Inovasi Dalam Akuisisi Data Magnetotellurics (MT)

Lendriadi Agung
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WEB SEMINAR #36
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Curriculum Vitae

Full Name : Lendriadi Agung

Occupation : Geoscientist/Geophysicist PT. PGE (BPS PGE 2012 - present)

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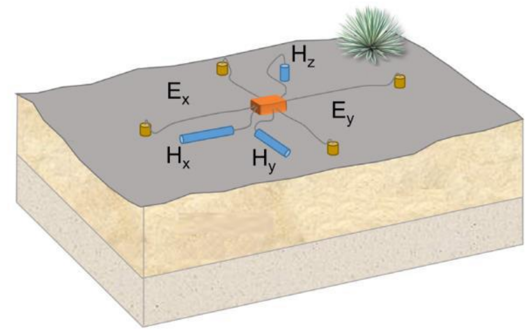
Education : Geophysics – Physics – FMIPA – UI (2005-2009)

Publications:

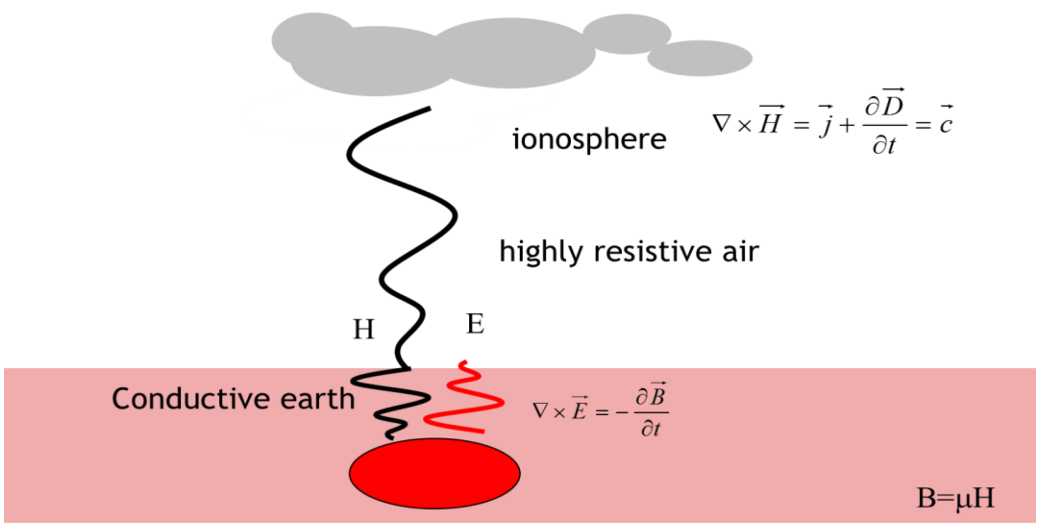
- The First Magnetotelluric Investigation of The Tawau Geothermal Prospect, Sabah, Malaysia – World Geothermal Congress 2010, Bali
- An Experimental Magnetotelluric Short Sounding During High Sun Spot Activity Cycle In 2013 – World Geothermal Congress 2015, Melbourne
- Magnetotelluric Investigation of The Arjuno-Welirang Geothermal Prospect – The 11th Annual Indonesian Geothermal Association Meeting & Conference 2011, Lampung
- Integrated Magnetotelluric Investigation of The Telomoyo Geothermal Prospect – The 11th Annual Indonesian Geothermal Association Meeting & Conference 2011, Lampung
- 3-D Inversion Of MT Data Using MT3DInv-X software – The 12th Annual Indonesian Geothermal Association Meeting & Conference 2012, Bandung
- Sonic Log Derived Porosity In Kamojang Geothermal Field – The 4th Indonesia International Geothermal Convention & Exhibition 2016, Jakarta
- Magnetotelluric Data Recording on The Variations of Sun Spot Cycle Activity To Improve Effectiveness of MT Measurements – Forum Sharing Technology Hulu 2017 (Pertamina), Makasar
- Kamojang Reservoir Mass Changes Revealed From The Application Of Gauss Theorem To Microgravity Data During Periods 2016-2014 – The 2nd Southeast Asian Conference on Geophysics 2018, Bali
- Improving the quality of the subsurface model from Magnetotelluric data using the Portable Radiation Detection Tool in Geothermal Field – Continuous Improvement Program 2019 (Pertamina).
- Net Mass Loss Estimation Using Repeat Microgravity and Leveling Monitoring From 2015-2019 at Lahendong Geothermal Field, North Sulawesi, Indonesia – World Geothermal Congress 2020, Reykjavik. (abstract accepted)
- Fault Characterization in Tondano Depression Using Focal Mechanism Analysis - World Geothermal Congress 2020, Reykjavik

Magnetotellurics

Magnetotellurics (MT) is a passive exploration technique that utilizes a broad spectrum of naturally occurring geomagnetic variations as a power source for electromagnetic induction in the earth, that is helpful to image the earth resistivity structure. (Tikhonov 1950, Cagniard 1953, Simpson and Bahr, 2005).



Objective : to delineate subsurface resistivity associated with geothermal features : clay cap and reservoir



Apparent Resistivity

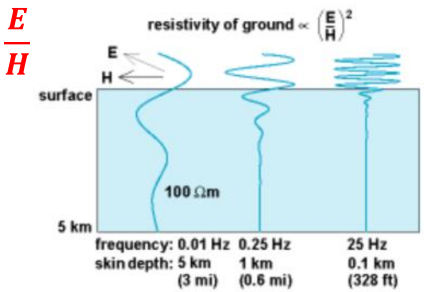
$$E = \frac{\Delta V}{r} \qquad Z = \frac{E}{H}$$

Skin Depth

$$\delta \approx 503\sqrt{\frac{\rho}{f}}$$

$$\boldsymbol{Z = \frac{\omega\mu}{\sqrt{-i\omega\mu\sigma}} = \sqrt{\frac{-i\omega\mu}{\sigma}} = \frac{E}{H}}$$

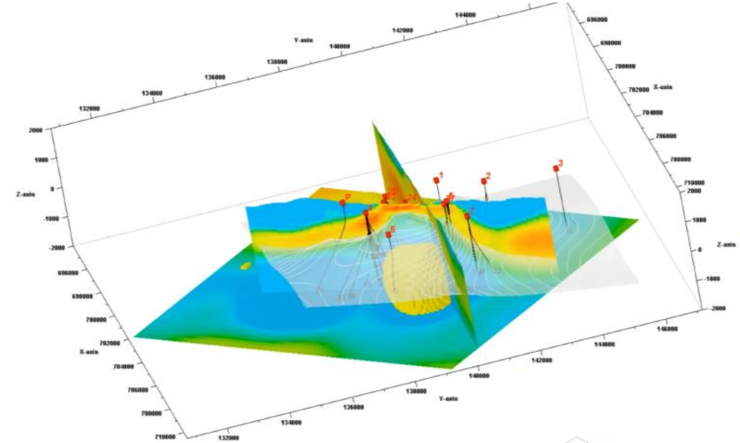
$$\frac{1}{\sigma_{app}} = \rho_{app} = \frac{|Z|^2}{\omega\mu}$$



Phase

$$\varphi = tan^{-1}(Z)$$

Magnetotellurics



- ***Magnetotellurics* (MT)** adalah salah satu metode geofisika untuk mengetahui struktur resistivitas bawah permukaan

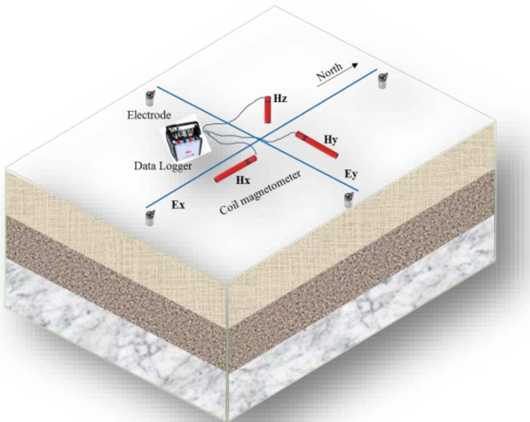
(Geothermal – Oil & Gas – Mining Industry - deep crustal research)

- Tujuan studi MT :
  - Menentukan **geometri reservoir (2-5 km kedalaman)**
  - Dasar pembuatan **model konseptual** sistem geothermal
  - ***Well targeting***
- MT memanfaatkan gelombang elektromagnetik (EM) natural dari matahari (*sun spots*) dan ionosfer (petir)
  - **signal-to-noise ratio → Low**

$$\rho_{xy} = \frac{1}{\omega\mu_0}\left|\overrightarrow{Z_{xy}}\right| \quad ; \quad \overrightarrow{Z_{xy}} = \frac{\overrightarrow{E_x}}{\overrightarrow{H_y}}$$

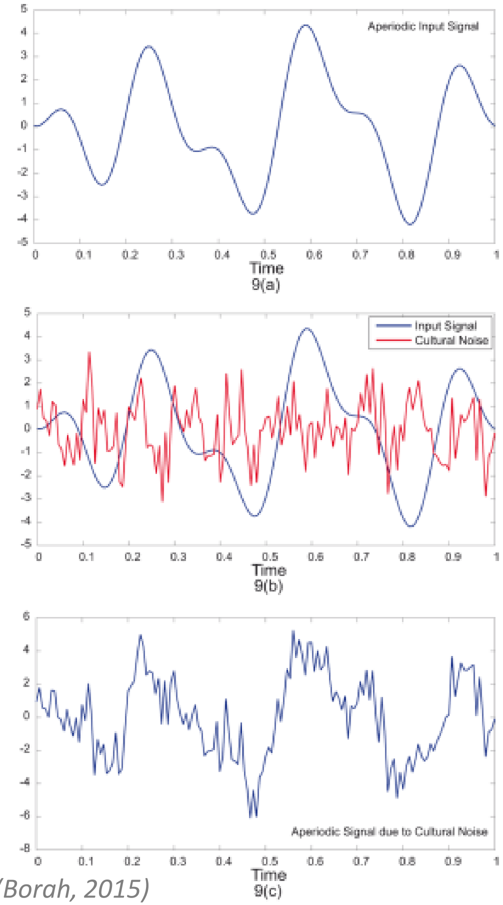
Noise Contaminant

$$\overrightarrow{Z + n_z} = \frac{[\overrightarrow{E_{0x}} + \boxed{n_E}]}{[\overrightarrow{H_{0y}} + \boxed{n_H}]}$$

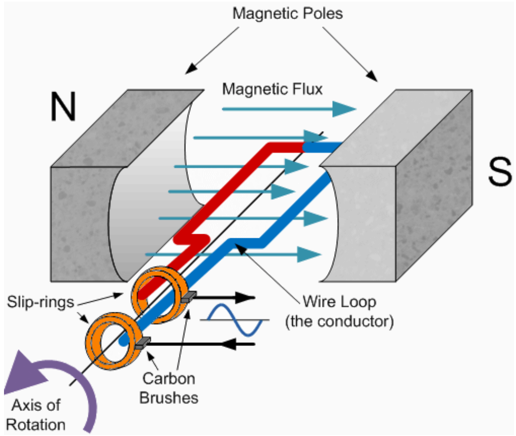


MUDAH TERKONTAMINASI NOISE DARI SUMBER ELEKTROMAGNETIK LAIN

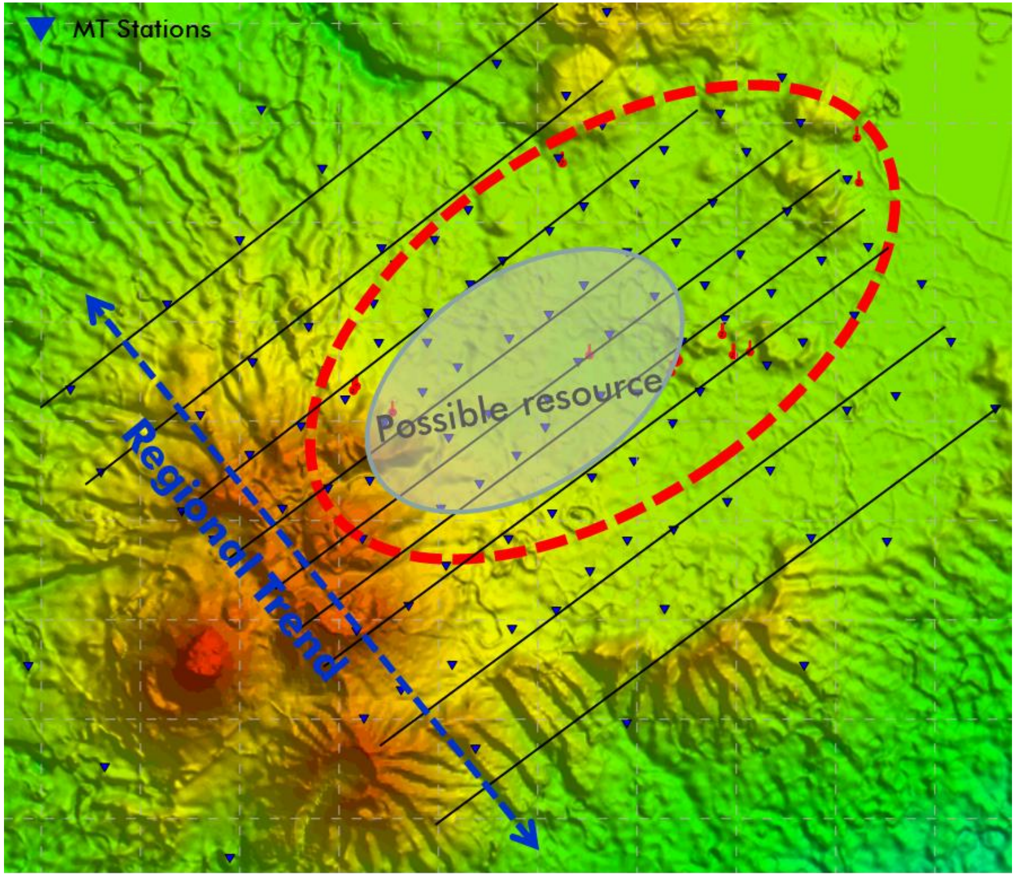
Source of Noise in Magnetotellurics

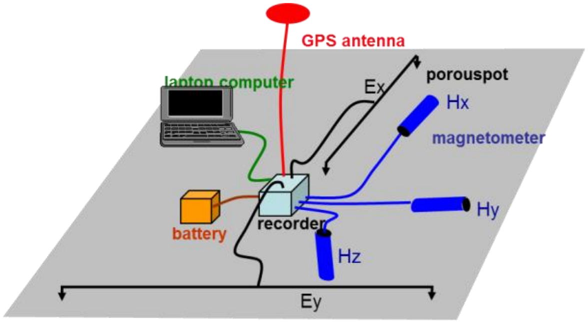


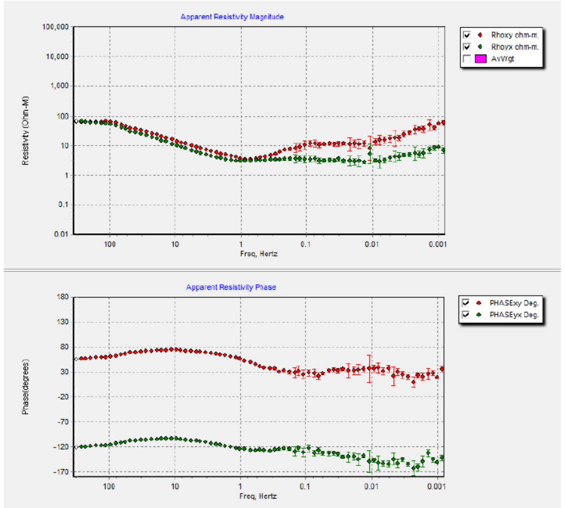
(Borah, 2015)

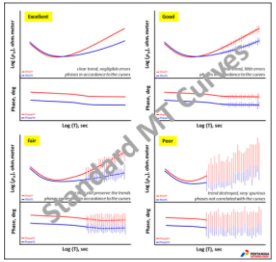


MT Design Survey









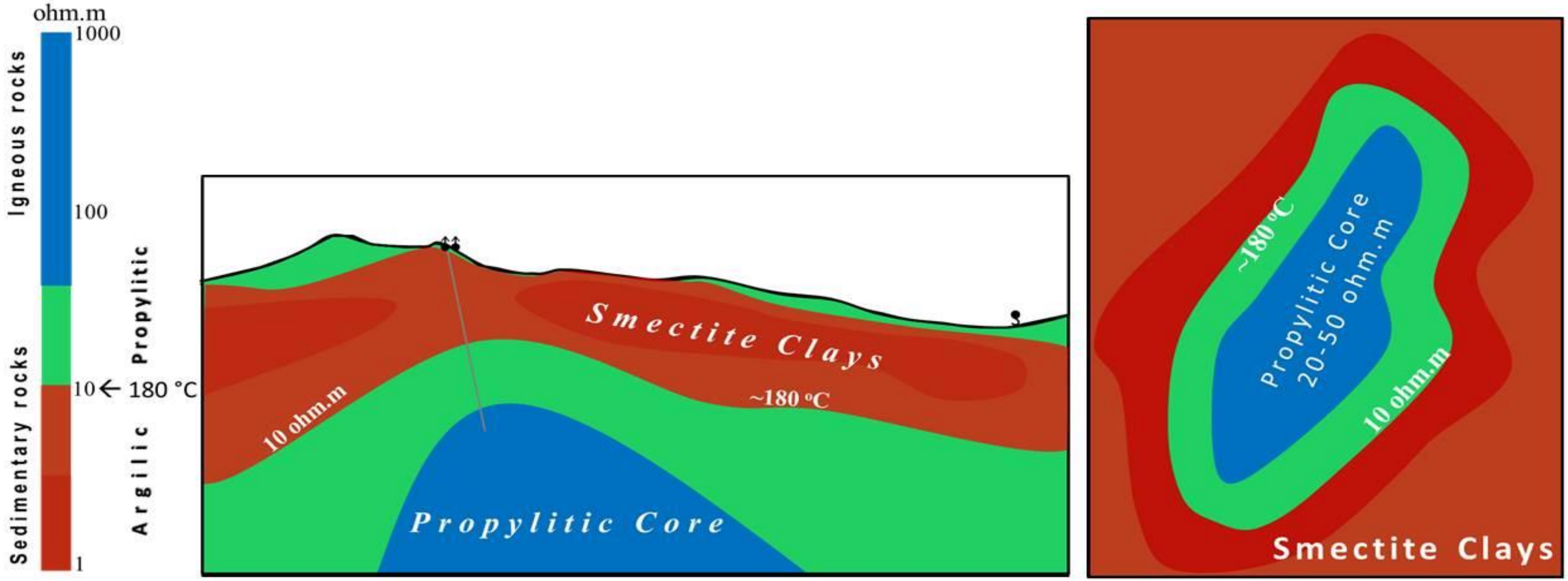
MT Field Campaign

- MTU-5A 5 channel per instrument with 24-bit digital resolution, 10kHz-0.00002Hz
- MTC-80H Coil : 5kg, 97 cm, provides from 400 – 10.000 Hz
- Non polarize PbCl Porouspot

CONVETIONAL MT Field Campaign

13-17 hours recording per site

MT Standard Interpretations



- Conductive layer 1 – 10 Ωm (conductive clays smectites)
- Conductive layer 60 ^{o}C (top) up to 180 ^{o}C at the base
- Base of conductive usually is the transition from smectites to illites
- Dome shape reservoir with higher resistivity value (propylitic alteration signature)

Problems of MT (Signal and Noise)

‘‘*Sources of noise MT are not well understood*, but general experience has indicated that a separation of several kilometers between the base and reference stations is sufficient to ensure that the data are unbiased.’’

- Wolfgang M. Goubau, Ph. D (1984) -

“In practice, it is very difficult to distinguish coherent cultural signals from the natural electromagnetic fields in which we are interested. To tackle the problems we *require not only sophisticated data-processing procedures but also highly specialized geophysical instrumentation*”.

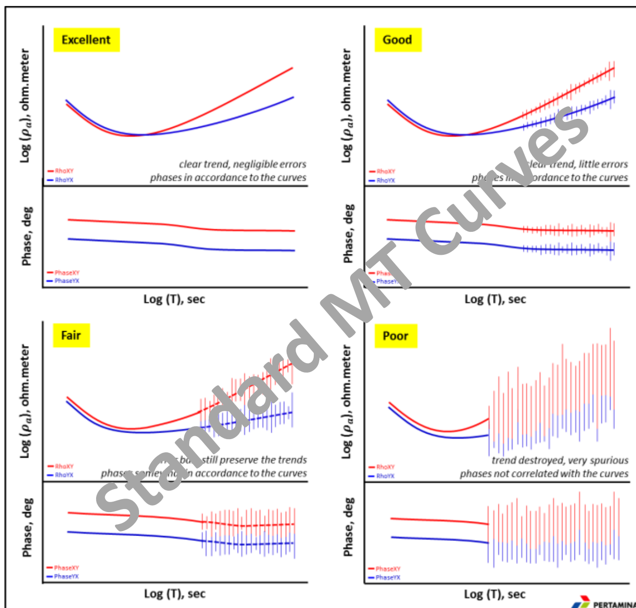
- Prof. Dr. Oliver Ritter (1998) -

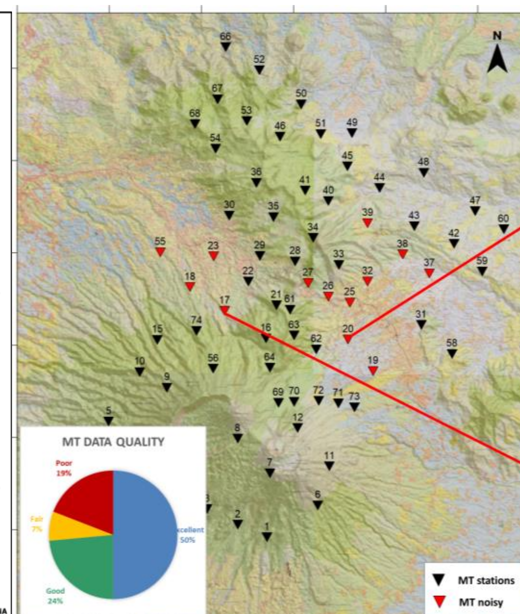
Problems of MT (Case Study)

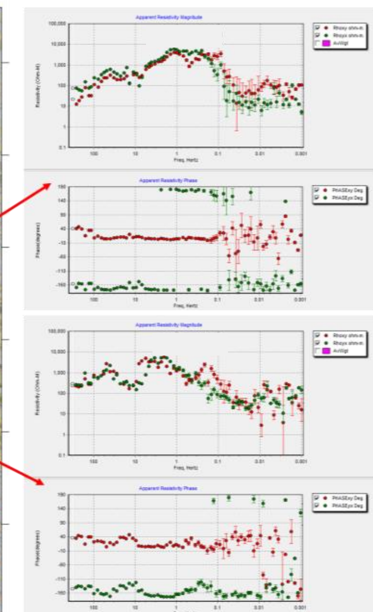
Pada tahun 2013 & 2017 dilakukan studi MT di sejumlah prospek geothermal, lokasi penelitian berada pada daerah perkotaan/padat penduduk dan banyak sumber EM buatan dari aktivitas manusia.

Terdapat 13 lokasi titik MT yang memiliki kualitas data sangat rendah dan tidak bisa digunakan.

Perlu pengenalan karakteristik sinyal EM yang lebih baik dan identifikasi noise EM sebelum pengukuran MT dilakukan untuk meningkatkan kualitas data







1. Noise Identification Using Electromagnetic Field Detector


Hasil Riset, Paparan Radiasi Ponsel Bikin Ibu Hamil Sangat Rentan Keguguran

Agregasi VOA, Jurnalis · Kamis 21 Desember 2017 13:59 WIB


Terpajan Medan Magnet Saat Hamil Berisiko Bayi Lahir Terkena Asma

Kamis 04 Agu 2011 19:32 WIB

Tingginya **resiko keguguran dan cacat janin** pada ibu hamil karena terpapar **radiasi Elektromagnetik** tinggi

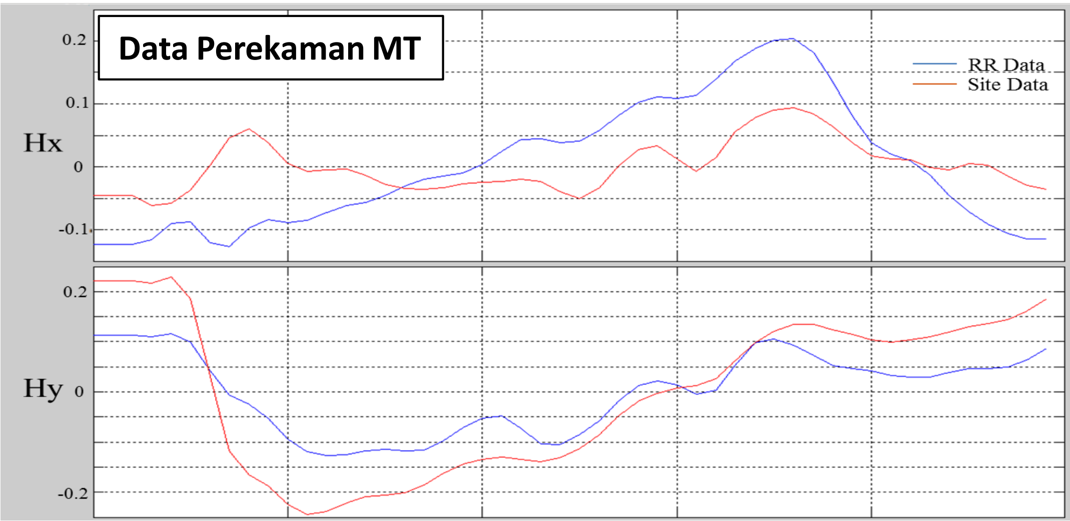
Professional Electromagnetic radiation detector Household High-Voltage Line Radiation Measuring Instrument for Pregnant women

Electromagnetic radiation tester Dosimeter Tester Pregnant women radiation instrument computer mobile phone radiation measuring

Tools:

Antisipasi dengan menggunakan **EMF-detector** untuk **menghindari paparan radiasi EM** pada janin

1. Noise Identification Using Electromagnetic Field Detector



Data Pengukuran di Lapangan

Besar medan elektromagnetik pada MT ± 0.25 µT dan ± 0.001 V/m

Device	Axis Field Measurment	Measuring range V/m	Measuring range µT	Accuracy V/m	Accuracy µT	Alarm threshold Yes/No	Alarm threshold Value	Bandwith Hz	Power Supply	Price Rp
	✓ Three Axis	✗ 200-20000	✗ 20-2000	✗ -	✗ -	No	-	✓ 30-300	Battery 1x9V	2,575,000
	✓ Single Axis	✗ 1-1999	✓ 0.01-19.00	✗ 1	✓ 0.01	✓ Yes	✓ 40 V/m 0.40 µT	✓ 30-300	Battery 1x9V	✓ 789,000
	✓ Single Axis	✗ 0-2000	✗ 0-200	✗ 1	✗ 0.1	✓ Yes	✓ 40 V/m 0.40 µT	✓ 30-300	Battery 3x1.5 V AAA	650,000
	✓ Single Axis	✗ 20-2000	✓ 0-200	✗ 0.1	✓ 0.01	-	-	✓ 30-300	Battery 1x9V	✓ 1,998,000

EMF DETECTOR

guidelines for EMF exposure - International Commission on Non-Ionizing Radiation Protection (ICNIRP)

Spesifikasi:

Measuring range

1-1999 V/m (Electric Field)

0.01-19.00 µT (Magnetic Field)

Akurasi:

1 V/m (Electric Field)

0.01 µT (Magnetic Field)

1. Noise Identification Using Electromagnetic Field Detector

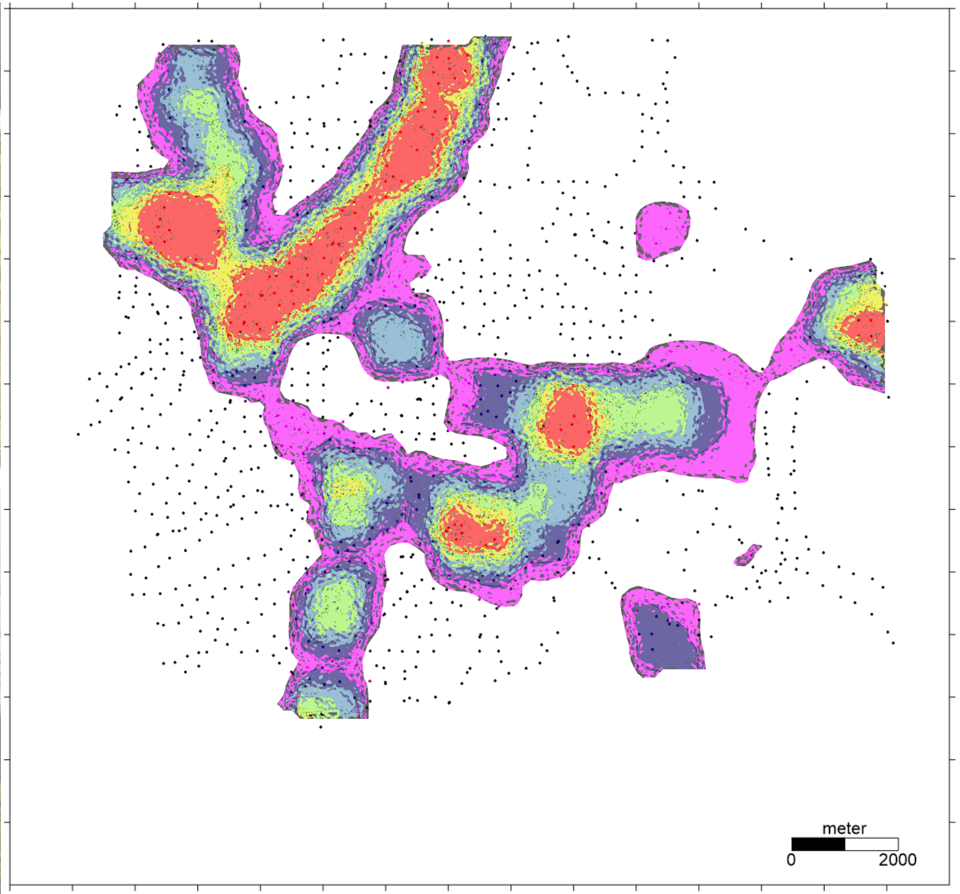
Mapping High Electromagnetic Field Distribution

Over 1000 Stations measurement

Spacing station ±200m

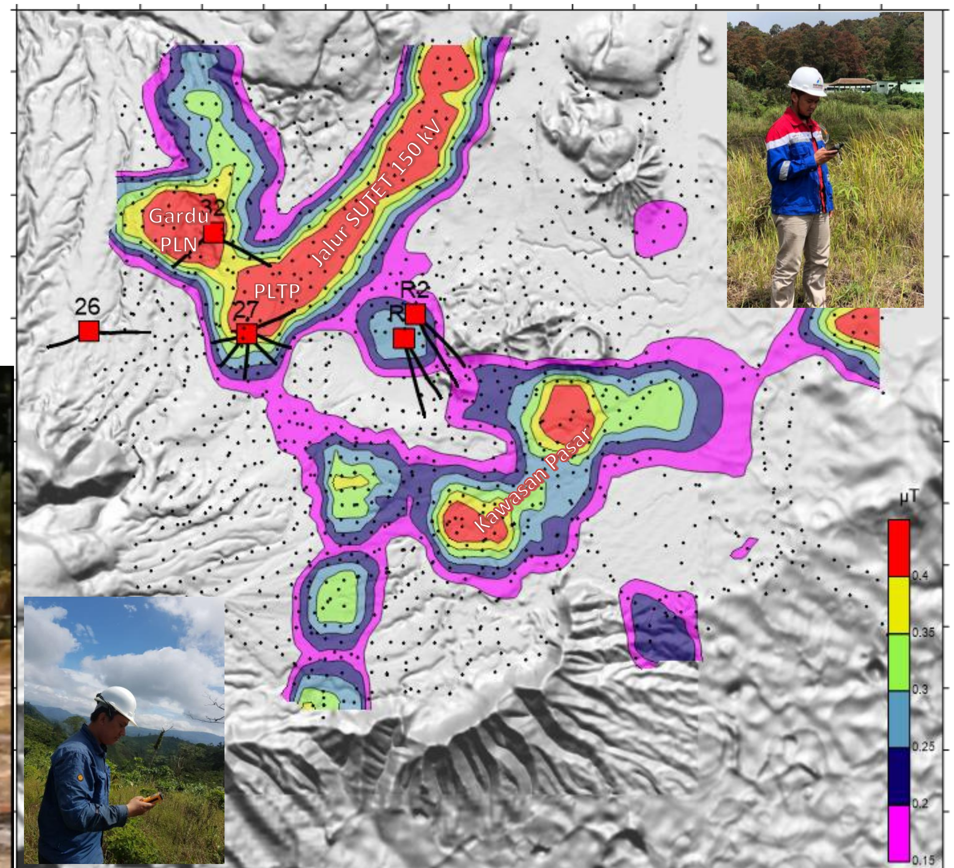
50-70 Station measurement/day

MT measurements cannot be carried out in areas that have high electromagnetic fields



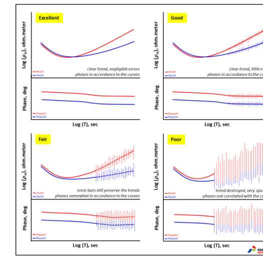
1. Noise Identification Using Electromagnetic Field Detector

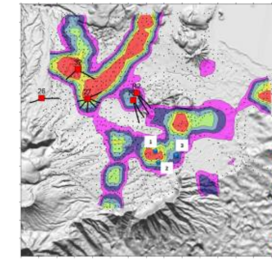
- Mapping High Electromagnetic Field Distribution
- 1314 Stations measurement
- Spacing station ±200m
- 50-70 Station measurement/day
- **MT measurements cannot be carried out in areas that have high electromagnetic noise**



1. Noise Identification Using Electromagnetic Field Detector

Pengukuran MT dapat dilakukan pada noise level EM <0.35 μT

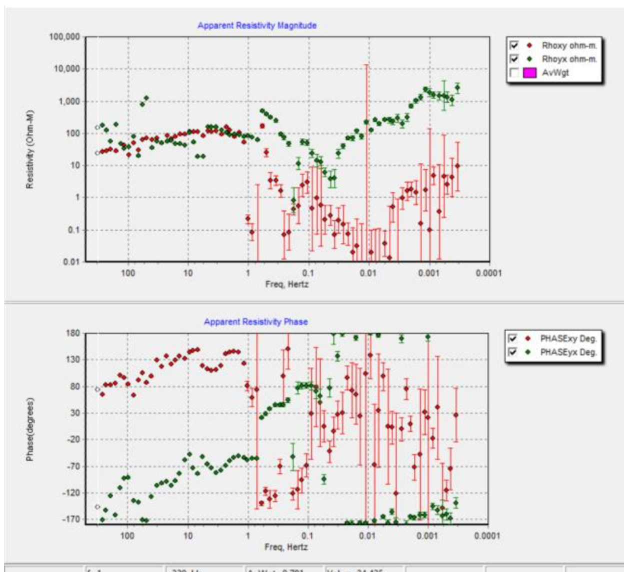




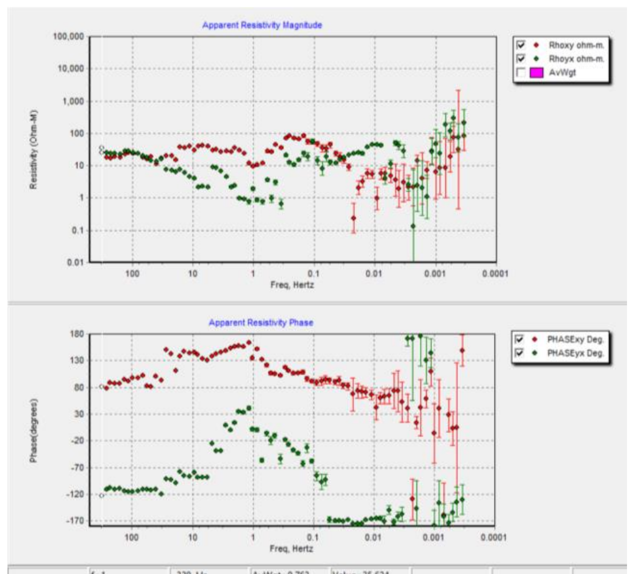
$$\overrightarrow{Z + n_Z} = \frac{[\overrightarrow{E_{0x}} + n_E]}{[\overrightarrow{H_{0y}} + n_H]}$$

Acceptable Noise EM Limit 0.35 μT

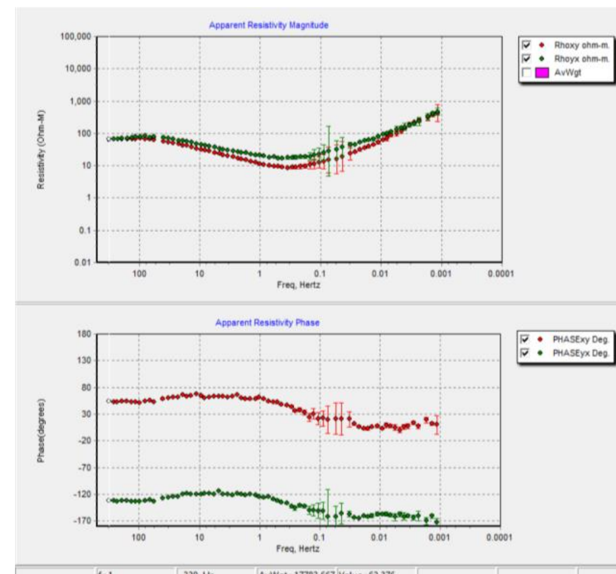
1. EM 0.95 μT



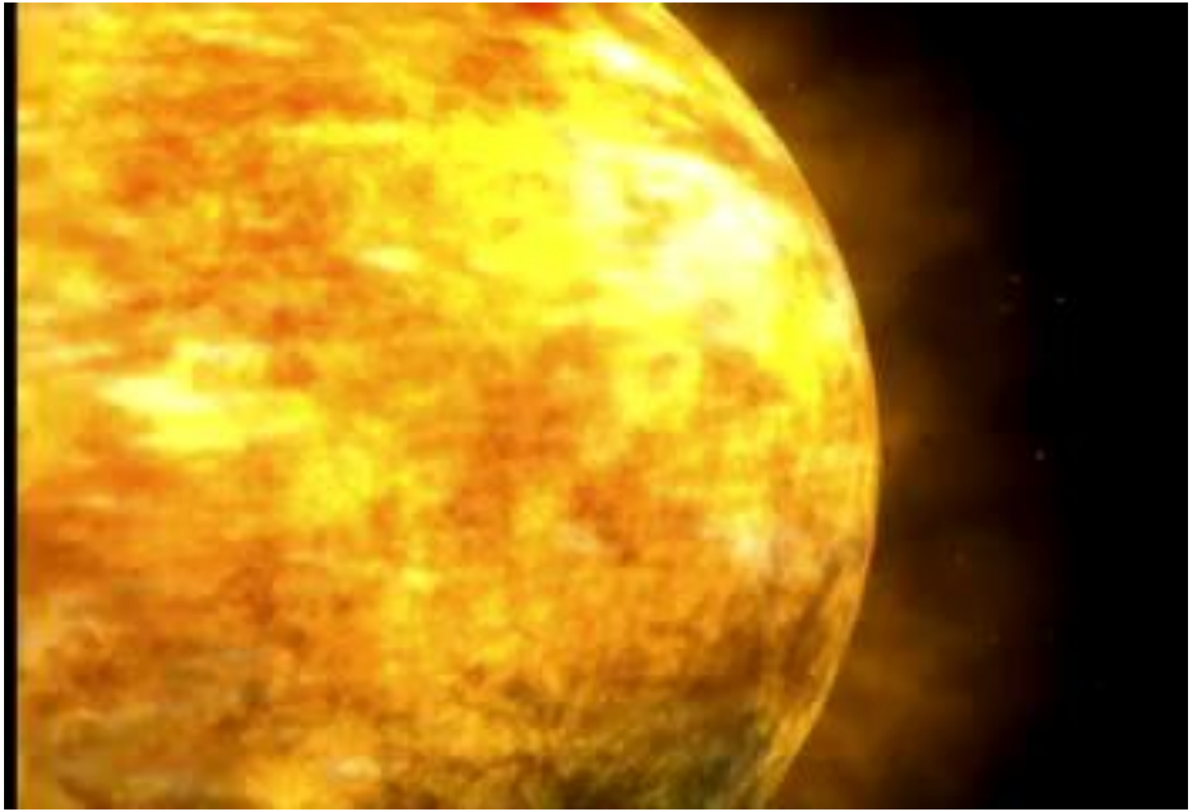
2. EM 0.65 μT

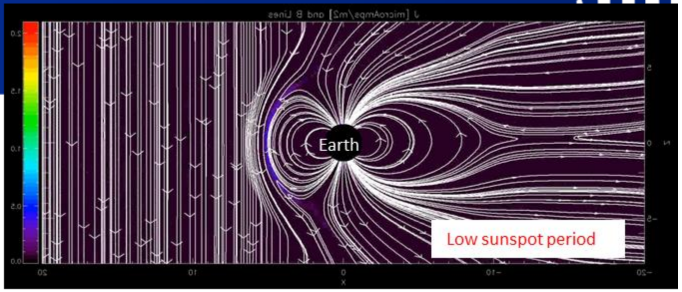


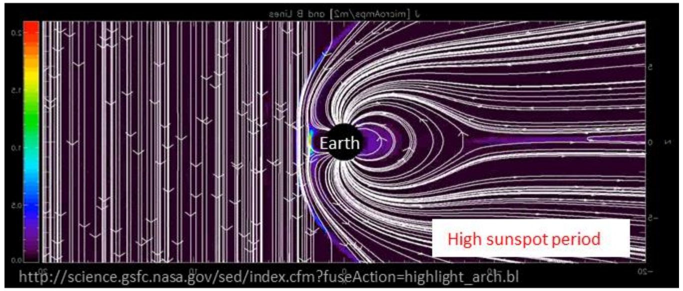
3. EM 0.35 μT

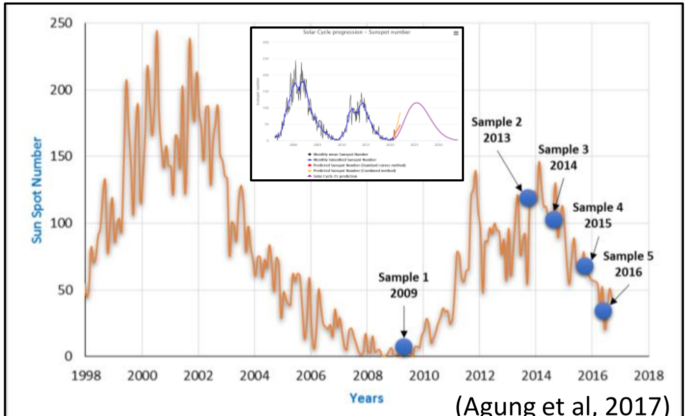


2. Sun Spot Data Correlation









(Agung et al, 2017)

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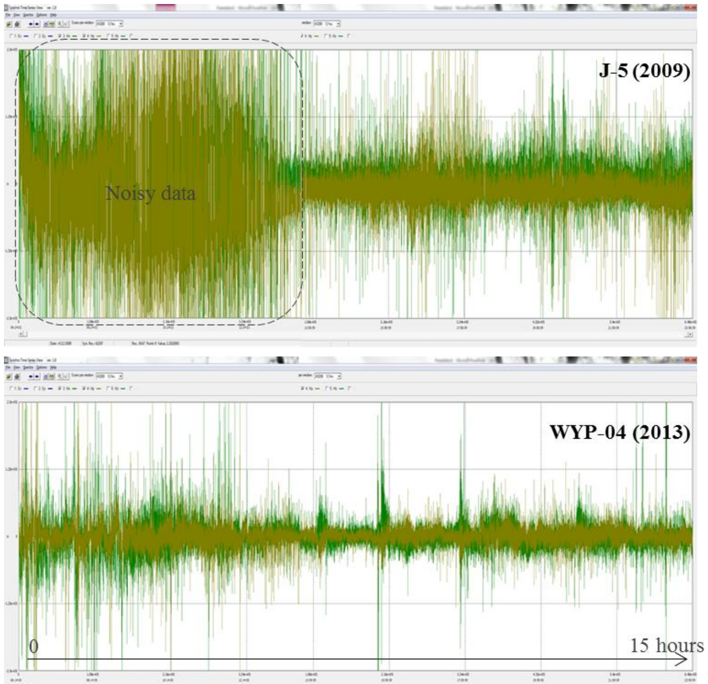
GEOTHERMAL ENERGY

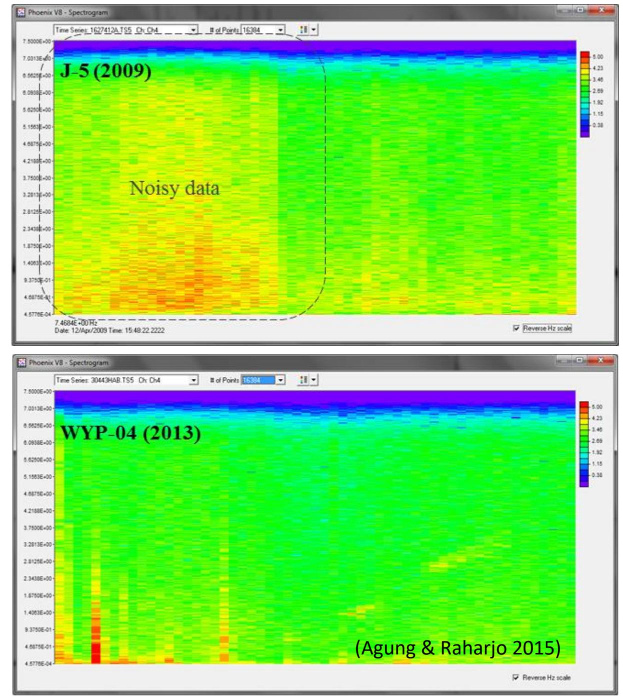
2. Sun Spot Data Correlation

Time-series Dan Analisa Spectogram

- Raw Data analysis to identify noise content on time series data during measurement
- Several hours at the beginning of data MT measurement contains higher noise level compared to the entire remaining data set in 2009 → **2013 reveals less noise**



Time-Series Comparison



Spectrogram Comparison

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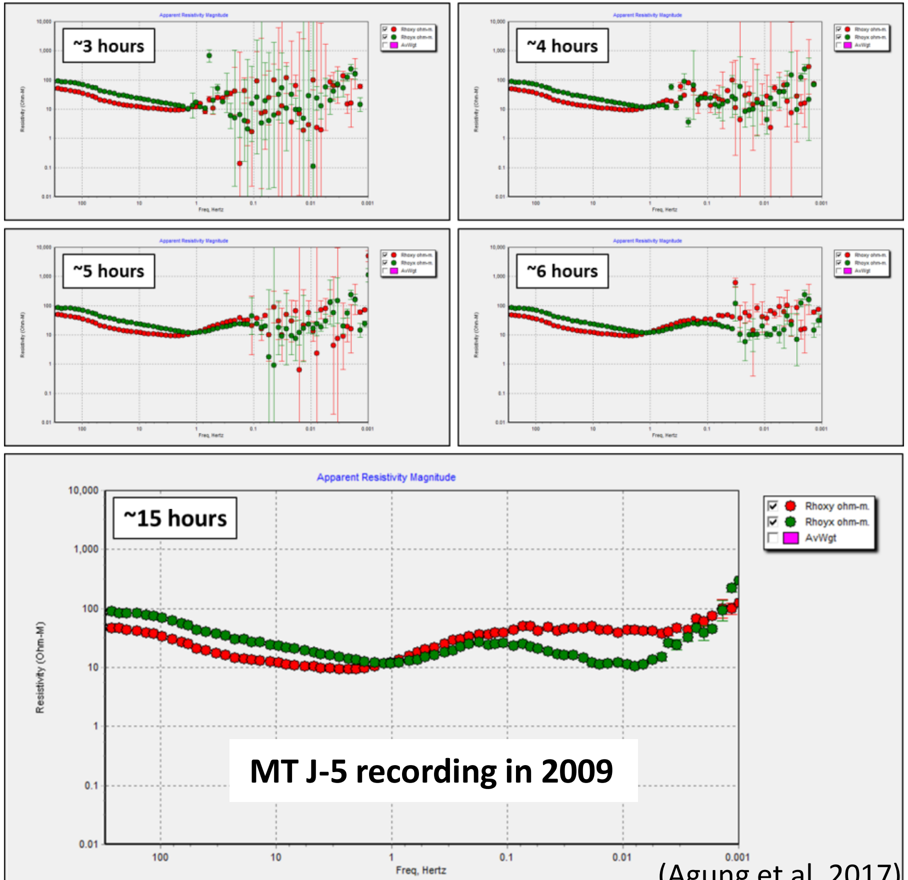
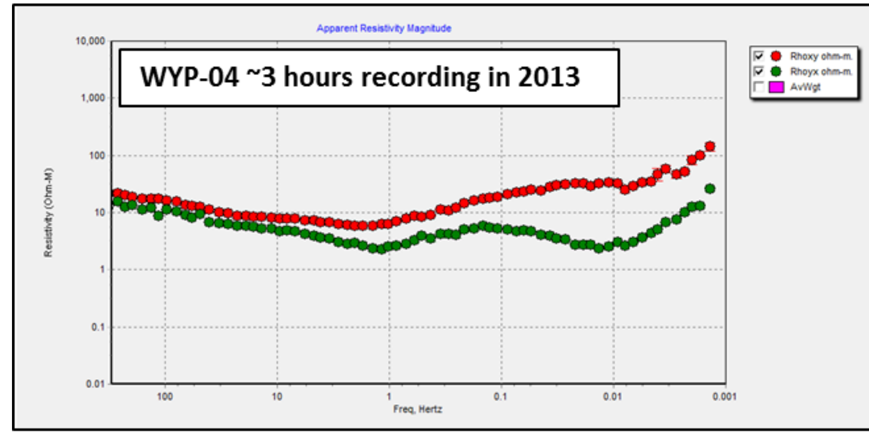
2. Sun Spot Data Correlation



(Agung et al, 2017)



(Agung & Raharjo, 2015)

MT Signal to Noise Ratio related with Sun Spot Number Activity

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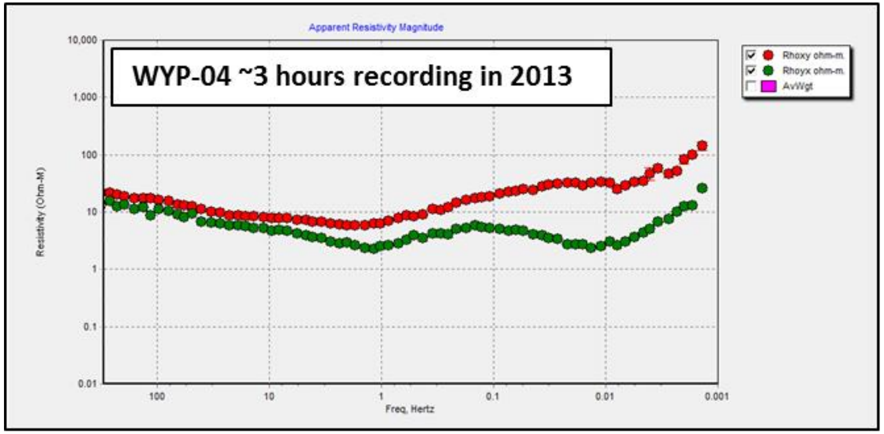
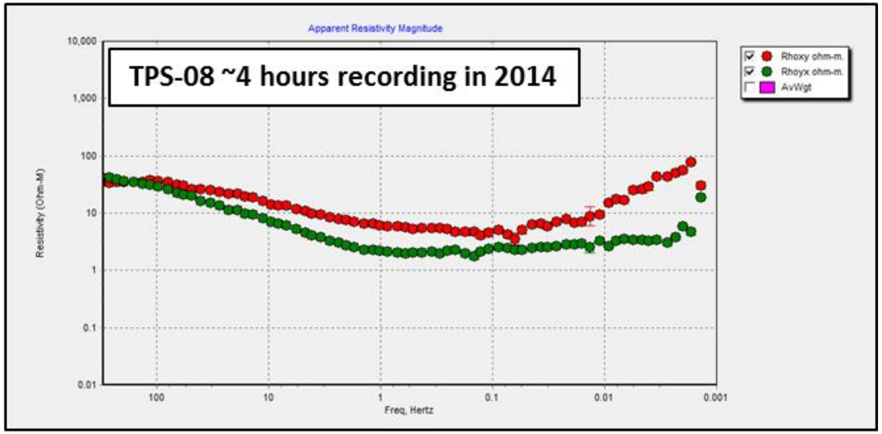
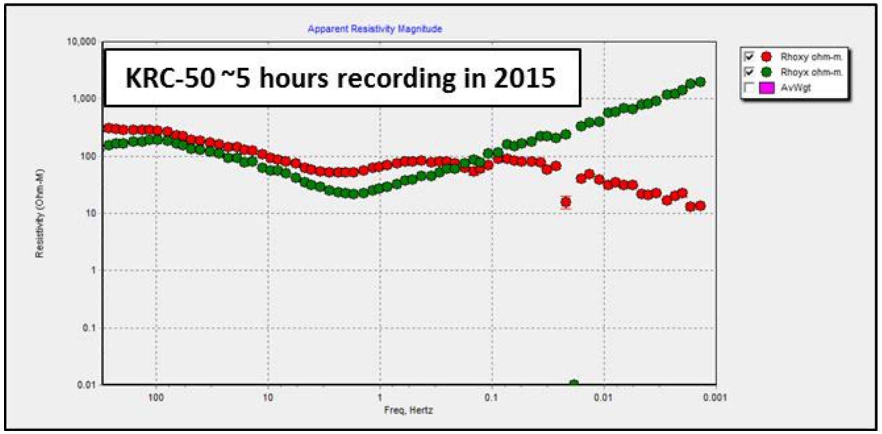
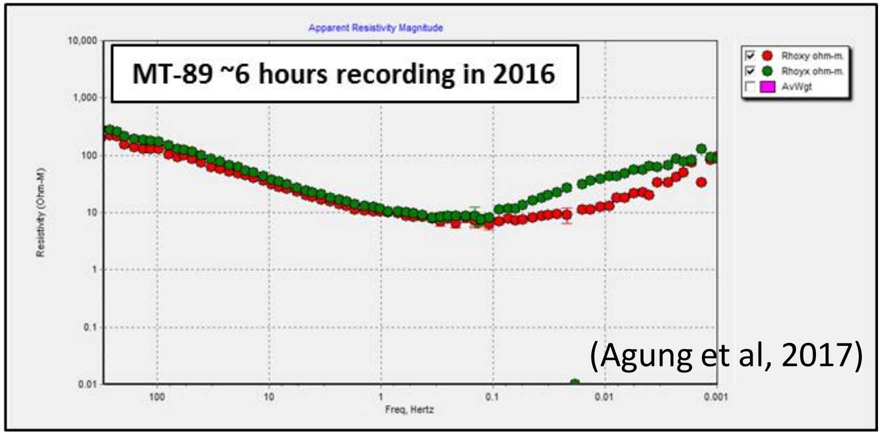
2. Sun Spot Data Correlation



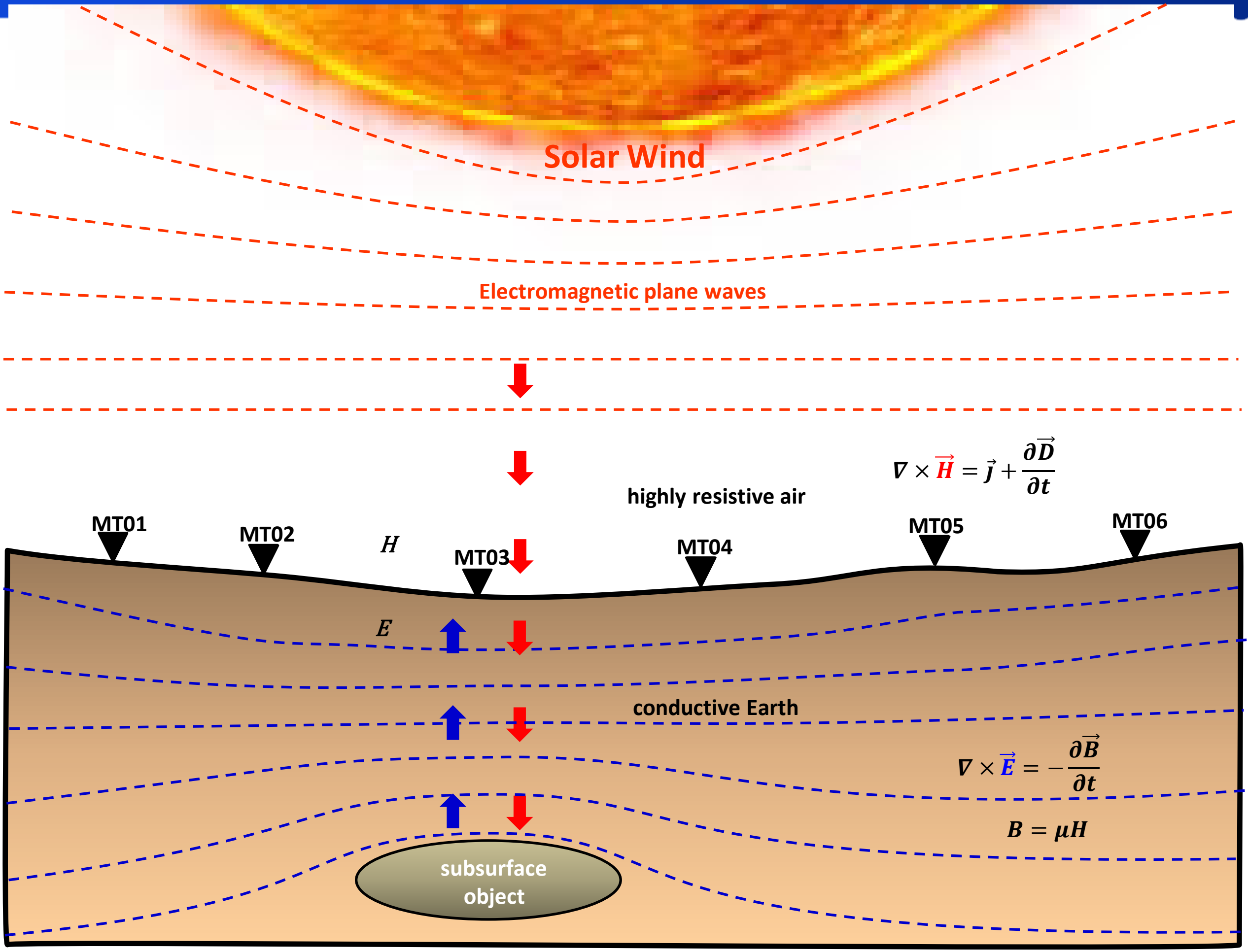


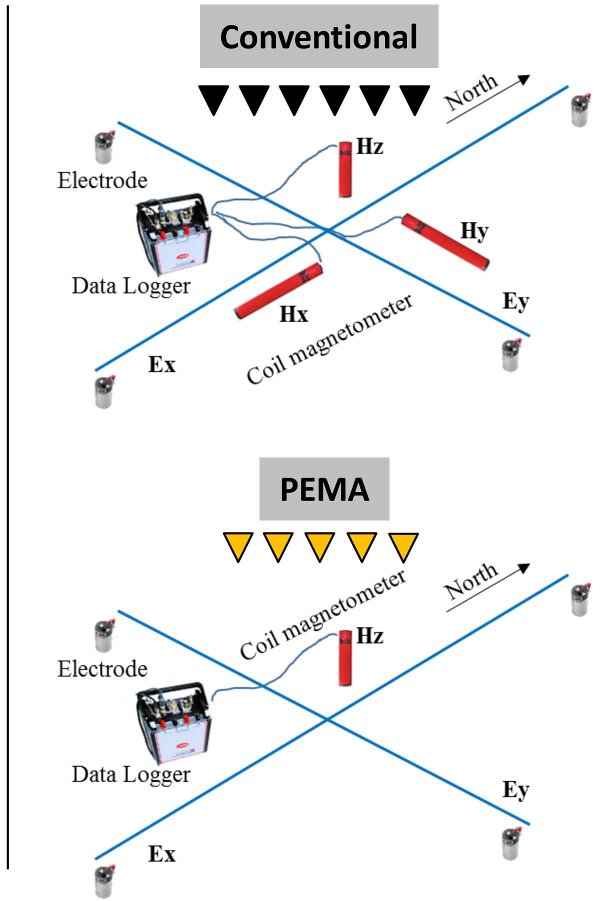




(Agung et al, 2017)

3. Partial Electromagnetic Array Measurement



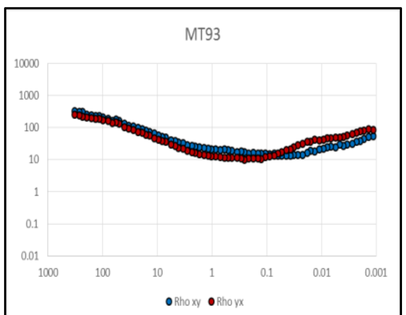


3. Partial Electromagnetic Array Measurement

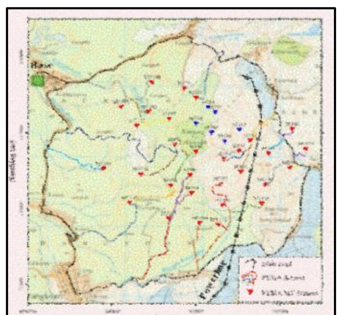
1 Orientasi medan

2 Identifikasi *noise*

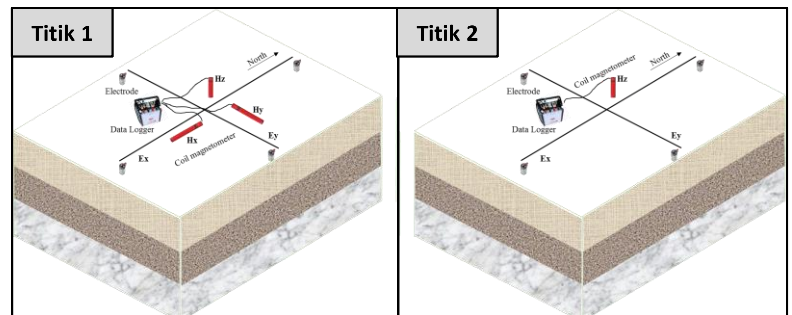
3 *Trial & Error* Pengukuran



4 Analisis Hasil



5 Skenario Pergerakan



6 *Quick Sounding* + PEMA (2 titik pada waktu yang sama)

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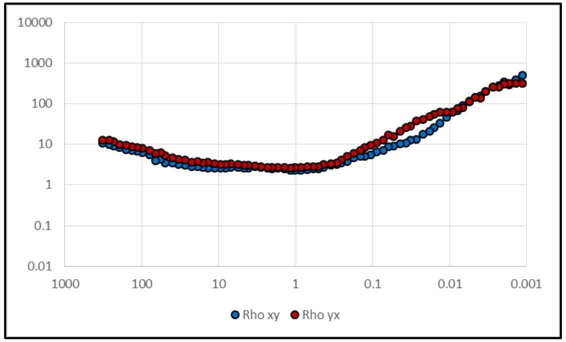
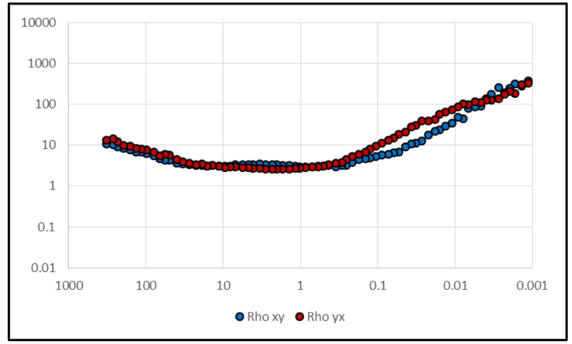
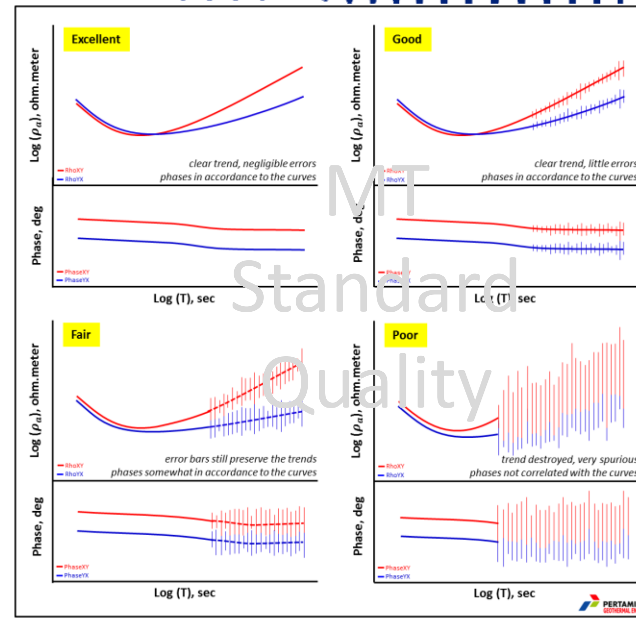
3. Partial Electromagnetic Array Measurement

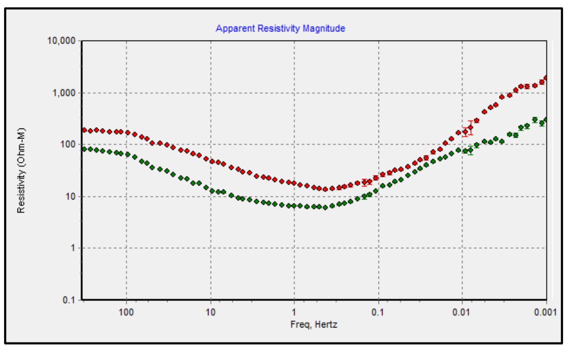


Conventional TPS-09

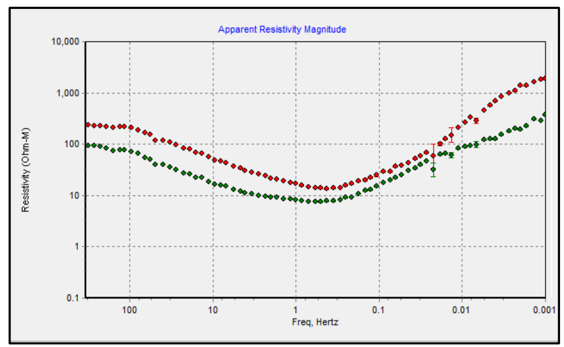


PEMA TPS-09





Conventional KMJ-18



PEMA KMJ-18

Hasil metode PEMA pada kurva MT relatif sama jika dibandingkan dengan metode conventional yang memanfaatkan medan magnetik horizontal local.

4. Dimentional Subsurface Analysis

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \begin{pmatrix} H_x \\ H_y \end{pmatrix}$$

***1-D → $\boldsymbol{Z_{xx} = Z_{yy} = 0 \; ; \; Z_{xy} = Z_{yx} = Z}$**

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} 0 & Z \\ Z & 0 \end{pmatrix} \begin{pmatrix} H_x \\ H_y \end{pmatrix}$$

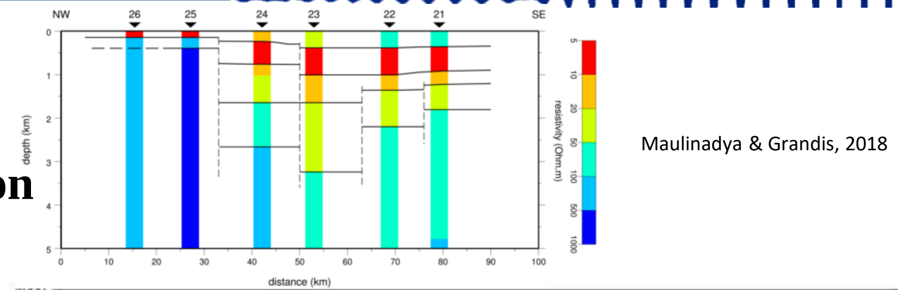
***2-D → $\boldsymbol{Z_{xx} = Z_{yy} = 0}$**

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} 0 & Z_{xy} \\ Z_{yx} & 0 \end{pmatrix} \begin{pmatrix} H_x \\ H_y \end{pmatrix}$$

***3-D → Full Impedance**

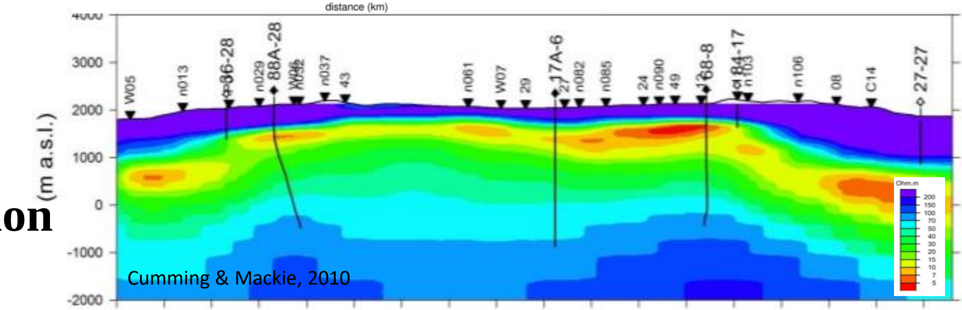
$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \begin{pmatrix} H_x \\ H_y \end{pmatrix}$$

1-D Inversion

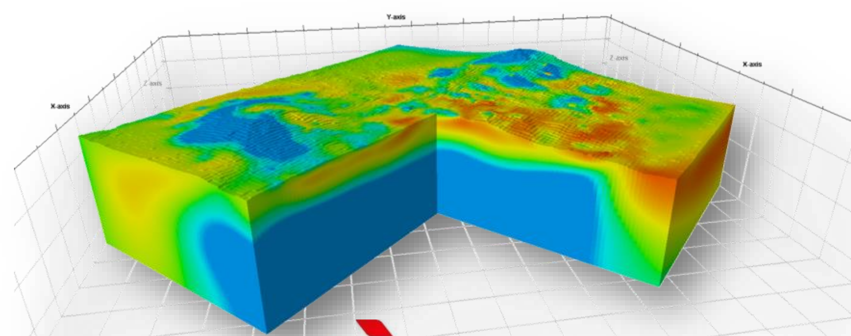


Maulinadya & Grandis, 2018

2-D Inversion

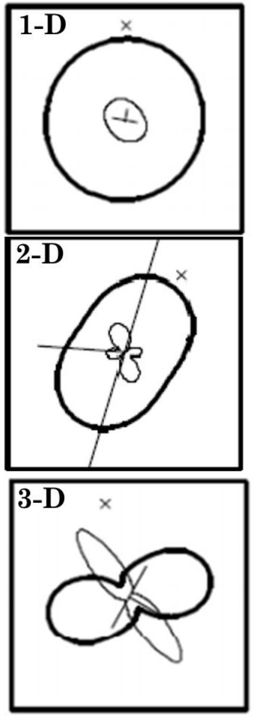


3-D Inversion



4. Dimentional Analysis

1. Polar Diagram: To find out the anisotropy of medium



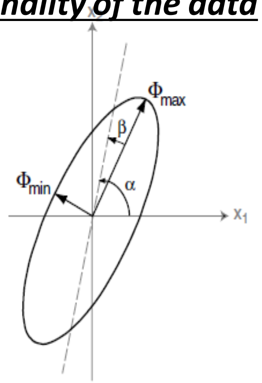
Zxx = Zyy = 0
Zxy = - Zyx

Zxx = Zyy = 0
Zxy ≠ Zyx

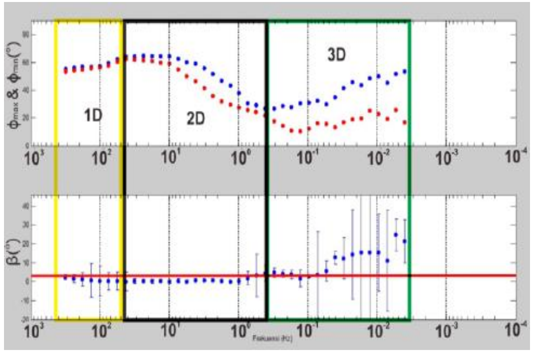
Zxx ≠ Zyy
Zxy ≠ Zyx

Polar diagram for 1D, 2D and 3D medium (Berdichevsky and Dmitriev, 2008).

2. Phase Tensor: To know the direction of geoelectrical strike & the dimensionality of the data

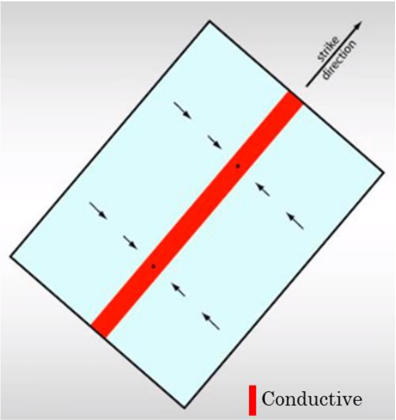


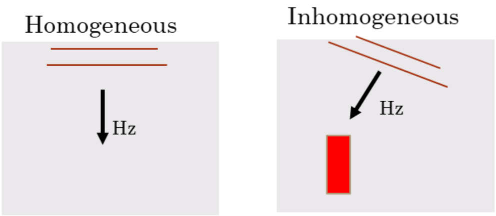
Phase ellipse (Caldwell, 2004).



Maximum phase, minimum phase and beta curve (Ramdhani, et al., 2017)

3. Tipper: To figure out the existence of conductive anomalies





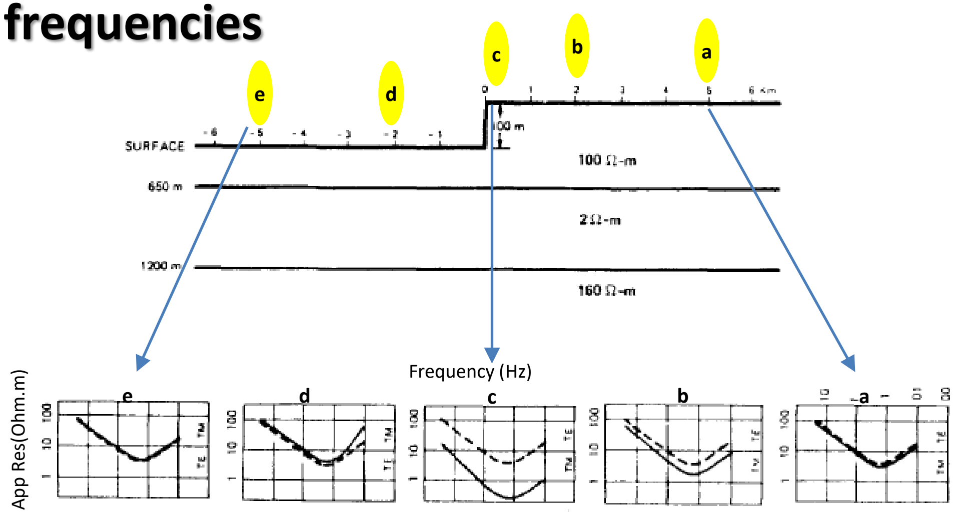
Vector direction of the vertical magnetic induction (Modified from Unsworth, M.J. 2006).

What Next???

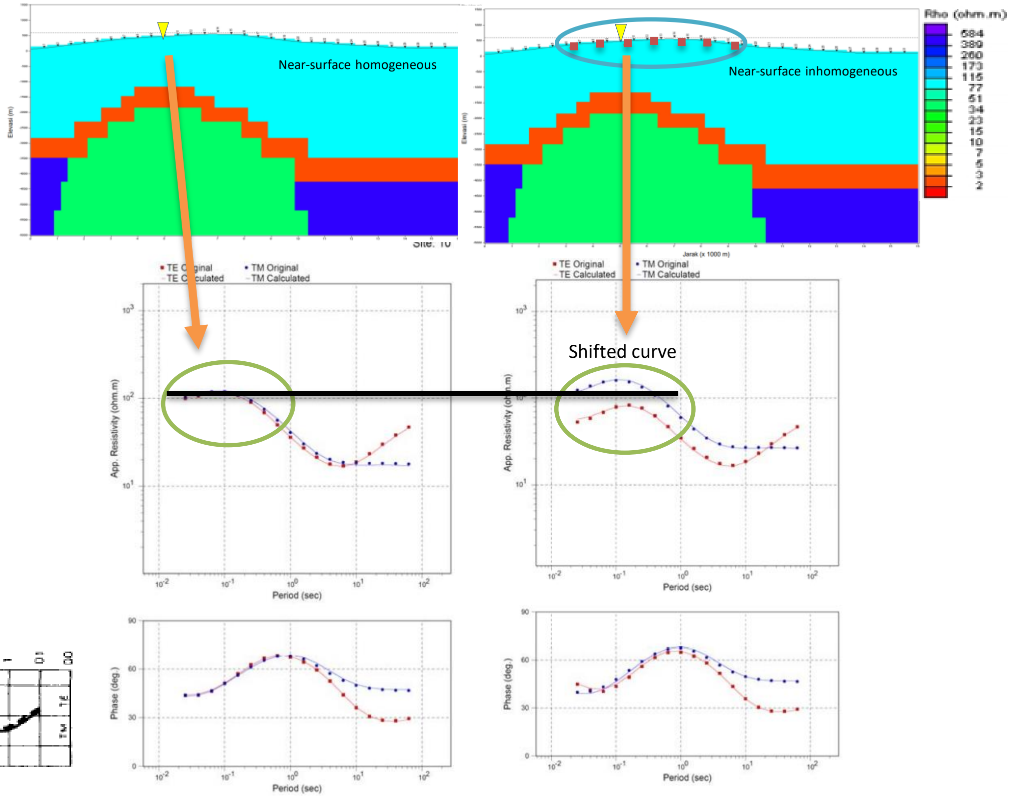
Galvanic Distorsion

The electric field distorted due to **local heterogeneity** and **topographic effects.**

MT curved **distorted from high to low frequencies**



Topographic distortions (Jiracek,1990).



Near-surface distortions (Grandis,2010).

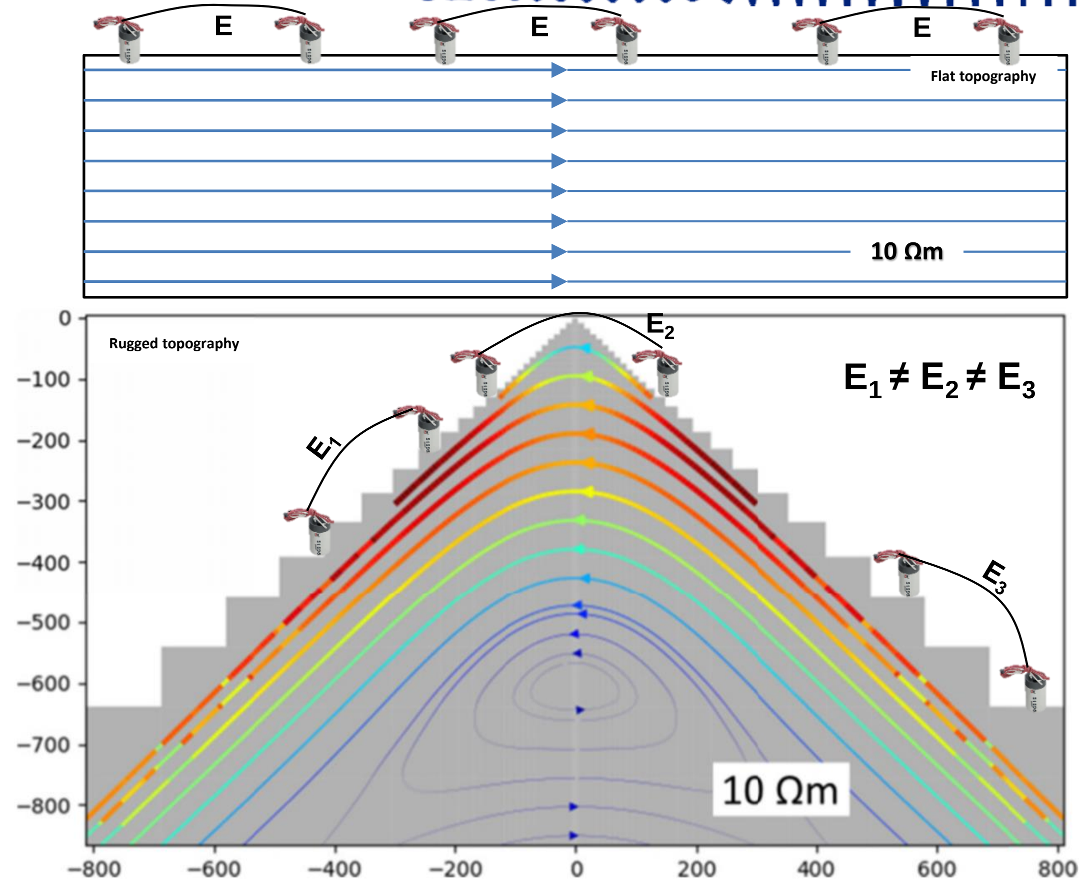
What Next???

Pemodelan data MT dengan memasukan ***parameter posisi sensor MT***

Membuat ***model streamline – current density*** berdasarkan perbedaan elevasi

Mempertimbangan ***efek perbedaan streamline - current density*** terhadap bacaan sensor MT

Meningkatkan resolusi dan akurasi



**Streamline width and coloring related to absolute current density*

Thank You

Semoga keberkahan dan kebermanfaatan untuk semua

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