Monitoring Coal Seam Gas Depressurisation Using Magnetotellurics*

Nigel Rees[1], Graham Heinson[1], and Lars Krieger[1]

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Abstract

The depressurisation of coal seam gas (CSG) formations causes in situ fluids to migrate through pores and fractures in the Earth. The removal of large volumes of water from coal seams has the potential to affect water table levels and groundwater flow. Magnetotellurics (MT) is a passive electromagnetic technique that utilises the natural fluctuations of electric and magnetic fields at the Earth's surface to determine the conductivity structure of Earth. The bulk movement of fluids during CSG depressurisation causes a conductivity change in the subsurface and this change can be continuously monitored by deploying an array of magnetotelluric instruments. Various techniques will be presented to analyse a magnetotelluric CSG monitoring dataset. Firstly, we examine electric phase tensors and quasi-electric phase tensors and compare these with standard MT responses. These tensors relate the electric fields at survey sites with the electric or magnetic fields at base sites and are almost or entirely free from distortion effects. Secondly, we apply eigenanalysis and singular value decomposition (SVD) methods to the distortion tensor. Both techniques can be used to determine the geologic strike direction for the two-dimensional (2D) case as well as determining if a situation is far from two-dimensional such that 2D modelling is not justified. The results of eigenanalysis and SVD can be displayed on a Mohr diagram, which is a useful way to display a wide range of properties of the distortion matrix. Finally, we link the above analysis to standard 1D and 2D inversions of our dataset. 2D models of resistivity show the spatial pattern of change pre- and post- CSG production. 1D time-lapse inversions show the temporal variations in sub-surface resistivity as a function of time.

Monitoring Coal Seam Gas Depressurisation Using Magnetotellurics

THE UNIVERSITY of ADELAIDE

Nigel Rees, Graham Heinson, Lars Krieger

Project Objectives

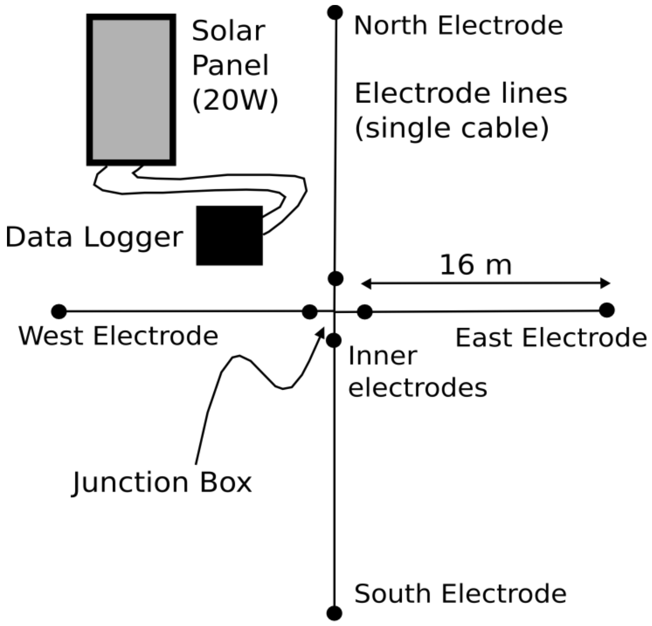
Monitor the movement of fluids and changes in the Earth resulting from CSG production

Understand what direction fluids and gases move and how far they migrate

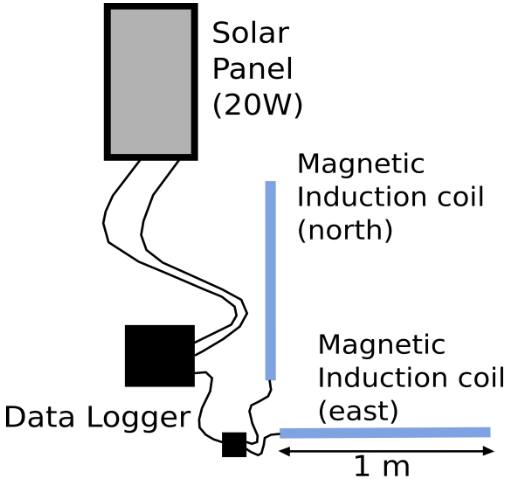
Determine the short and long-term consequences of CSG production

How does MT work?

Records time variations of Earth's magnetic and electric fields over a wide frequency range to image electrical resistivity (conductivity) structure with depth



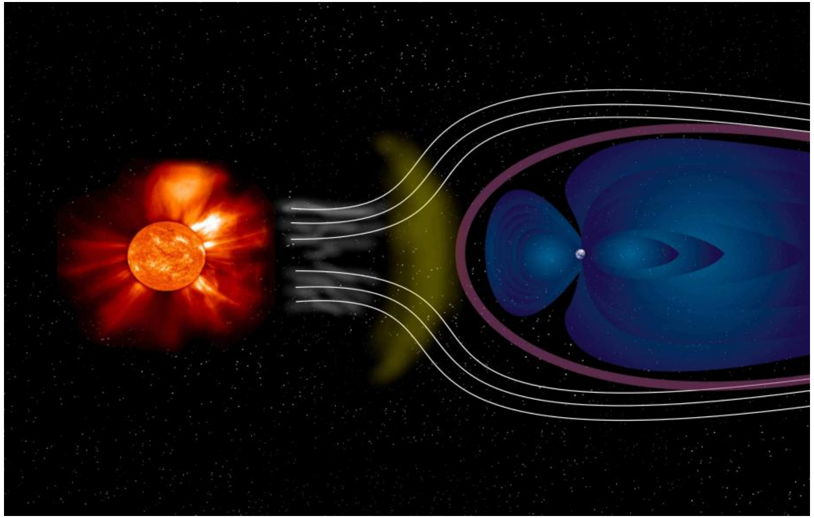
E-logger setup



B-logger setup

Source fields

Low frequencies (<1 Hz): Interaction of the solar wind with the Earth's magnetic field.



High frequencies (>1 Hz): World-wide thunderstorm activity, usually near the equator.

Dead Band: 10^0 to 10^{-1} Hz (1 to 10s): Natural EM fluctuations have a low intensity. Skin depths 1.5 to 15 km, upper middle crust.

Depth of investigation – skin depth

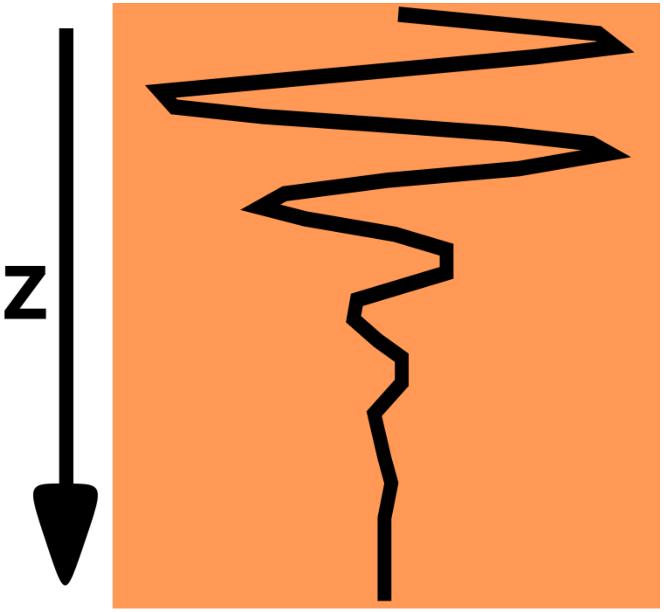
$$\delta = \sqrt{\frac{2}{\mu_0 \sigma \omega}} \approx 500\sqrt{T\rho}$$

T is the period

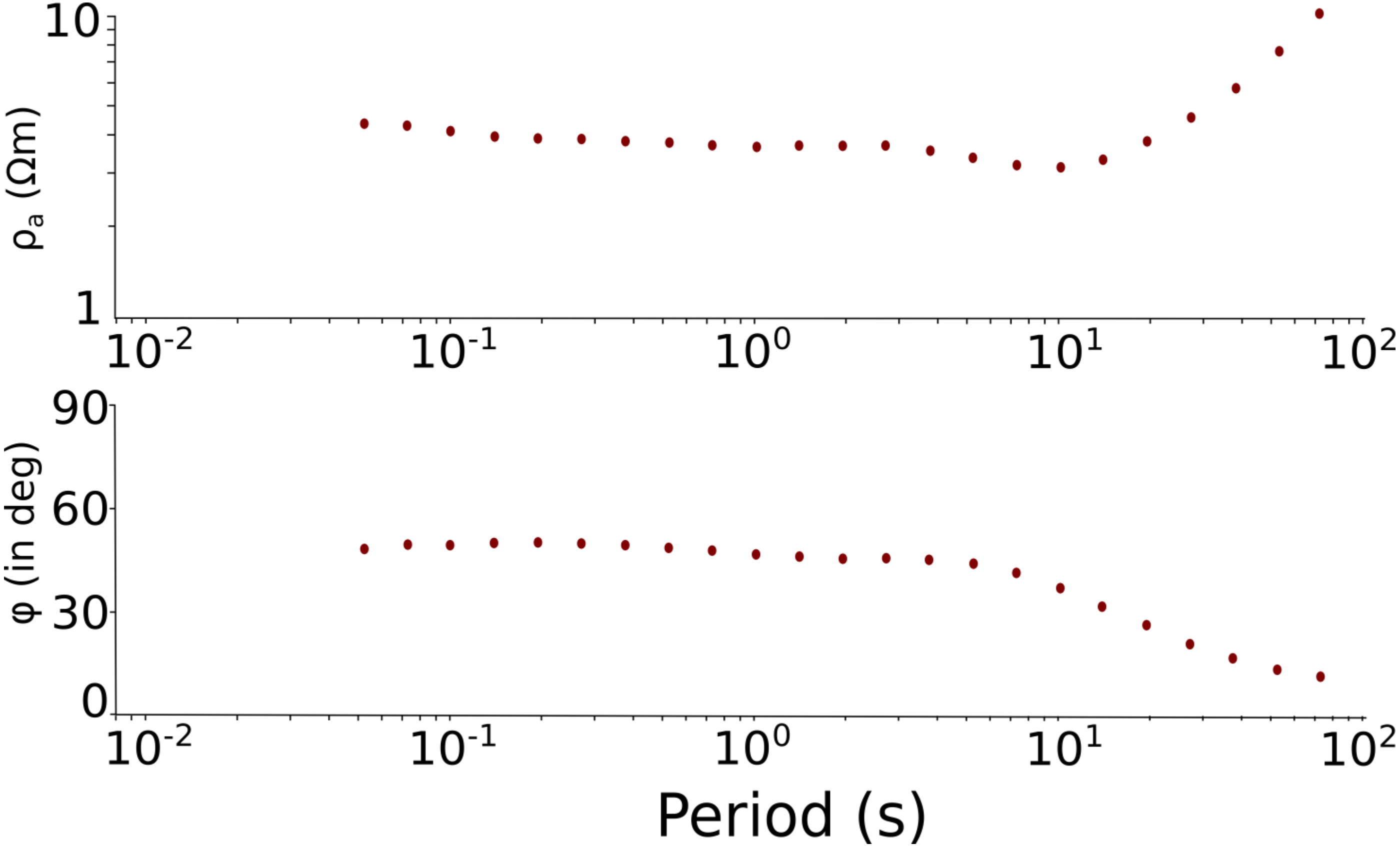
ρ is the apparent resistivity

High frequencies image the near-surface

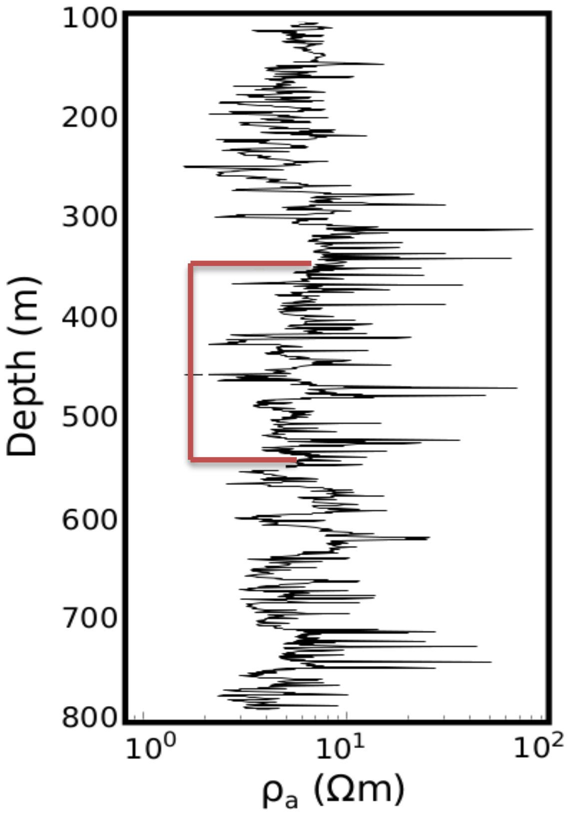
Low frequencies penetrate to greater depths

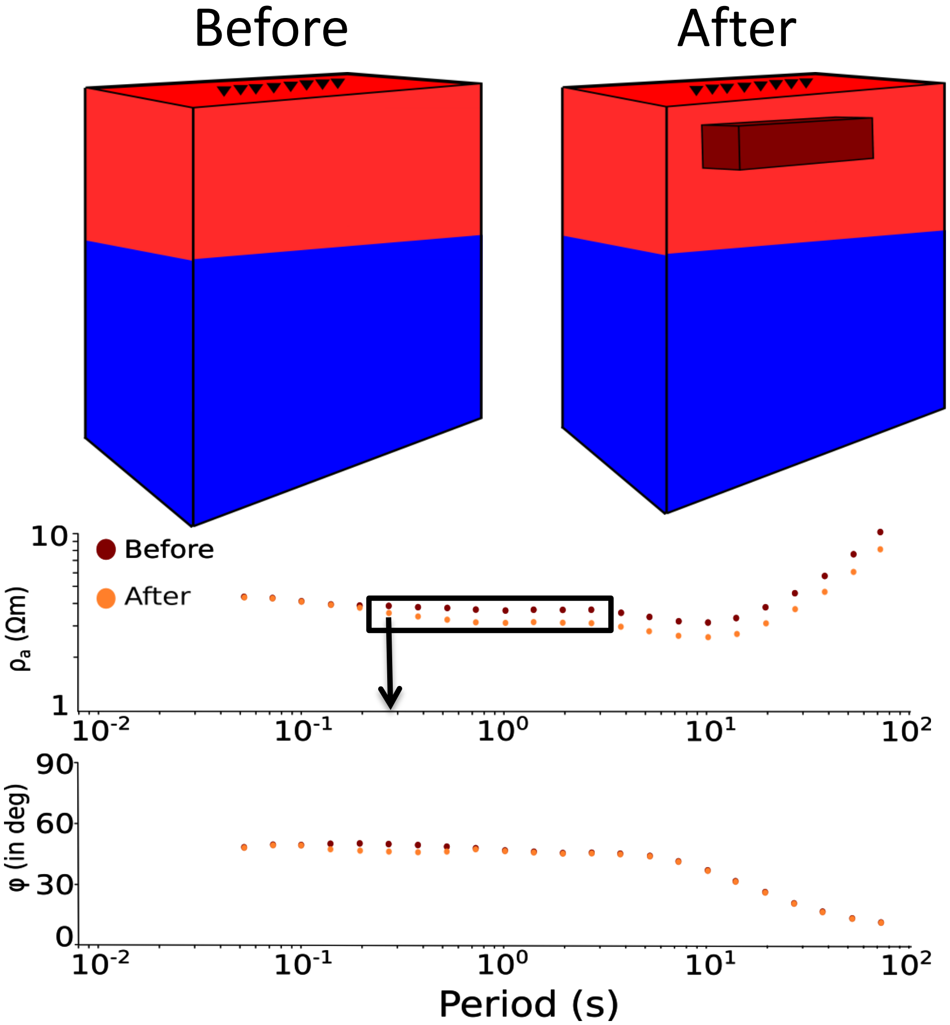


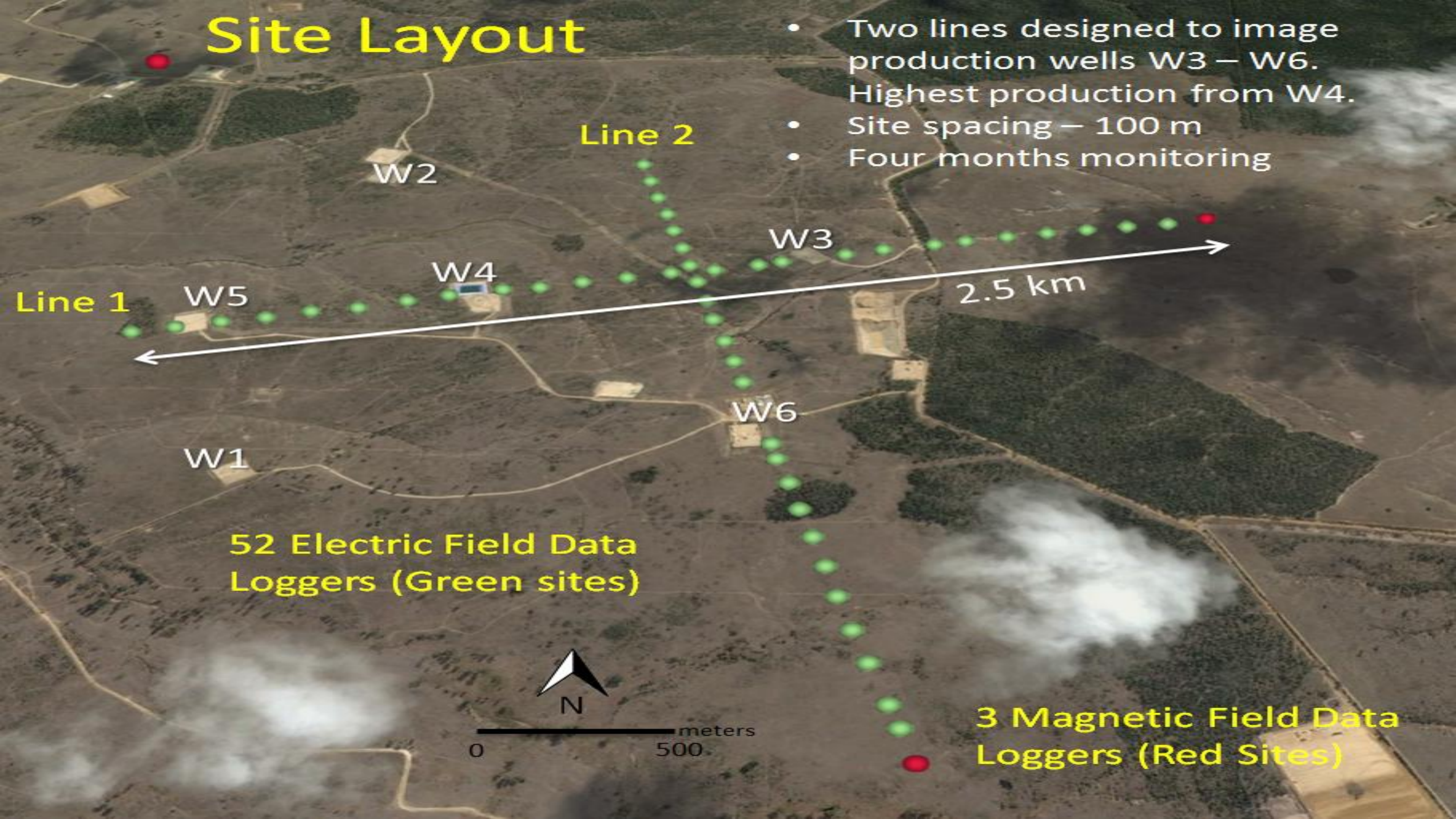
Apparent resistivity and phase



Forward modelling






Site Layout
• Two lines designed to image production wells W3 – W6. Highest production from W4.
• Site spacing – 100 m
• Four months monitoring
Line 2
W2
W3
W4
W5
Line 1
2.5 km
W6
W1
52 Electric Field Data Loggers (Green sites)
N
0
500
meters
3 Magnetic Field Data Loggers (Red Sites)

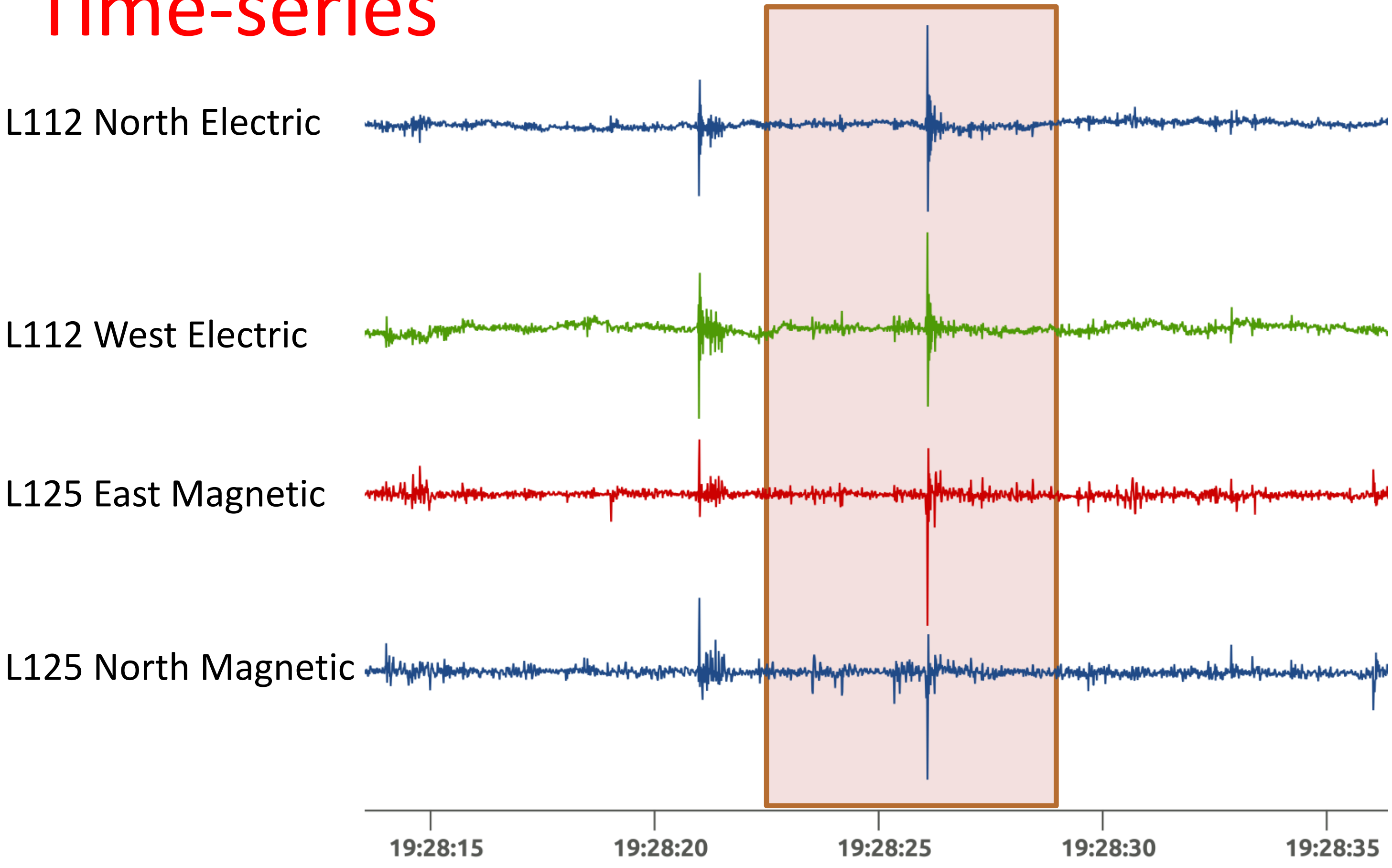
Instrumentation

Electric (E) logger setup:
- 4 sets of dipoles of length 16m
- 8 unpolarisable Pb-$PbCl_2$ NaCl electrodes

Magnetic (B) logger setup:
- 2 LEMI-120 induction coil magnetometers set up horizontally orthogonal to each other
- Frequency range : 0.001 Hz - 1000 Hz

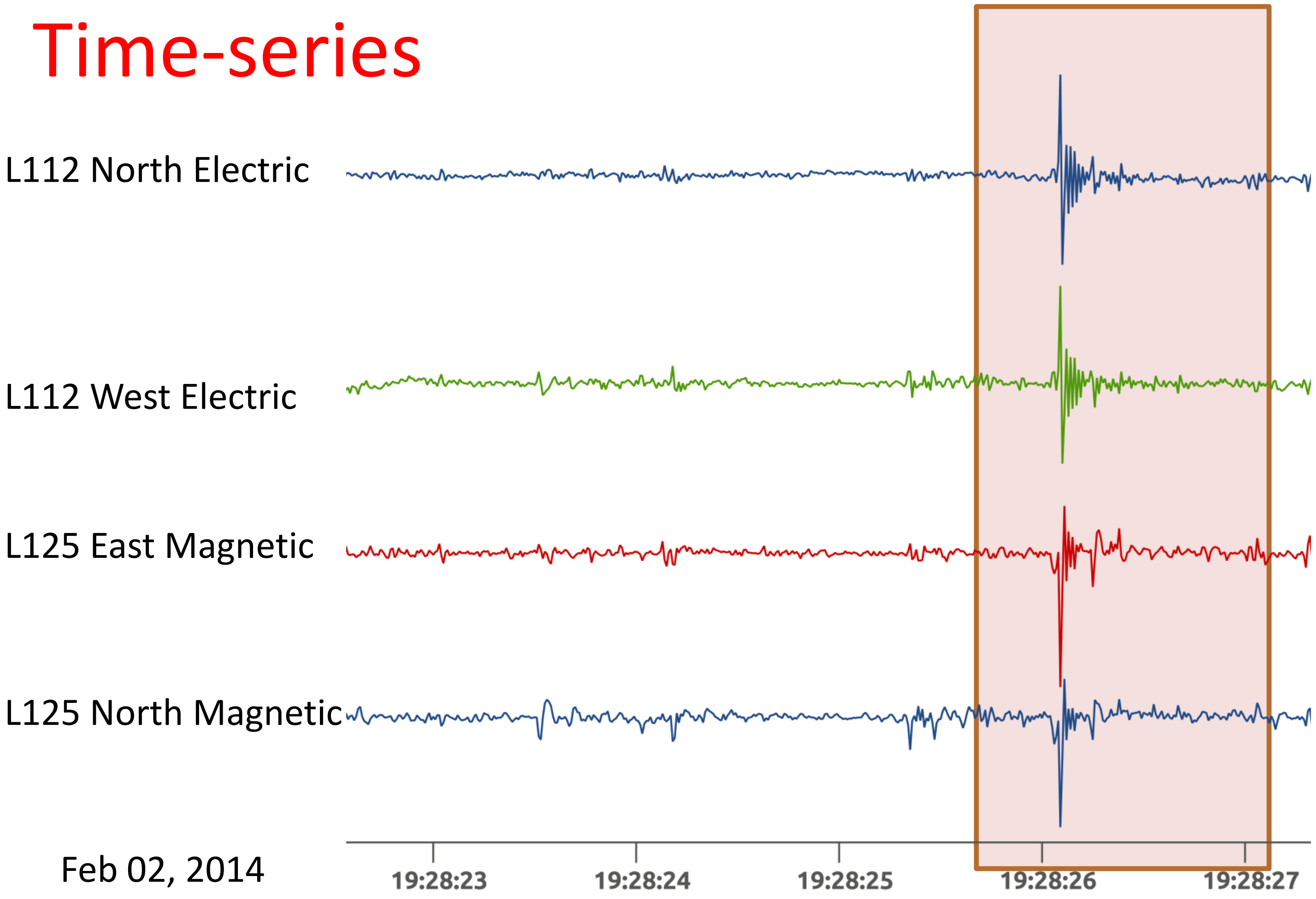
General specifications:
- Box dimensions : 40 x 30 cm^2
- Boxes are waterproof
- Powered by battery and solar panel allowing months of continuous logging
- GPS interface - Time stamping with 800 nanosecond accuracy
- 4 channel 24 bit analog and digital data acquisition system
- Can be used in the temperature range of -20° to +70°C
- Data stored on 32 GB USB drives

Time-series

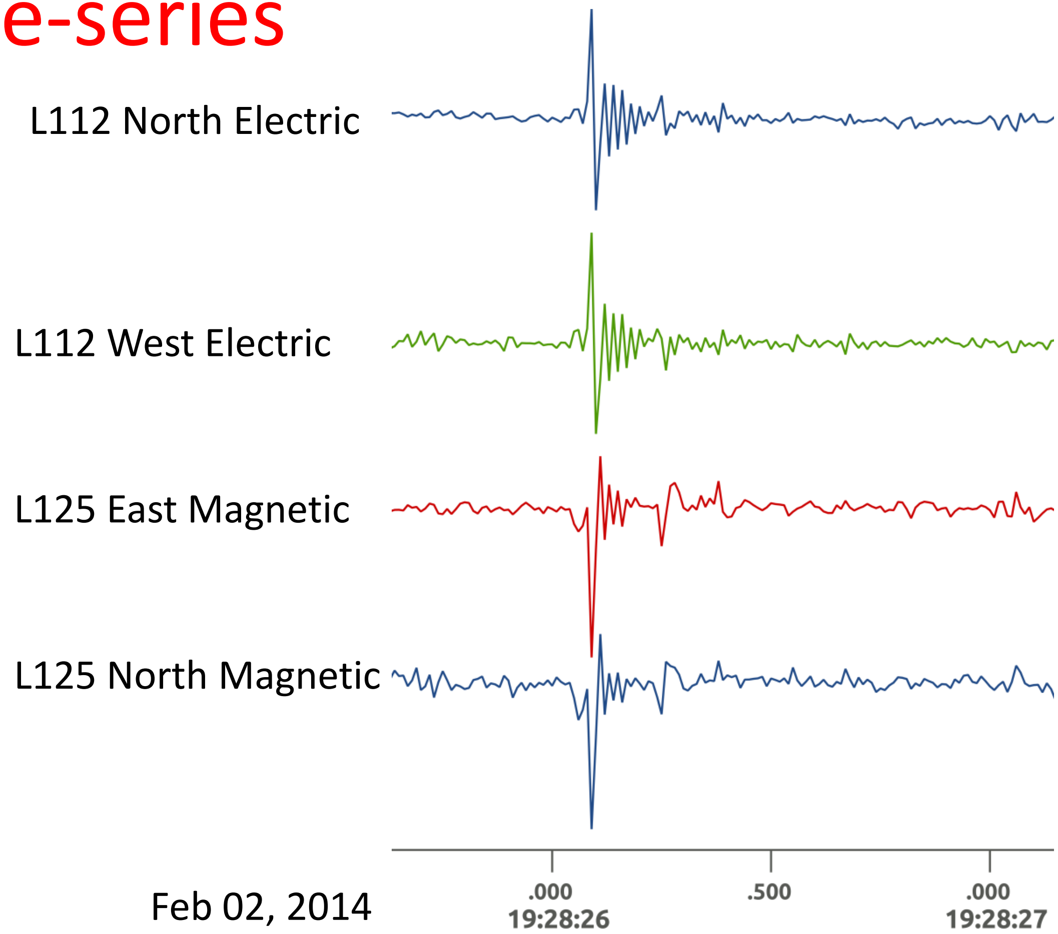


Feb 02, 2014

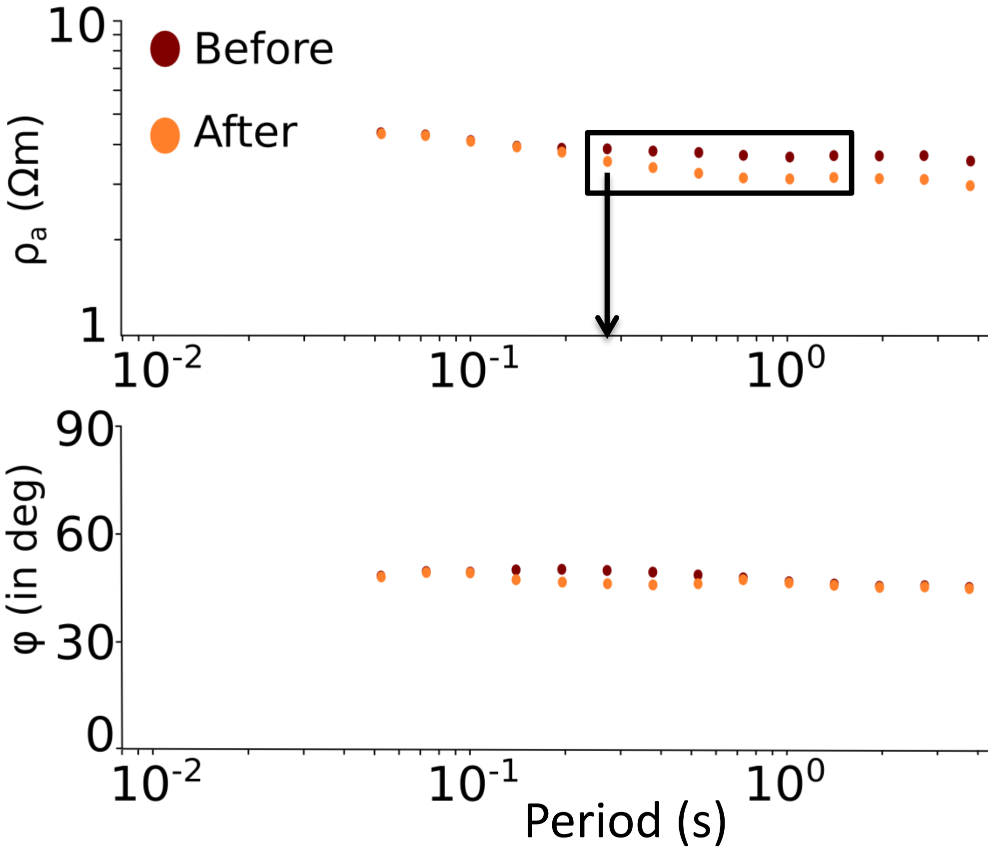
Time-series


L112 North Electric
L112 West Electric
L125 East Magnetic
L125 North Magnetic
Feb 02, 2014
19:28:23
19:28:24
19:28:25
19:28:26
19:28:27

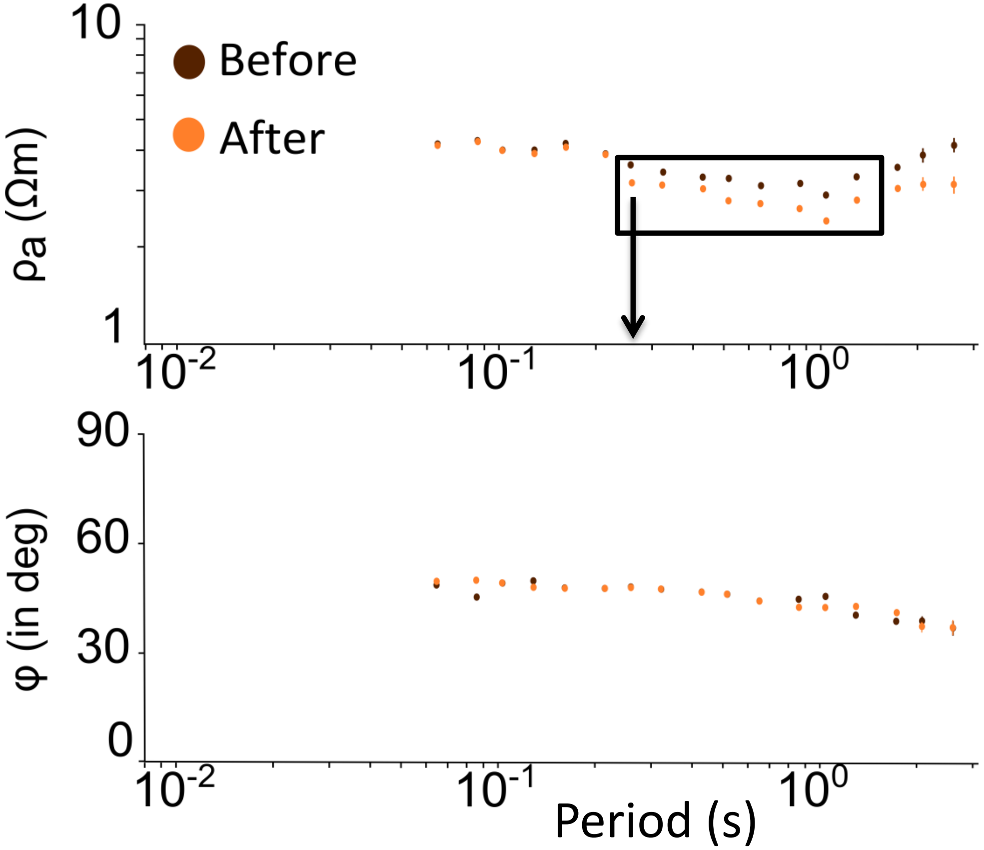
Time-series

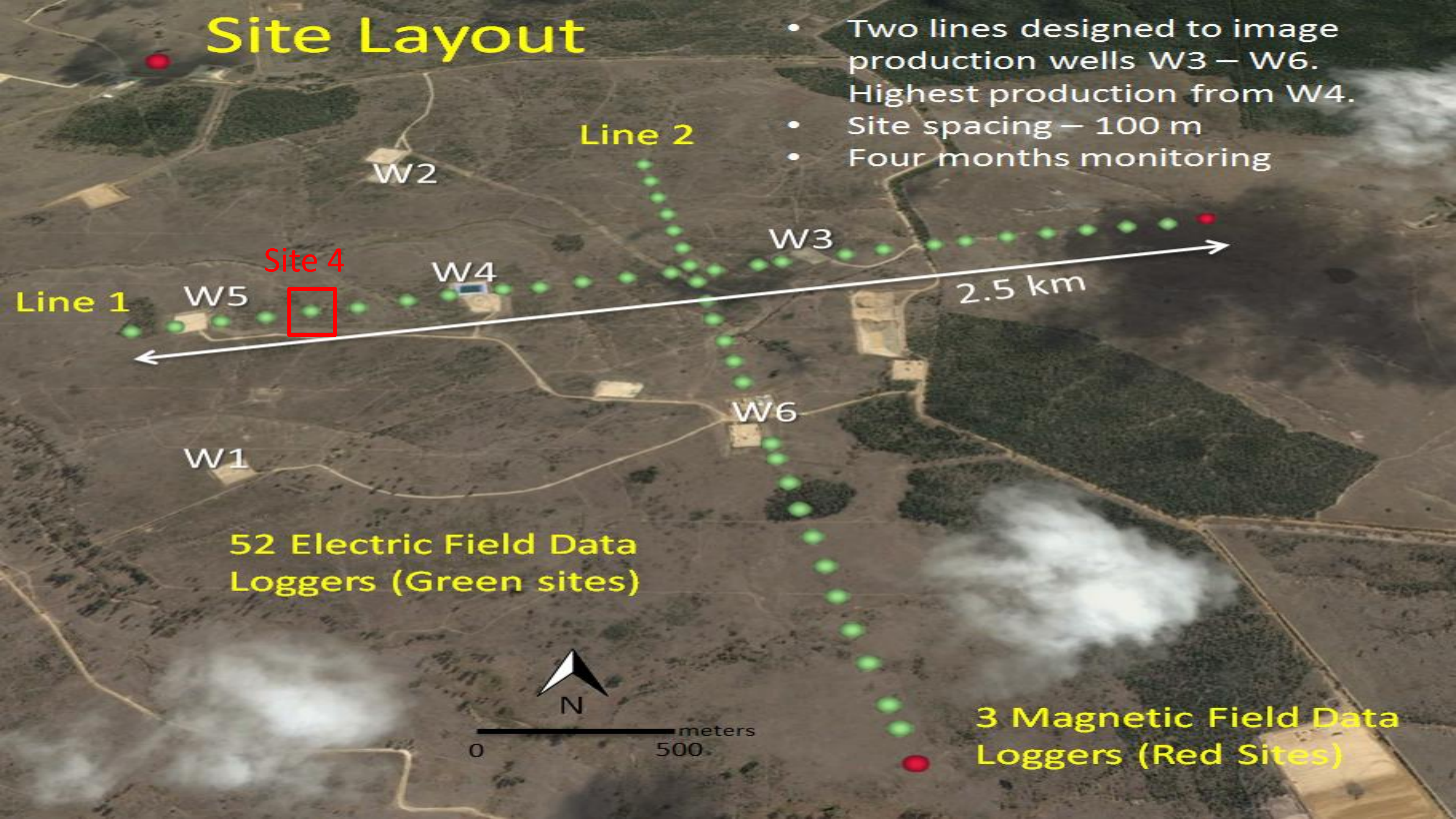

L112 North Electric
L112 West Electric
L125 East Magnetic
L125 North Magnetic
Feb 02, 2014
.000
19:28:26
.500
.000
19:28:27

Forward model predictions



Field data

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2.5 km
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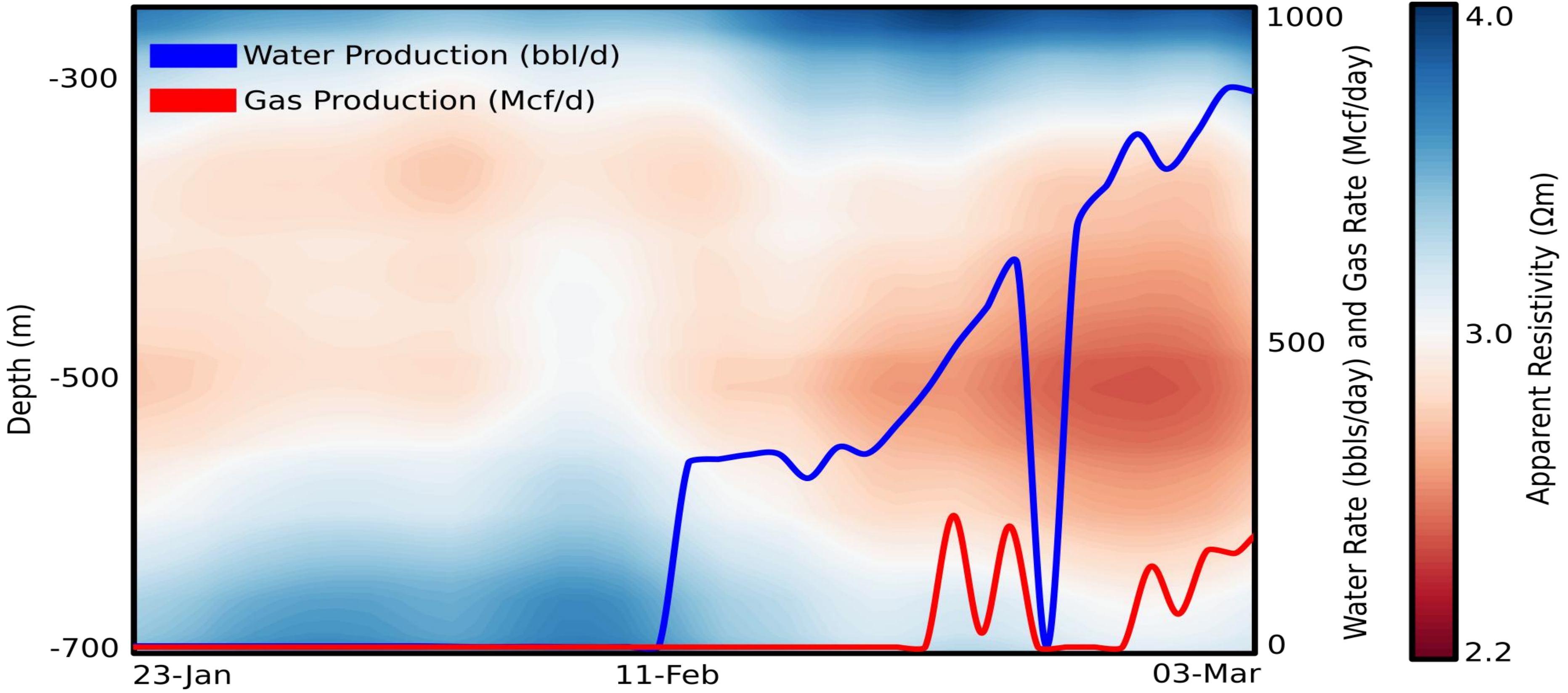
52 Electric Field Data Loggers (Green sites)
N
meters
0
500
3 Magnetic Field Data Loggers (Red Sites)

1D Time-lapse modelling



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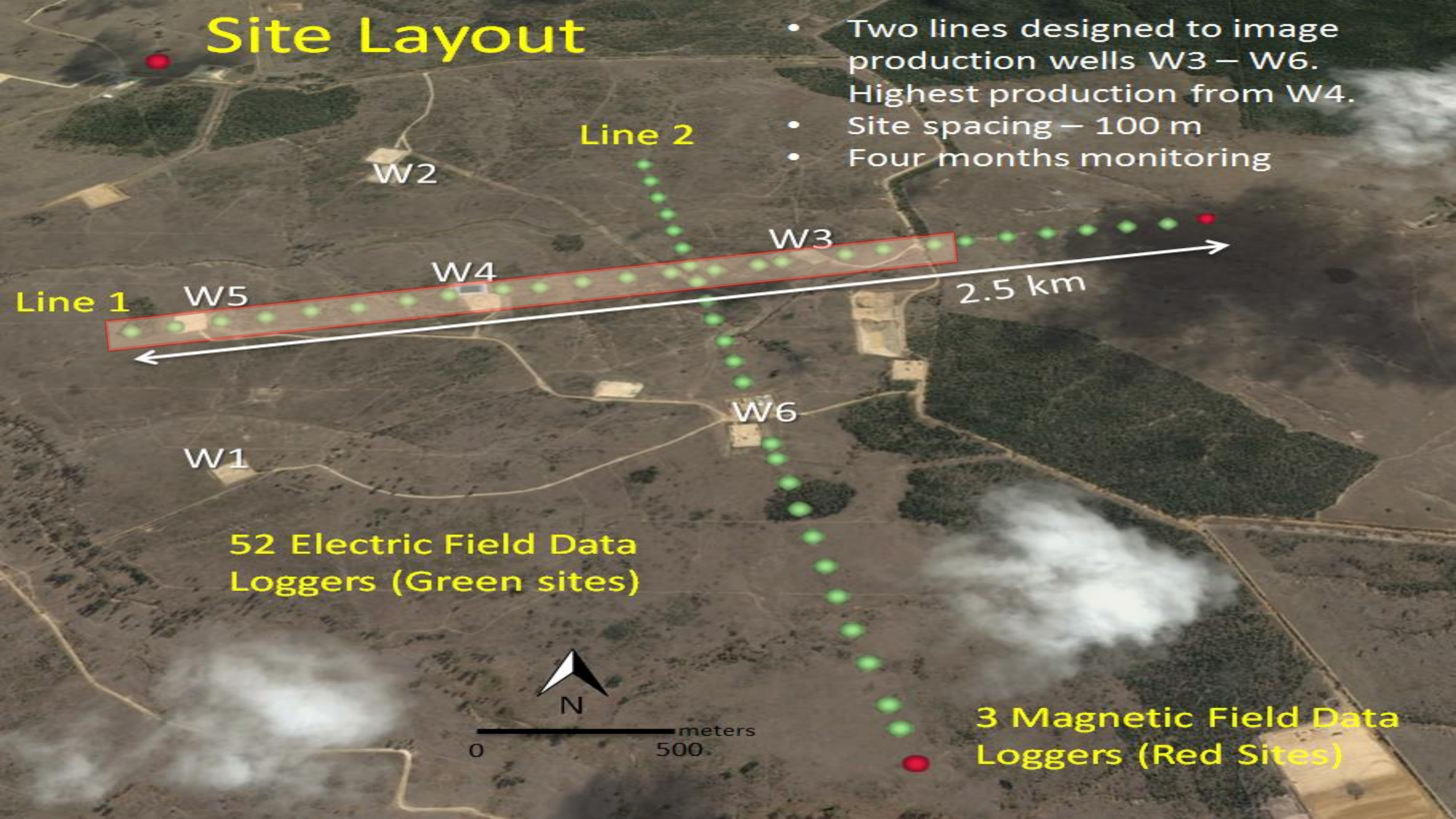
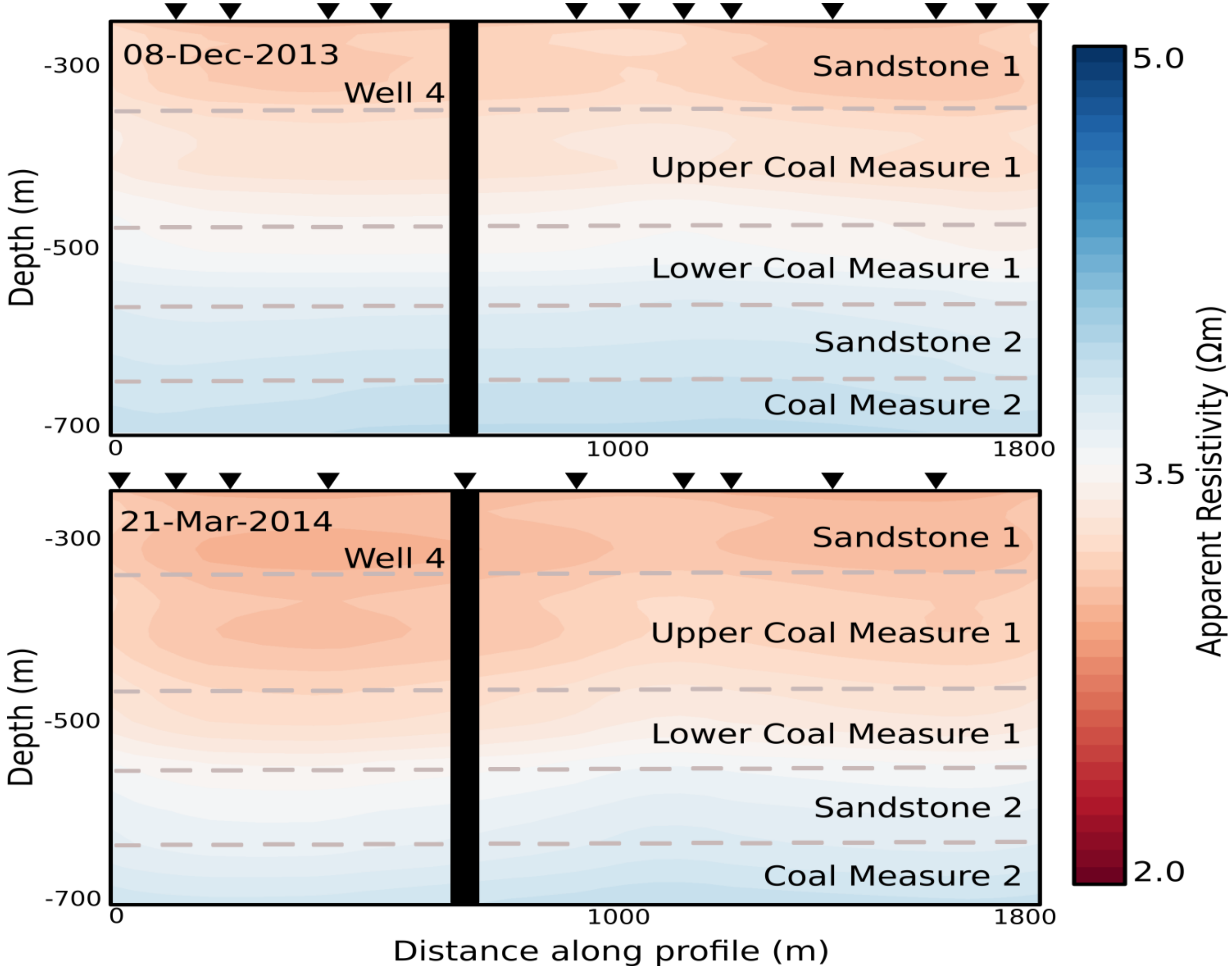
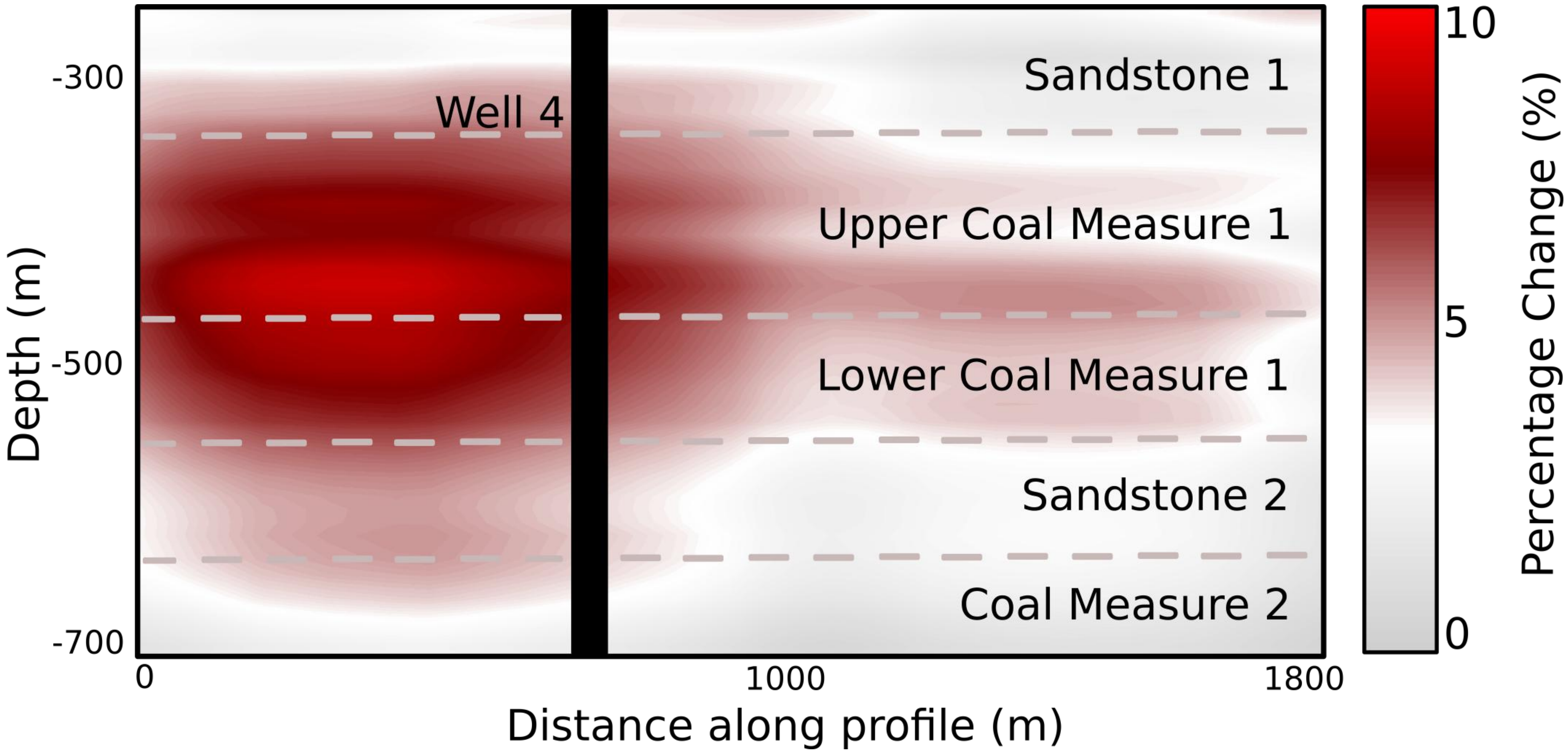


2D modelling





Well 4
Sandstone 1
Upper Coal Measure 1
Lower Coal Measure 1
Sandstone 2
Coal Measure 2
-300
-500
-700
Depth (m)
0
1000
1800
Distance along profile (m)
10
5
0
Percentage Change (%)

Conclusion

MT responses detect change in sub-surface resistivity in the depth interval of about 200-800 m.

1D time-lapse inversions show the temporal variations in sub-surface resistivity as a function of time.

2D models of resistivity show the spatial pattern of change pre- and post- production.


Thankyou