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Development and performance of solid Pb-$PbCl_2$ non-polarized electrode for geophysical applications

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1. Background and motivation

Non-polarized electrodes are used to measure the potential differences between two points of ionic conductors. They have been widely used in geoelectric measurements,e.g., induced polarization (IP), and spontaneous potential (SP), magnetotelluric (MT). Long term stability of electrodes is crucial to high quality electric data acquisition. Our goal is to develop very low noise electrodes for practical geoelectric application, especially,for long periods (>10^3 s) MT observation.

2. Development of Pb-$PbCl_2$ Electrodes

- From theyear of 2008, Hundred recipes with $PbCl_2$/Clay/ Bentonite/Gaolin/KCl/NaCl have been tried. The finally non polarized electrodes with different applications are shown below.

Fig.1 Our 5 types new developed Pb-$PbCl_2$ electrodes

SPECIFICATIONS TECHNIQUES

	IPEL	EL	LEL	SLEL	LREL
Self DC potential of each couple (mv)	0.5	0.5	0.3	0.2	0.2
Internal resistance(Ω)	200	200	300	300	400
Mass (kg)	0.15	0.15	0.25	0.3	0.4
Diameter(cm)	3.5	2.5	3.5	3.5	3.5
Hight (cm)	9	16	16	21	26
Temperature Coefficient (µv/ °C)	<40	<40	<20	<20	<10
potential drift in 24 h (mv)	<|0.5|	<|0.3|	<|0.2|	<|0.1|	<|0.1|
potential drift in a month (mv)	<|1|	<|0.5|	<|0.2|	<|0.1|	<|0.1|
Working life (year)	1	1	>2	>5	>10
Applications	IP/SP AMT/ CSAMT	IP/SP/ AMT/ CSAM T/MT	MT/ LMT	LMT/ /Monito ring	Very long MT/ Monitor ing

3. Synthetic long periods electric field

- In order to quantitatively evaluate the influence of electrode noise on electric field data acquisition,pure electric field (Fig.3) are predicted from Eq.(1) by combining a gobal electric model (Fig.2) and the measured magnetic data from JYG[N 39.8, E 98.2] Observation in the year of 2014.

$$E=ZH \quad (1)$$

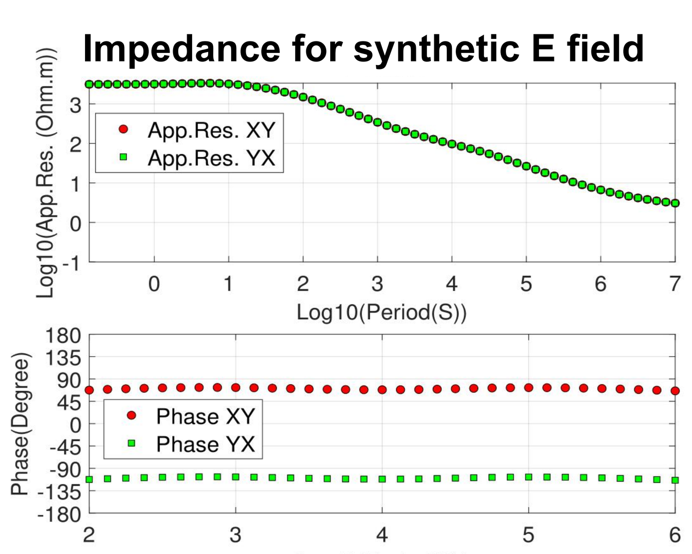

Fig.2 MT impedances from Kuvshinov (2021,EPS). With the increase of the conductivity in deep earth, the induced long-period electric field signal is weaker, which requires the electrodes must have long-term stability.

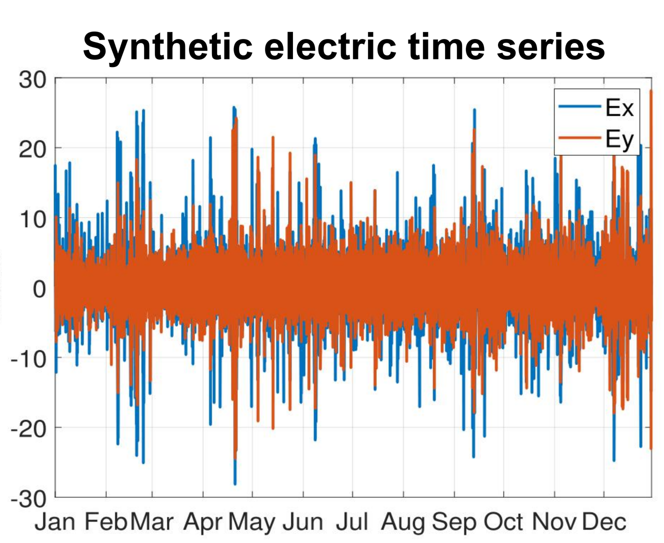

Fig.3 Synthetic electric time series by using impedance from Fig.2 and real magnetic data from JYG in the year of 2014. Our purpose is to show the clean electric field for discussing how long periods can LMT get for using different electrodes.

4. Measurement in Laboratory

- 4.1 Electrode potential drift and SNR

The electrodes were installed in baskets, on natural sponges soaked with saturated solutions of KCl or NaCl. Electrodes potential and temperature were measured continuously with 60s time interval.

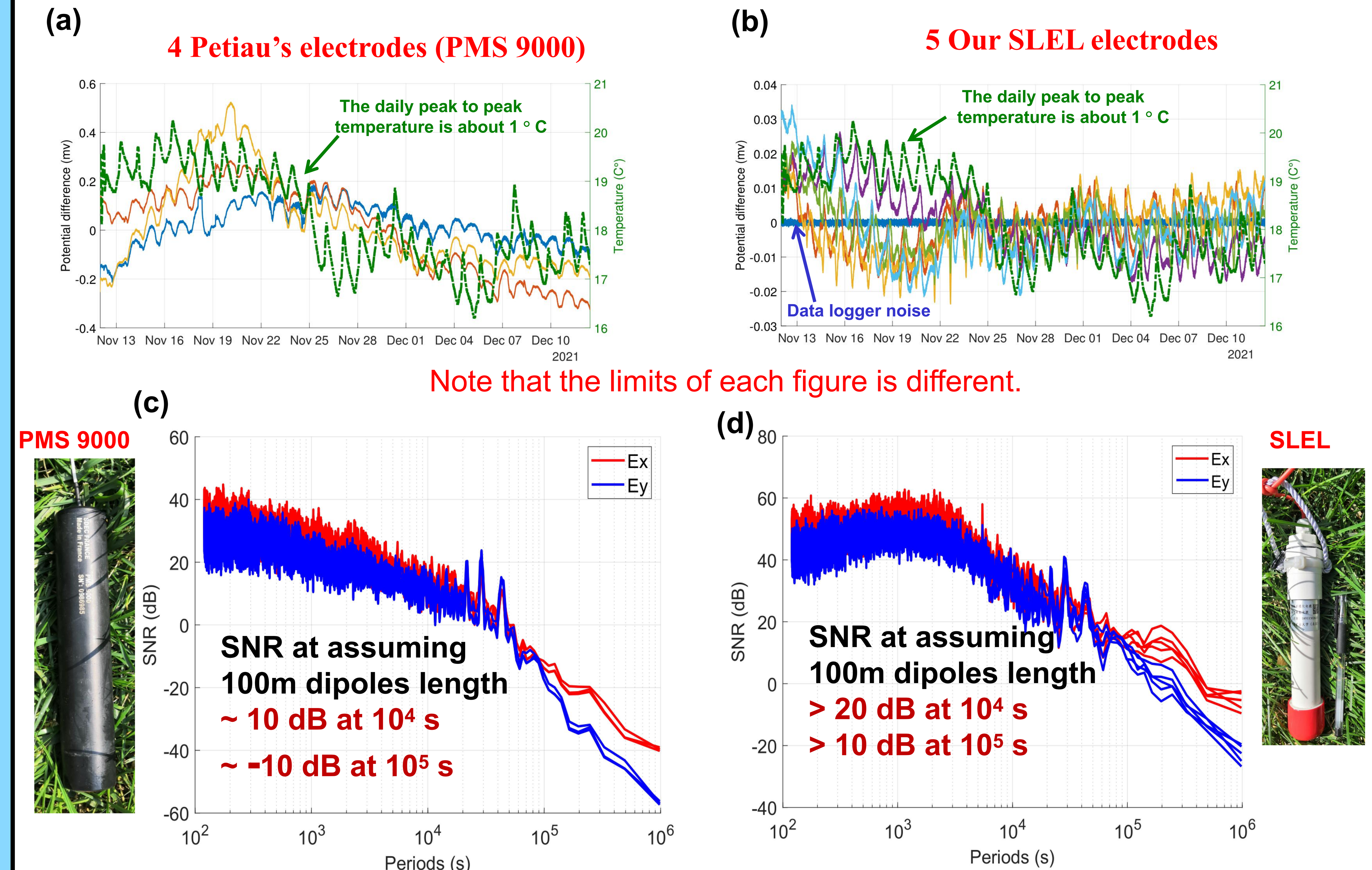

Fig.4 Electrodes potential drift for 40 days and the corresponding SNR for 100m dipole length from Fig.3.(a) PMS 9000 electrodes developed by Petiau (2000) (https://www.sdec-france.com/soil-science-equipment-sensor-pms9000.html).Right Y-axis gives the room temperature. After heating,the daily temperature change is about 1 ℃. (b) the same with (a) but for our SLEL electrodes. (c) The SNR(signal-noise ratio) where the signal is electric field with 100m electrode dipole length in Fig.3 and the noise from PMS 9000 electrodes. (d) the same with (c) but for our SLEL electrode. The SNR is >20 dB at periods of 10^4 s and 10 dB at periods of 10^5 s, comparing 10 dB and -10 dB for PMS 9000 electrods, respectively.

- **4.2 Temperature Coefficient**

Temperature Coefficient is **50~100 µv/℃** for Petiau's electrodes (PMS 9000) and **10~20 µv/℃** for our SLEL electrodes

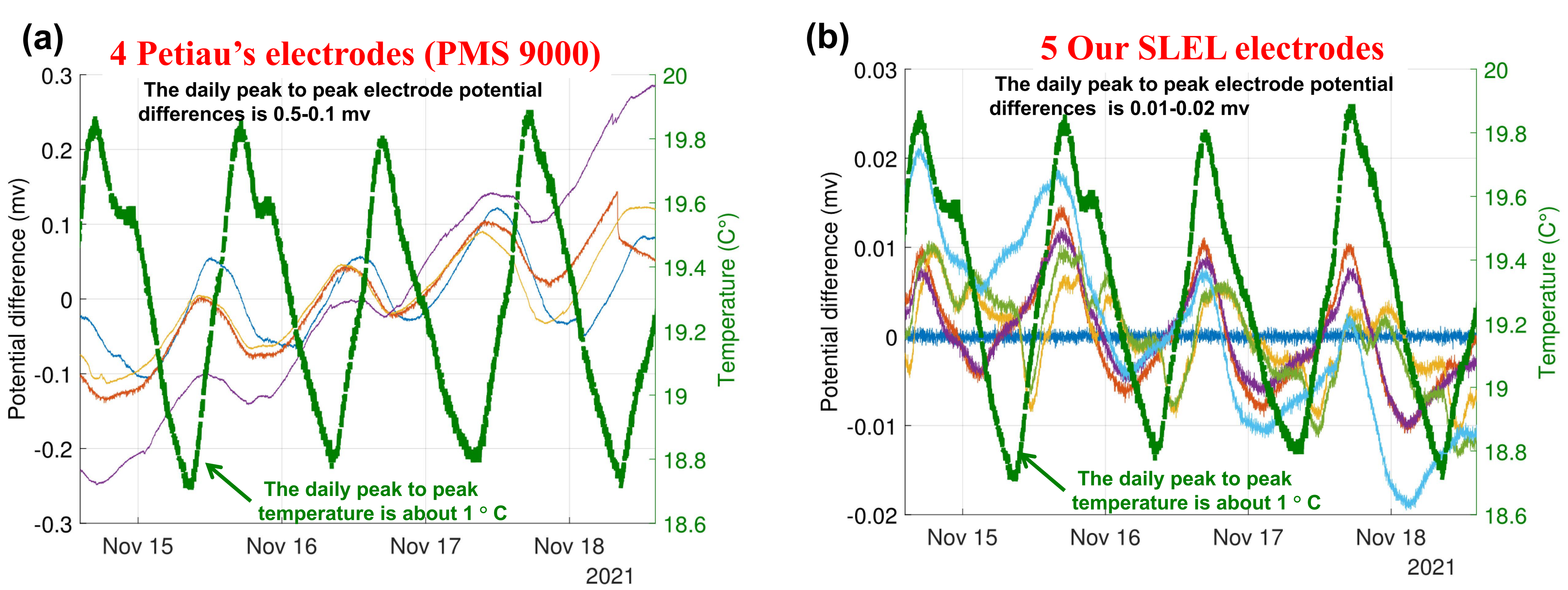

Fig.5 Electrodes potential differences for 4 days,Right Y-axis gives the temperature. The daily peak to peak temperature value is about 1 ℃. (a) PMS 9000 electrodes developed by Petiau(2000). (b) the same with (a) but for our SLEL electrodes. Note the Left Y-axis is different.

5. Field test

- 5.1 AMT measurement in Salt Lake area of Tibet

Fig.6 Our EL type electrode was fixed in plastic pipe and put it into lake bottom for measurement. Our electrodes can be used in the water.

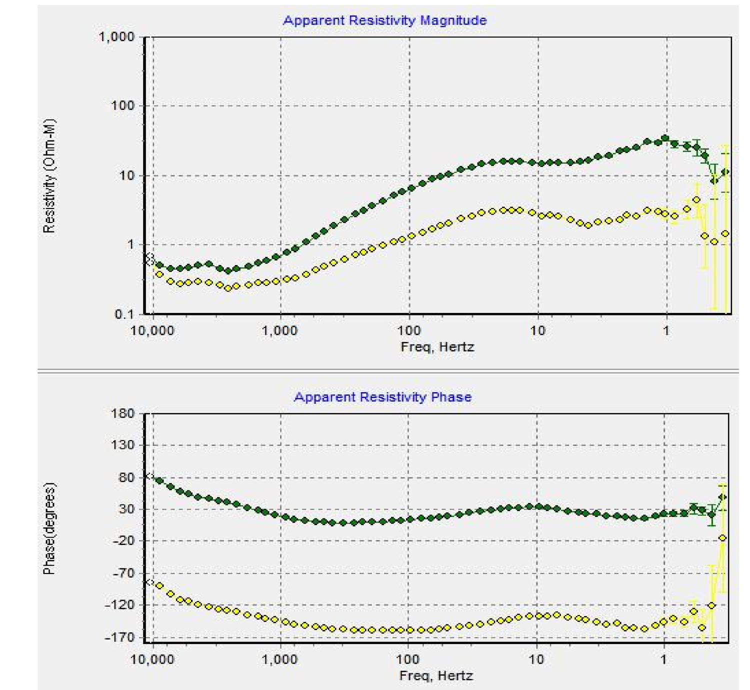

Fig.7 AMT apparent resisivity and phase for 1 hour acquisition using our EL electrodes, impedance was estimated by SSMT2000.

- 5.2 BBMT measurement

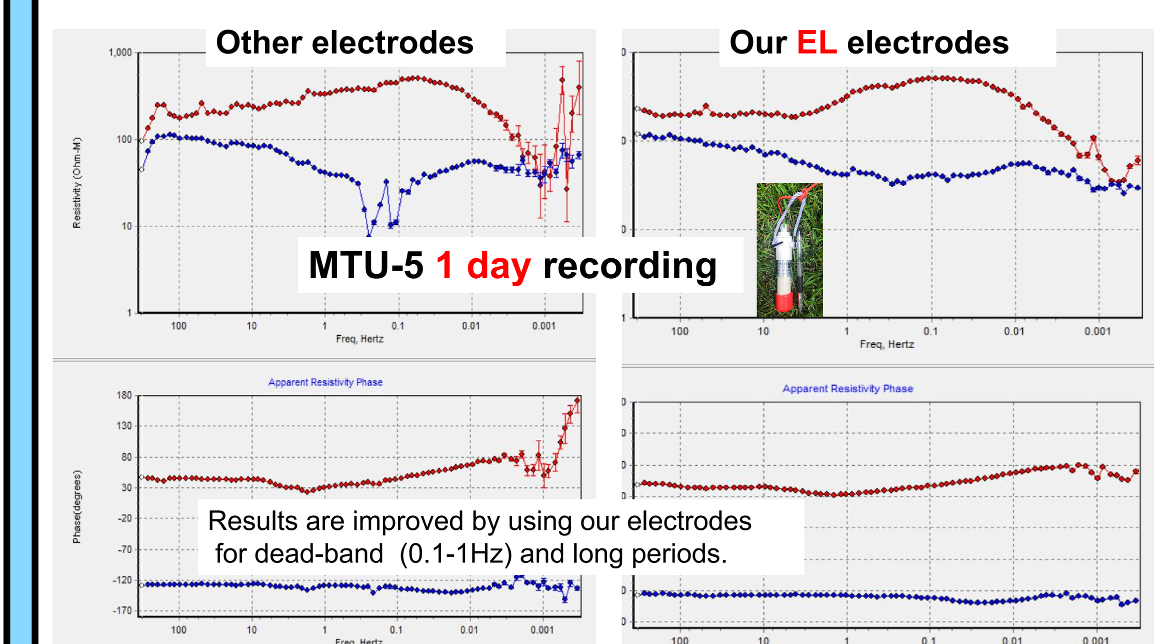

Fig.8 MT impedance with different electrodes, for 1 day acquisition using MTU-5 data logger. The apparent resistivity and phase are improved by using our electrodes for dead-band (0.1-1Hz) and long periods.

- 5.3 LMT measurement

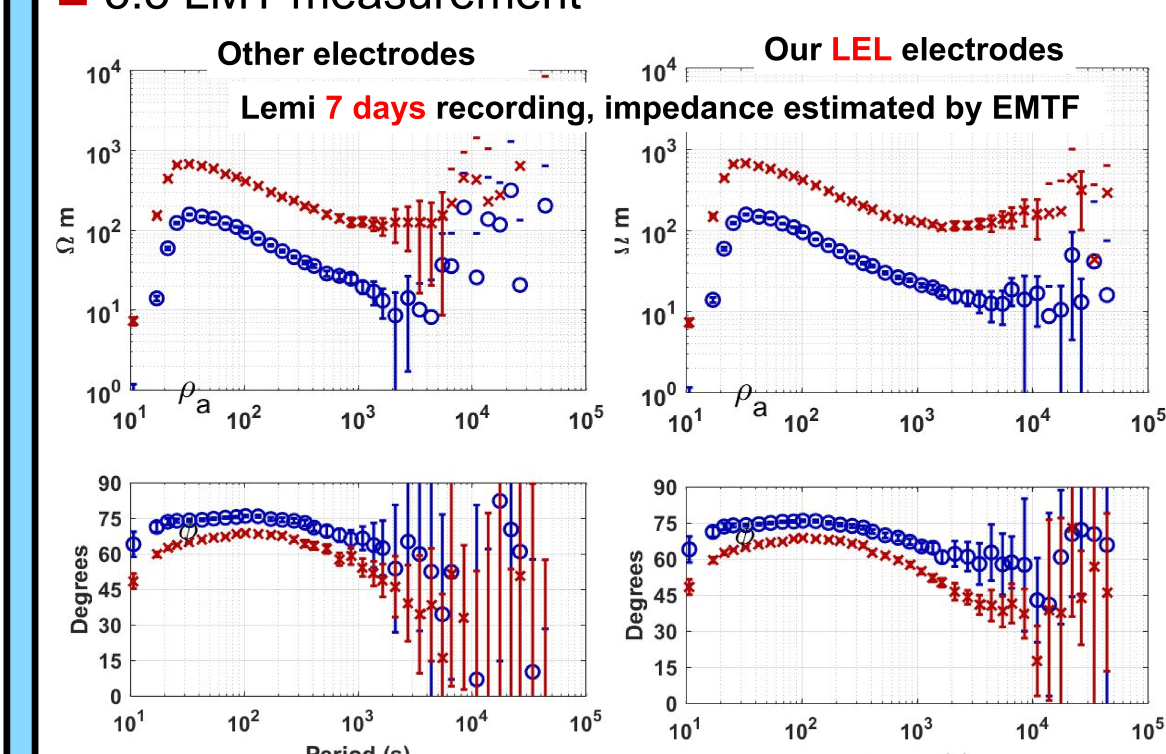

Fig.9 MT impedance with different electrodes, for 7 days acquisition using LEMI. Apparent resistivity and phase are well improved by using our electrodes for periods beyond 1000s.

- 5.4 Verylong period MT

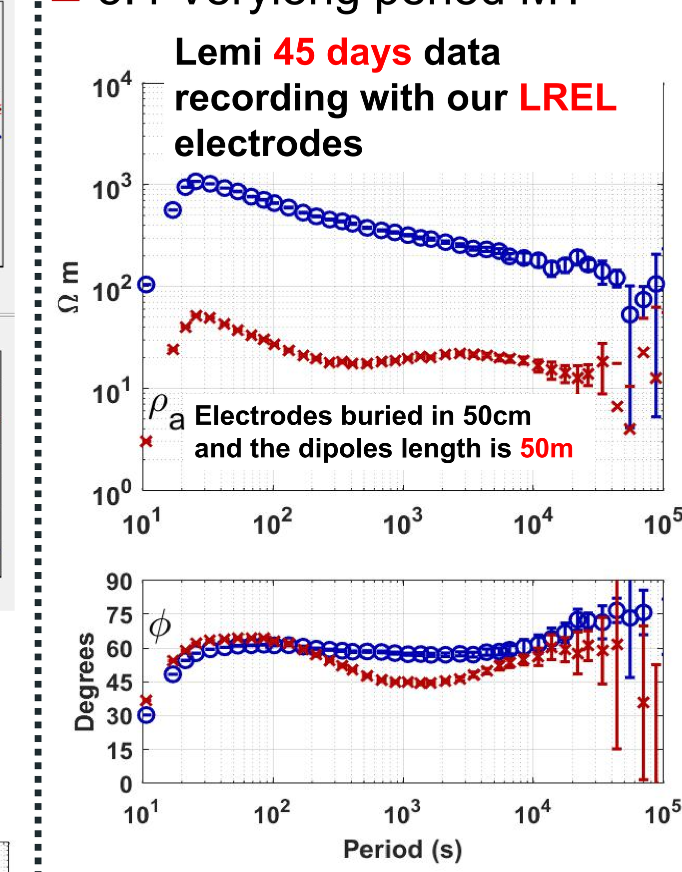

Fig.10 MT impedance with different electrodes, for 7 day acquisition using LEMI. Apparent resistivity and phase for 45 days data recording with our LREL electrodes. The electrodes was buried ~80cm and the dipole length is 50m. Impedances are estimated by EMTF (Egbert 1986).

Find more examples on the website: http://www.nonpolarizableelectrode.com/
Email to get 2 electrodes for free: wanghuigeo@qq.com

6. Conclusions

Thanks to the very low noise and temperature coefficient of our electrodes, these electrodes are good for MT, LMT and very long period MT,especially for long term measurment or monitoring. The impedance are much improved by using our electrodes, especially for dead-band (0.1~1Hz) and long period MT(>1000s).

Main References

Petiau G. Second generation of Lead-lead chloride electrodes for geophysical applications. Pure Appl Geophys. 2000;157(3):357-382
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