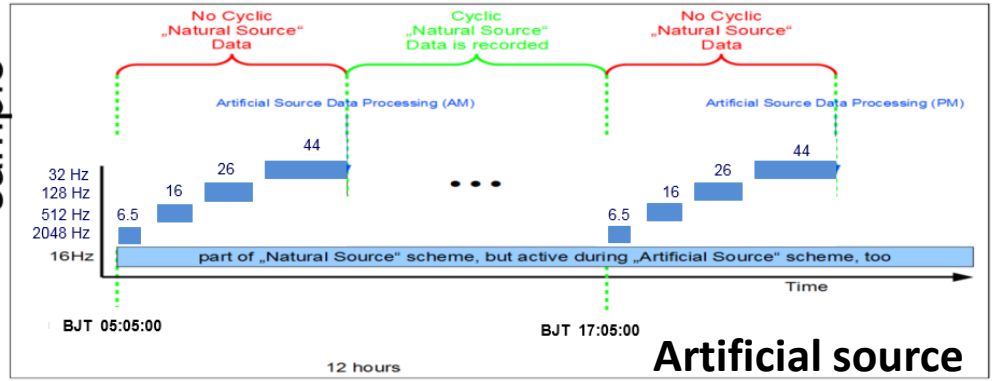
Ex—electric field (NS) Hx—magnetic field (NS)
Ey—electric field (EW) Hy—magnetic field (EW)
Hz—magnetic field (vertical)



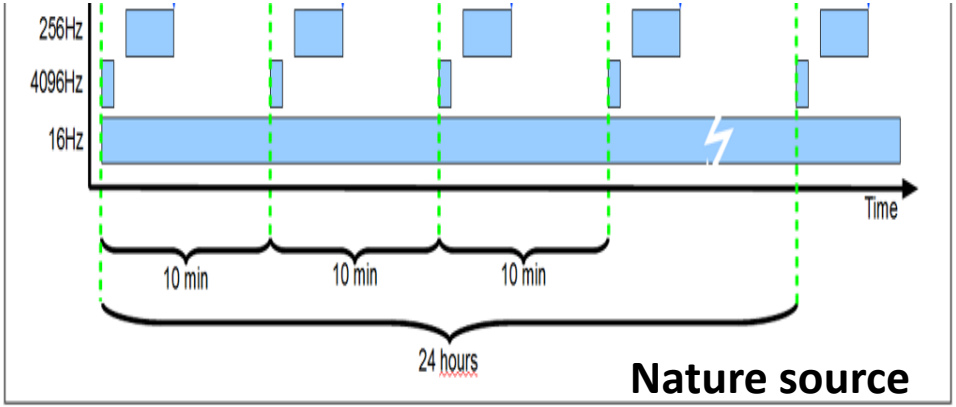
Station



Sample rate and recording mode at each station



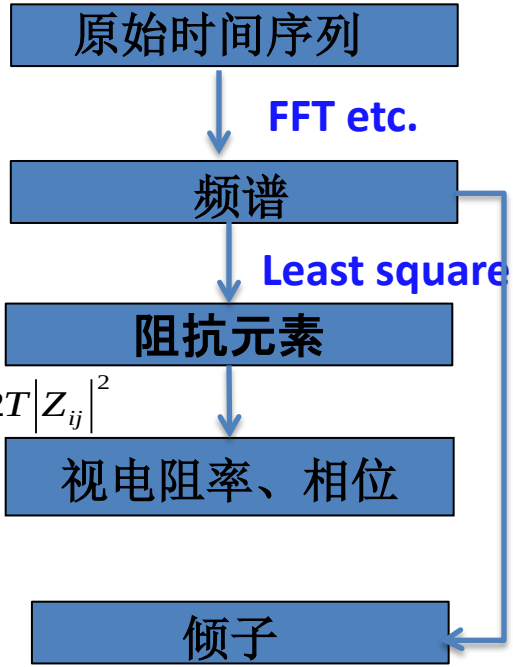
Source	Sample（Hz）	F (Hz)	Time periods
Man made (5~7 , 17~19 o'clock)	2048	216	392s
	512	63	960s
	128	16	1520s
	32	4	2640s
natural	4096	1000~22	4s/10mins
	256	57~3.9	64s /10mins
	16	3.9~0.001	All time



Artificial signals are recorded from 5~7 and 17~19 o'clock everyday using 4 different sample rates 2048,512,128 and 32Hz.

Natural signals are recorded using 3 different samples rates 4096,256 and 16 Hz for three different continuous time periods.

The procedure of data processing and the EM parameters



Raw time series

EM field spectrum, auto-power spectrum,

Elements of impedance tensor, Zxy, Zyx

Apparent resistivity, Rxy, Ryx
Impedance phase, φxy, φyx

Magnetic Tipper, Tx, Ty

$$\begin{bmatrix} Ex \\ Ey \end{bmatrix} = \begin{bmatrix} Zxx & Zxy \\ Zyx & Zyy \end{bmatrix} \begin{bmatrix} Hx \\ Hy \end{bmatrix}$$

$$\phi_{ij} = ArgZij = \frac{\mathrm{Im}(Zij)}{\mathrm{Re}(Zij)} \qquad \rho_{ij} = 0.2T\left|Z_{ij}\right|^2$$

$$Hz=AHx+BHy$$

Basic and important parameters are spectrum, resistivity, phase and tipper etc. for earthquake monitoring.

Reality photo in the station

Update the software

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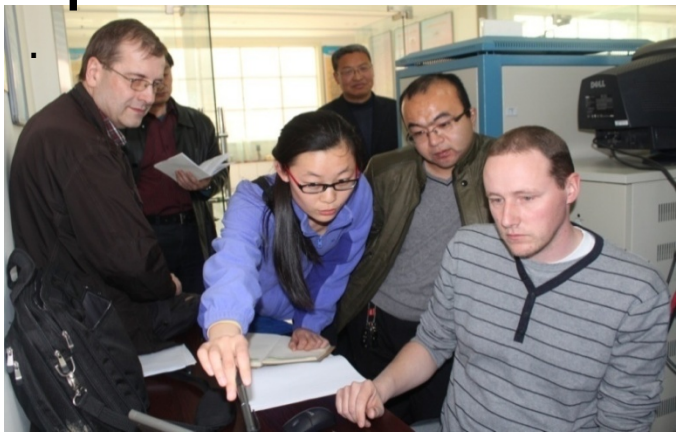

Solar power

Content

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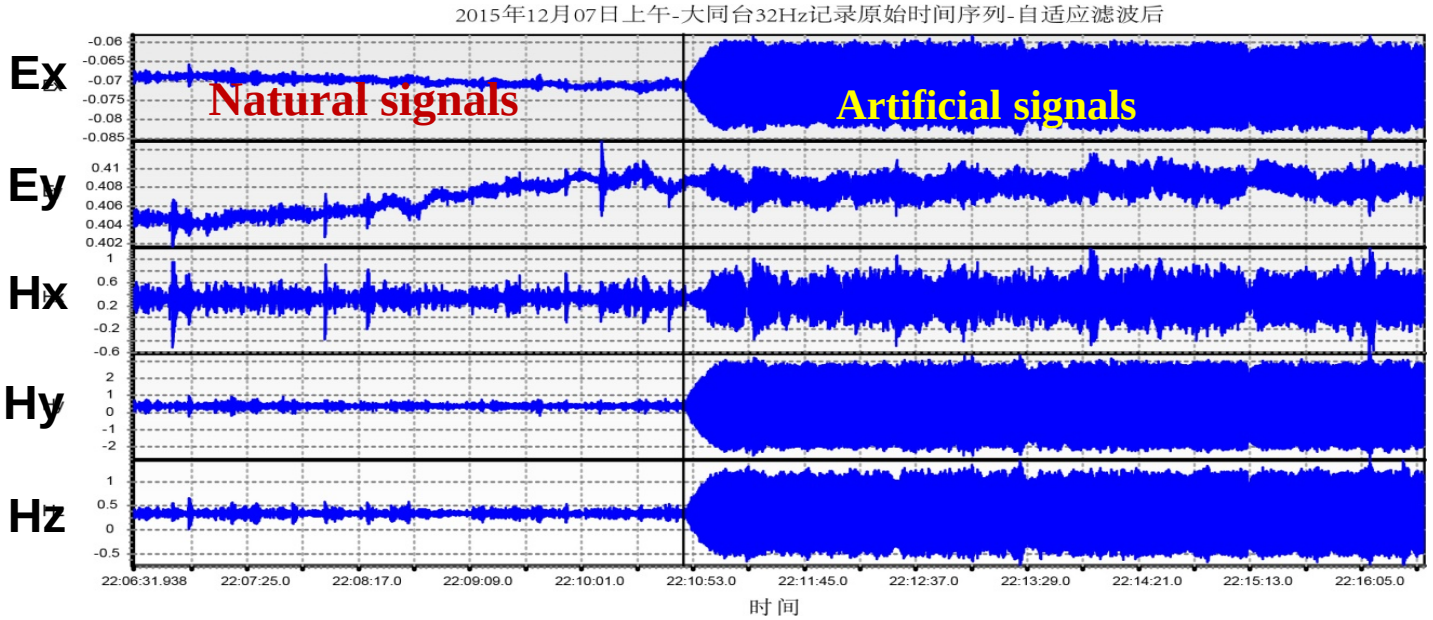
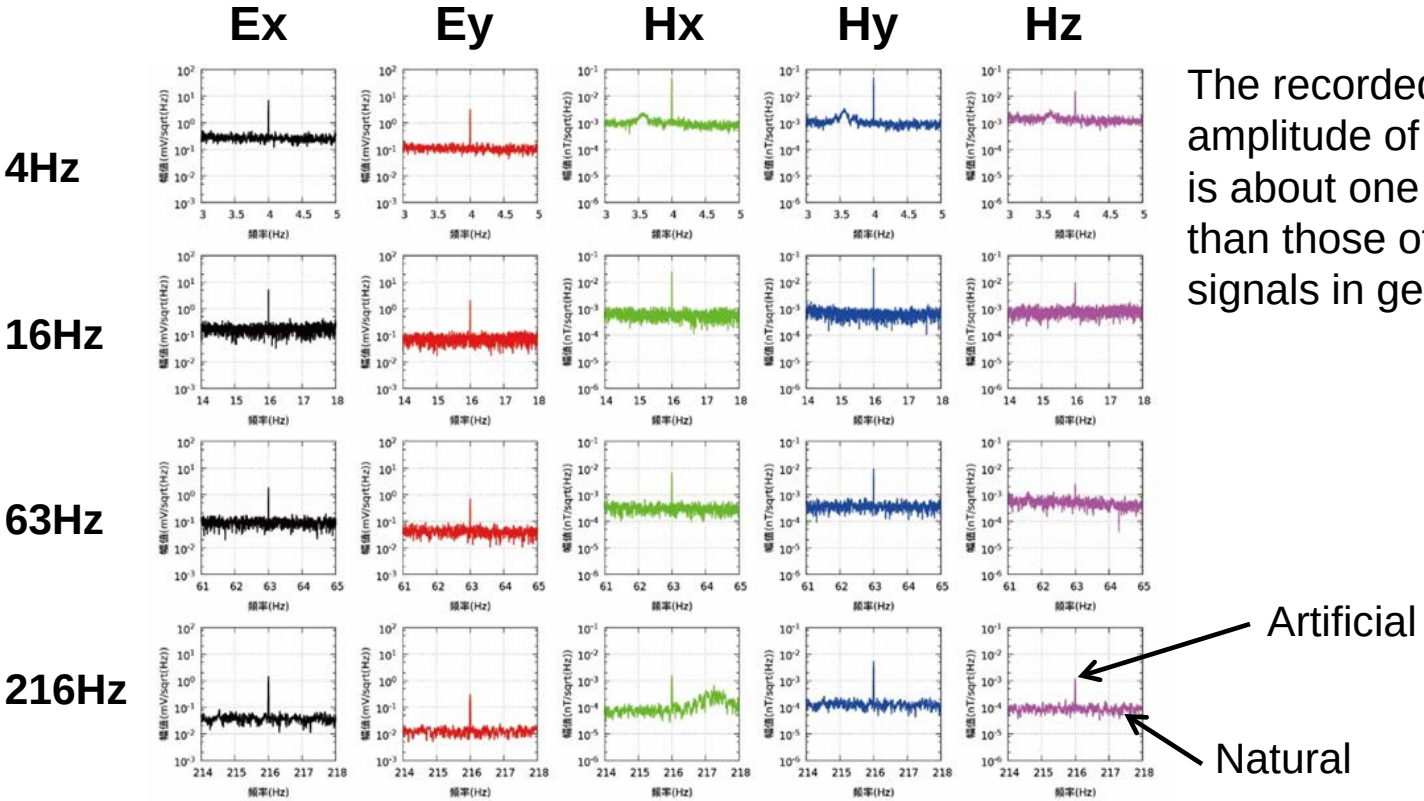
Comparison of artificial signal with natural signal in the recorded time series at CSELF station



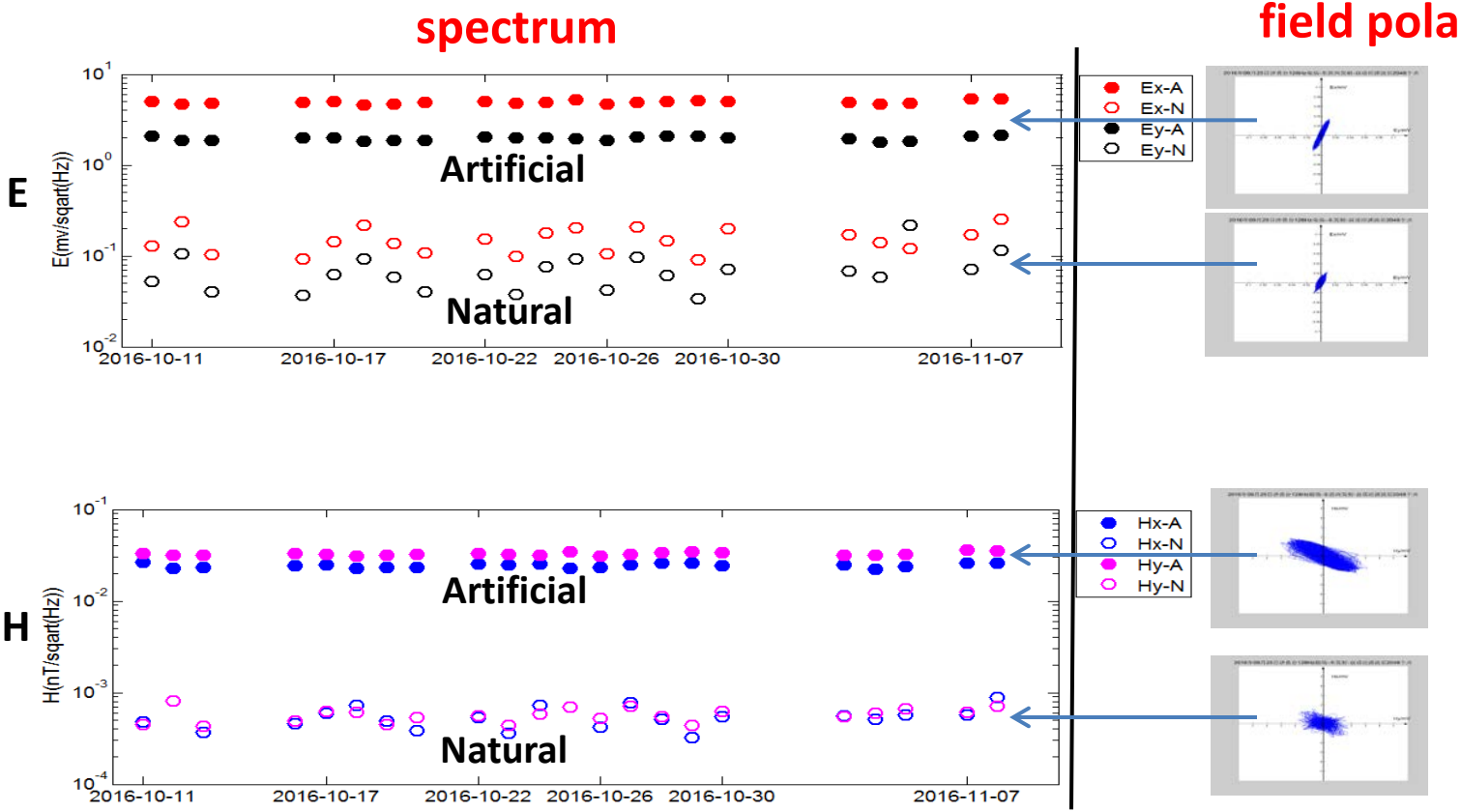
The amplitude of artificial signals are obviously bigger than the natural signals for five EM components. This is useful to enhance the S/N ratio of the data and benefit the recognition of the anomaly.

Comparison between the artificial source spectrum and natural source spectrum



The recorded spectrum amplitude of artificial signal is about one order bigger than those of natural signals in general.

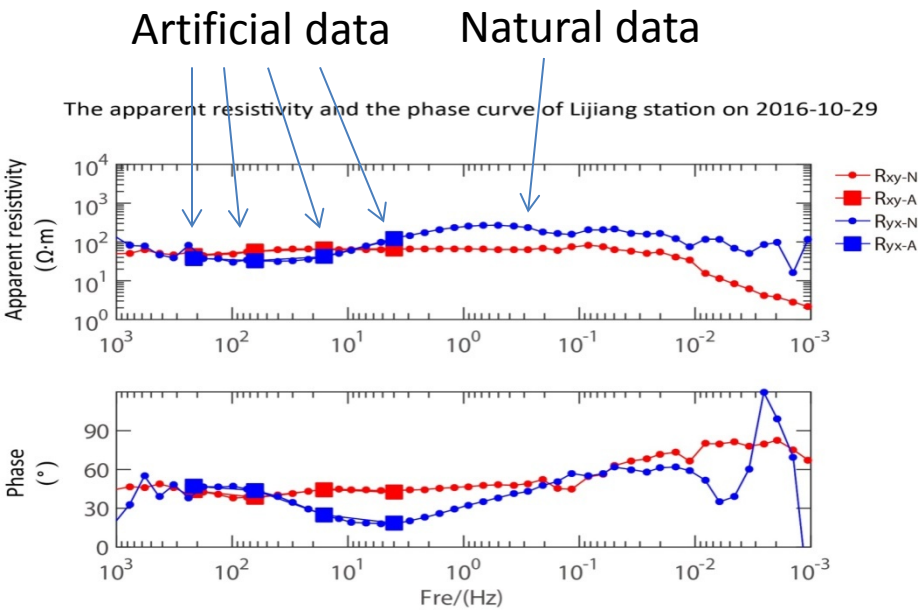
The spectrum of the artificial and the natural field and the polarization



The spectrum of artificial signal is stable over time, but natural spectrum changes greatly.

The stable polarization is also founded for artificial signals.

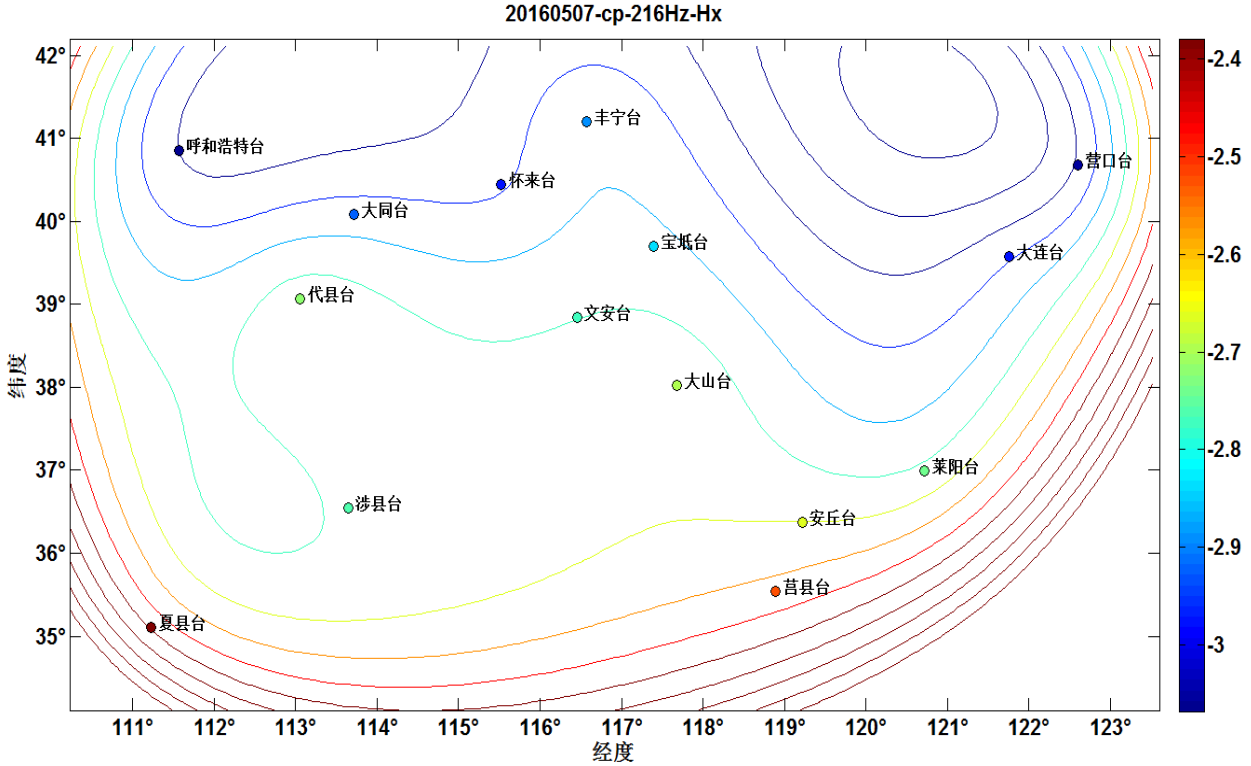
The apparent resistivity result



The apparent resistivity and impedance phase curves can be compared.

The apparent resistivity calculated from the artificial source signal is consistent with the nature source ,But when the noise is strong in the station , artificial result give a good correction

The space distribution of the artificial spectrum in BCA



The amplitude of transmitter signal decreased with the increasing distance between the stations and the transmitter

Content

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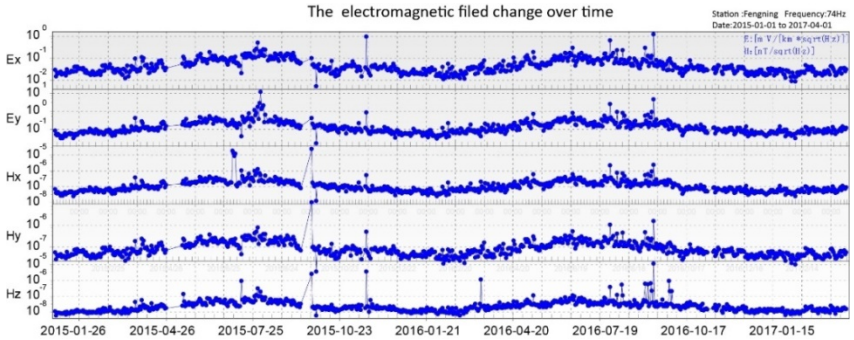
Quality of the data for anomaly recognition is important

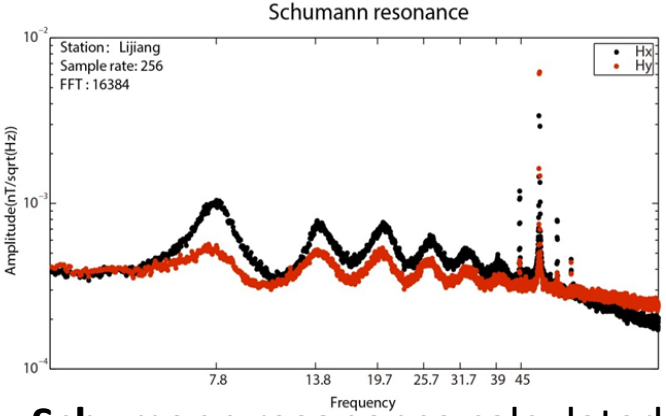
Find reliable frequency band

The following picture show some discriminant standards for data quality.



Annual variation of five EM component spectra for recorded data in two years.

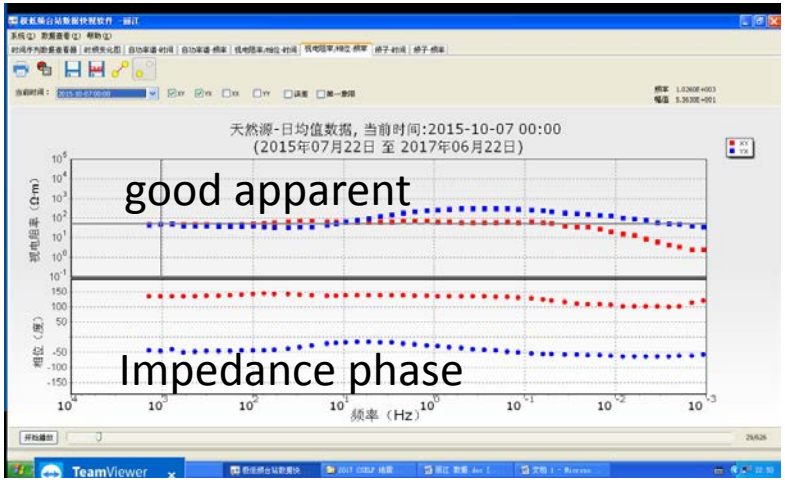
The clear annual variation should be shown by the observed data.

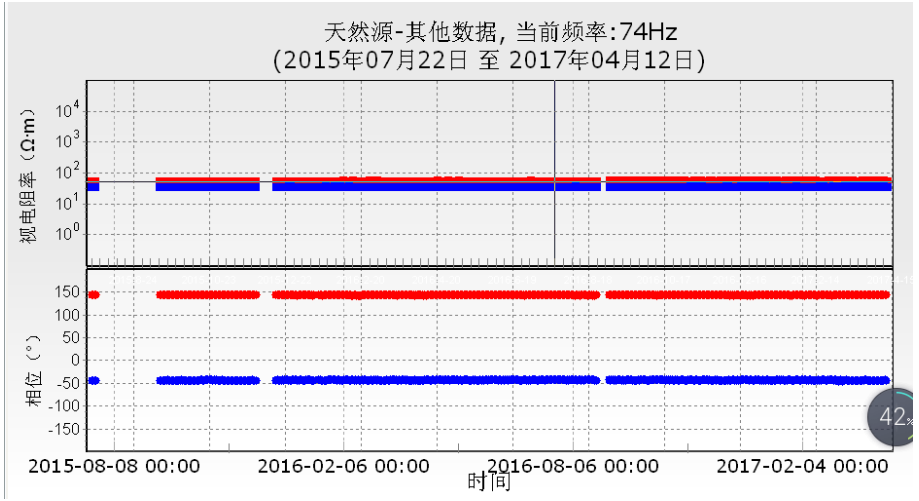


Schumann resonance calculated based On observed EM data.

The Schumann resonance should be appeared

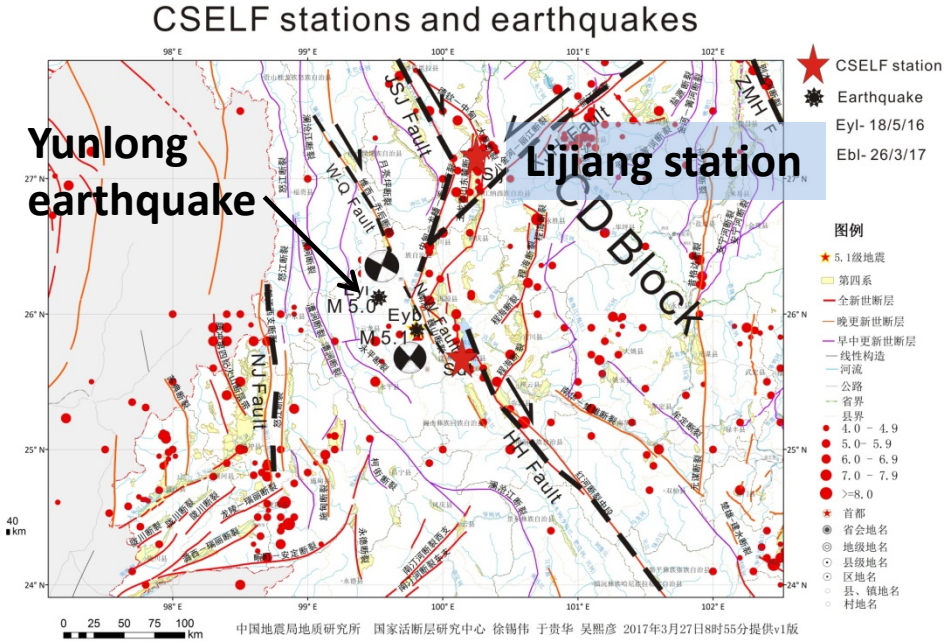
The good apparent resistivity and impedance phase should be obtained.

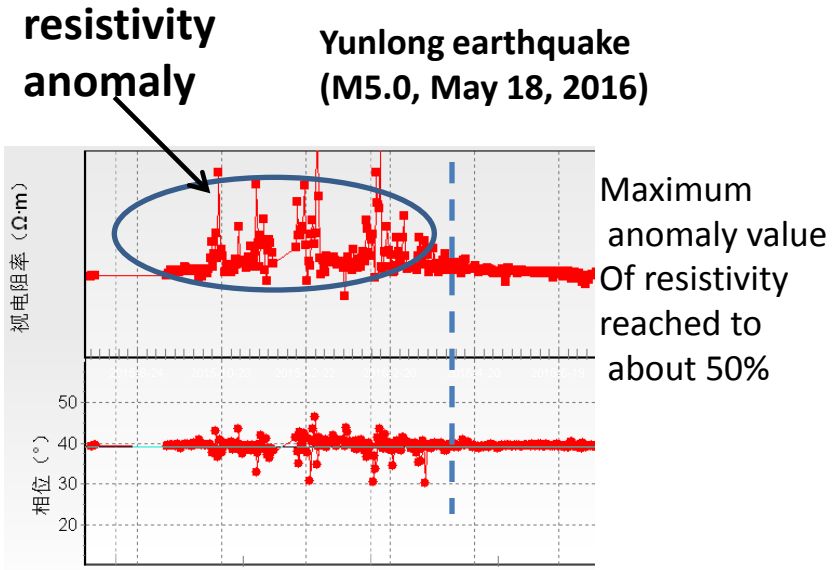




Apparent resistivity and impedance phase obtained using **natural signals** at Lijiang station in Yunan province .

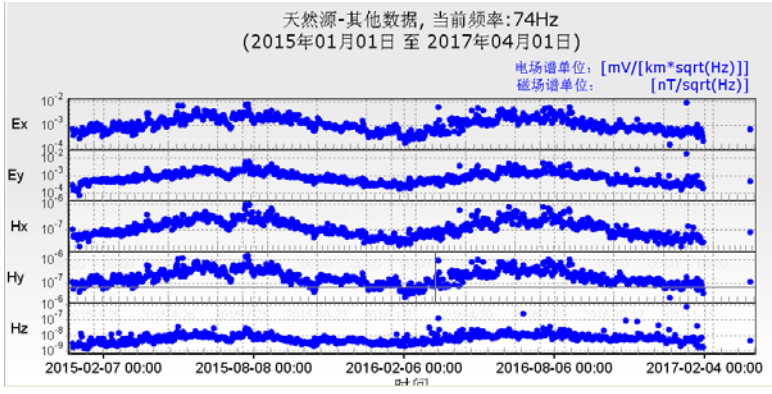
Result 3: resistivity anomaly before Yunlong earthquake (M5.0, May 18, 2016) at Lijiang station



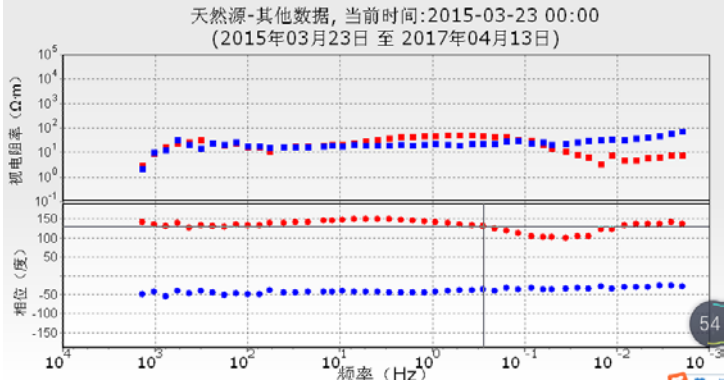


Result 4: Apparent resistivity increased before Yuncheng earthquake (M=4.4, March 12,2016) and decreased from shock time at Xiaxian station in Shanxi province (epicenter is about 33km).

Good data for annual variation

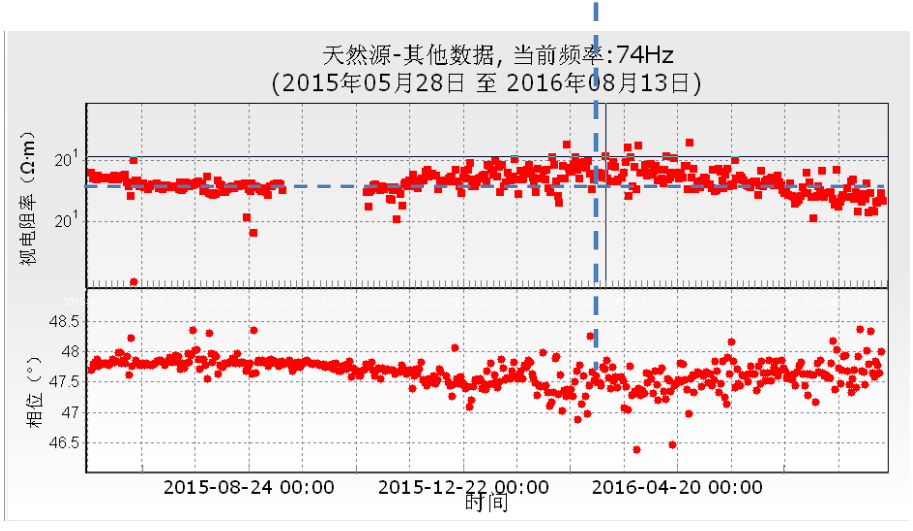


Good data for resistivity



Resistivity changes about 10% .

Yuncheng earthquake



Result 5: Spectrum variation before and after Litang earthquake

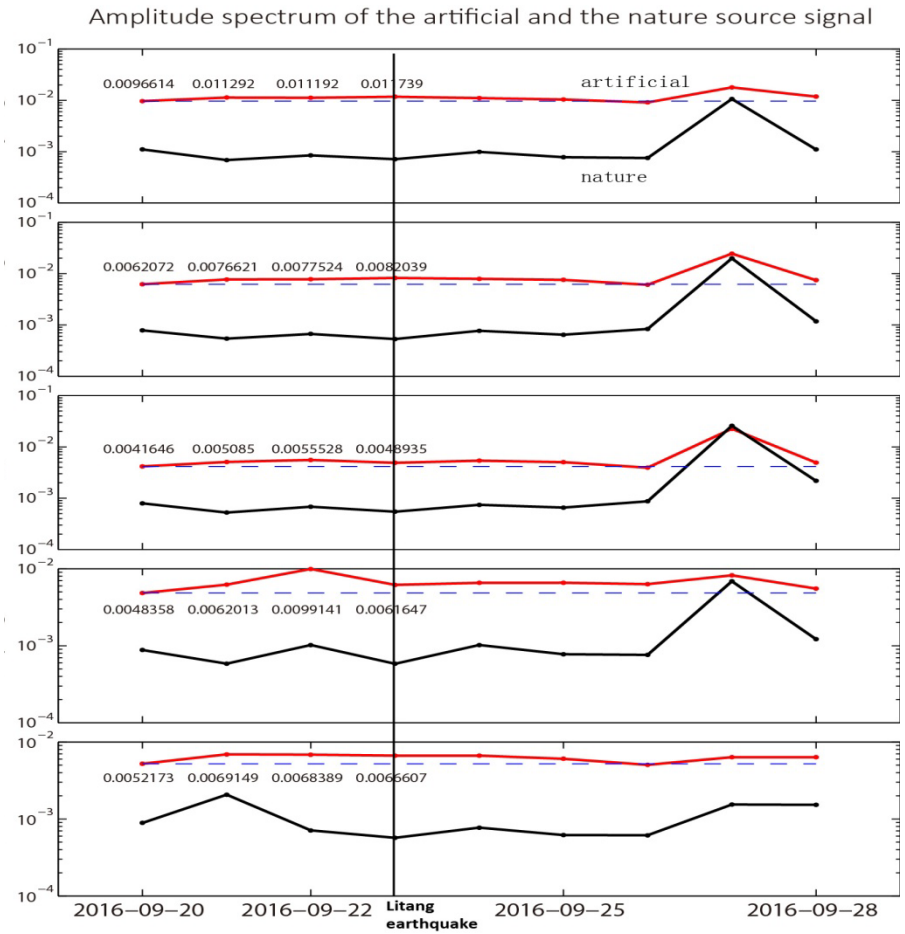
Lijiang

Mouding

Jinggu

Xinping

Dali



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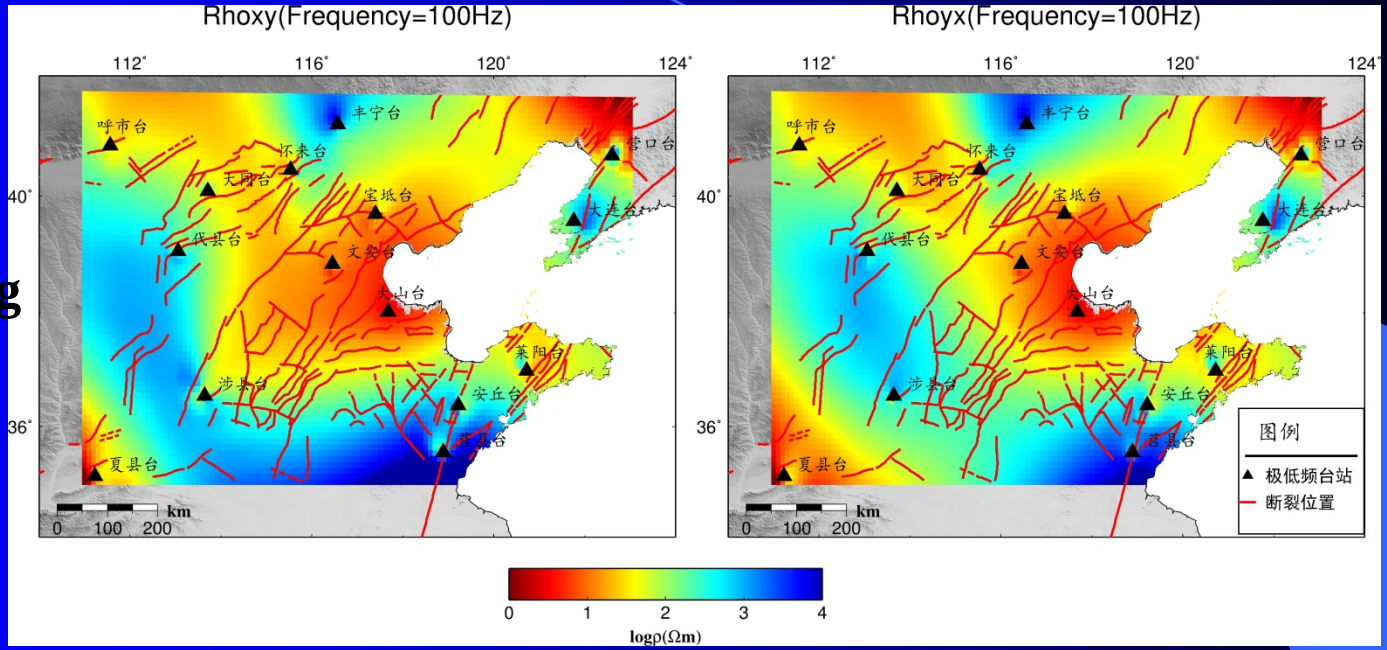
- Powered CSELF signal can enhance the data precision.
- Network observation in time-space domain is favor to earthquake anomaly detection.
- The CSELF network data can be used in comprehensive study with satellite data from CSES satellite.

Thank you
for your attention!

About 200MB data are recorded at each station a day. The total amount of the recorded can be reach to about 6GB for 30 stations.

The space distribution of apparent resistivity ‘cloud picture’ can be constructed

Space resistivity distribution of Rxy and Ryx obtained by using BCA network data, for 100Hz.



Scientific Payloads

Physical Parameter	Payloads	Main Specification
Electromagnetic Field	Search Coil magnetometer	Frequency Range: 10Hz ÷ 20 kHz
	Fluxgate Magnetometer	Frequency Range: DC ÷ 15Hz
	Electric field detector	Frequency Range: DC ÷ 3.5MHz
Plasma Construction	GNSS Occultation Receiver	Tomography and TEC by GNSS Occultation Signal
	Tri-Frequency Transmitter	Tomography and TEC by VHF/UHF/LF Signal
In situ Plasma	Plasma analyzer	Composition: H^+, He^+, O^+ Ion density: 5×10^2 ÷ 1×10^7 cm^{-3} Ion temperature: 500K÷ 10000K
	Langmuir probe	Electron density: 5×10^2 ÷ 1×10^7 cm^{-3} Electron temperature: 500K÷ 10000K
Energetic Particle	Energetic particle detector	Proton: 3MeV ÷ 200MeV Electron: 200KeV ÷ 10MeV