SUSTech Southern University of Science and Technology

南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

地球与空间科学系 DEPARTMENT OF EARTH AND SPACE SCIENCES

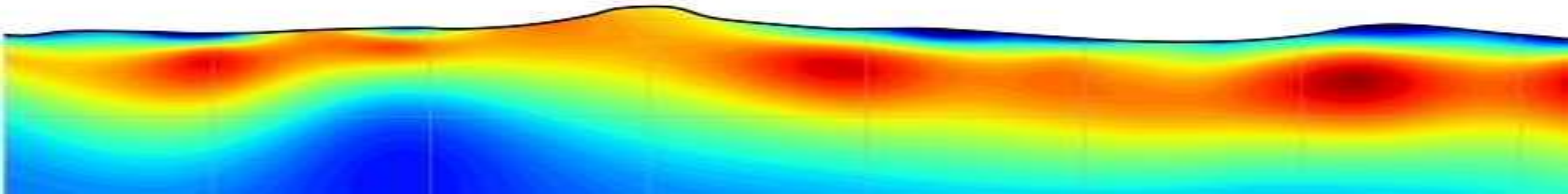
ESS302 Applied Geophysics II

Gravity, Magnetic, Electrical, Electromagnetic and Well Logging

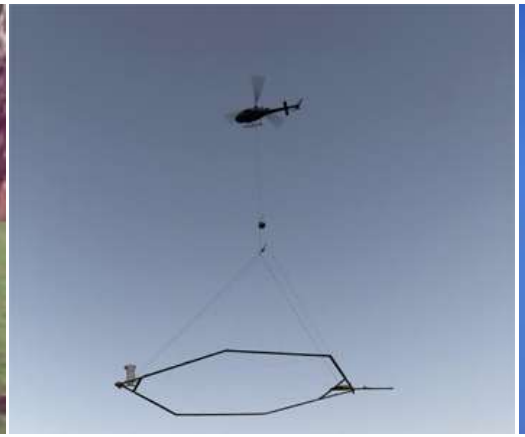
Electromagnetic 4: Induction Part B

Instructor: Dikun Yang

Feb – May, 2019







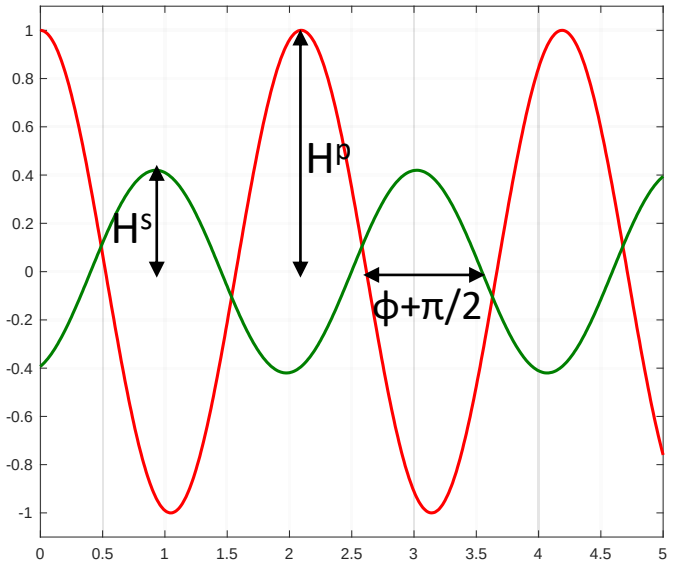







3-loop Model

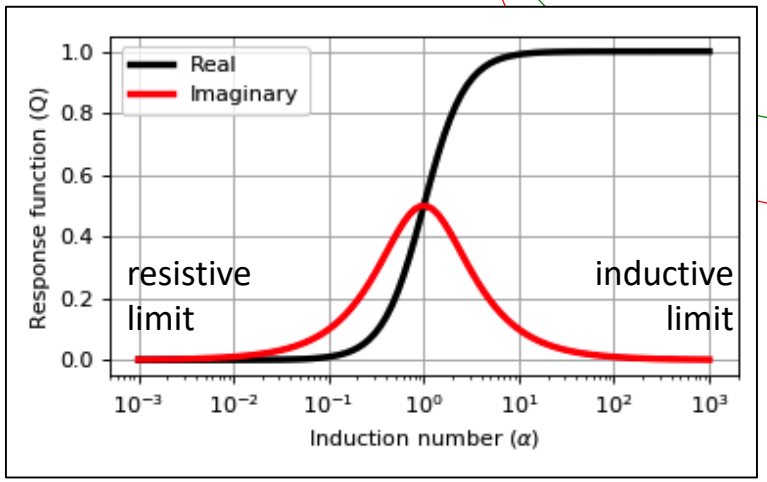
Three quantities measured at Rx

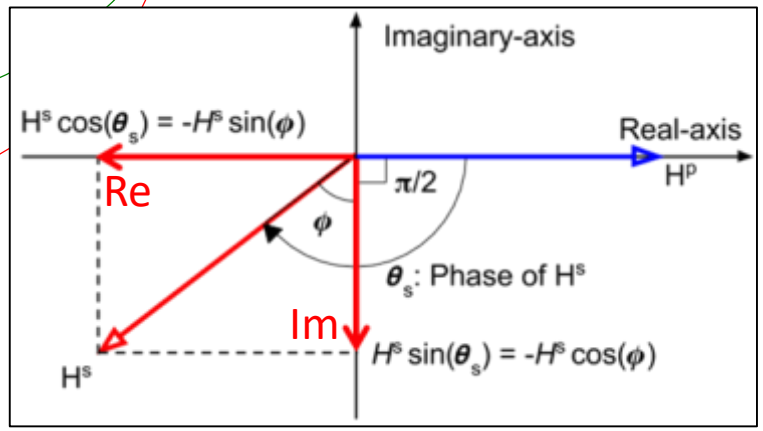


transmitter

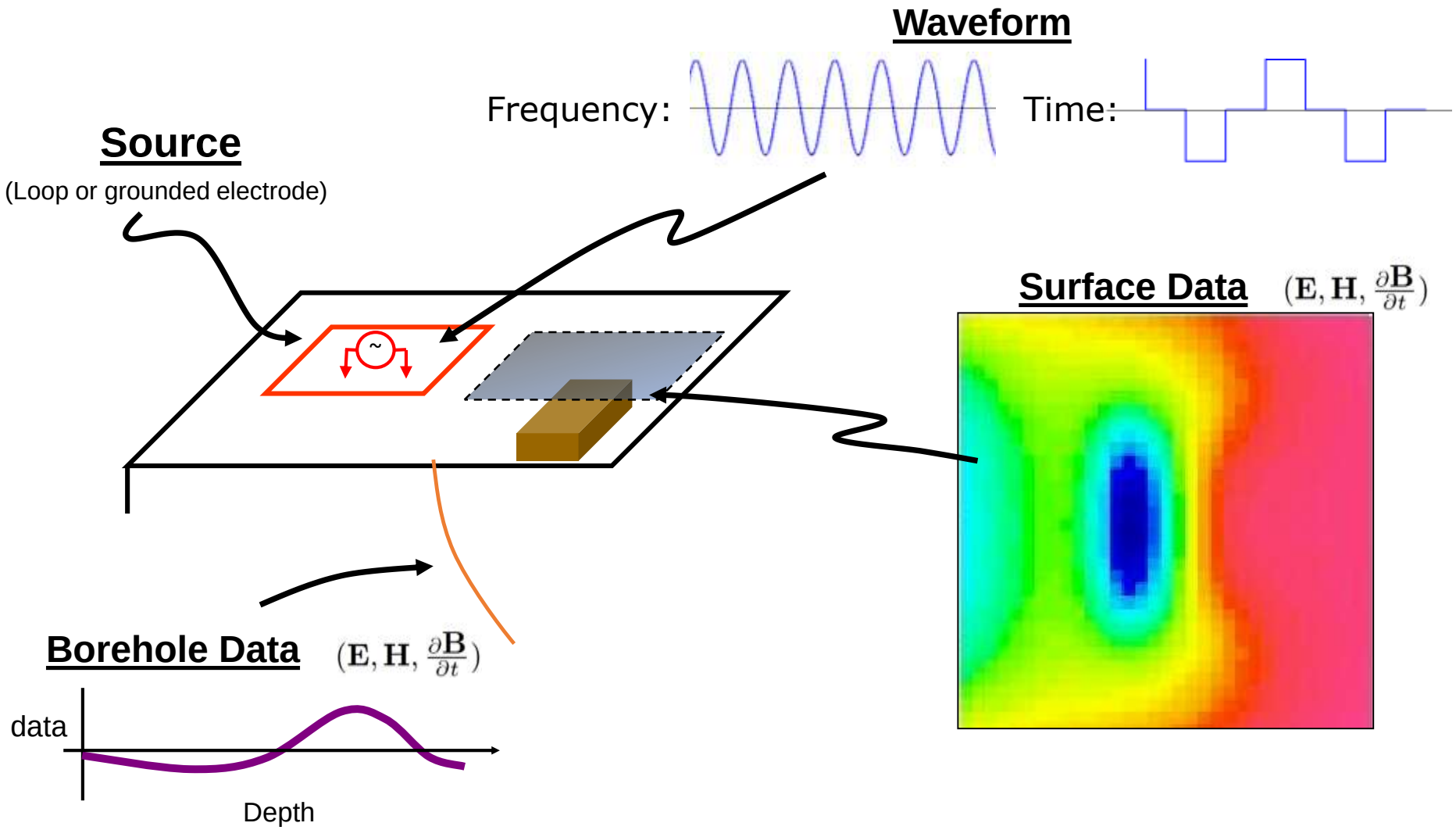
receiver

target





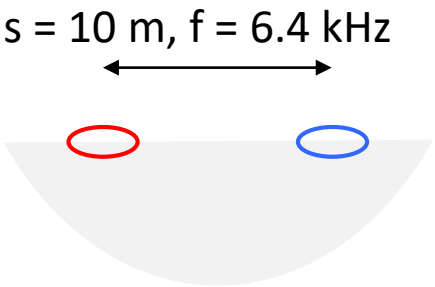
EM Surveys


Waveform
Frequency:
Time:
Source
(Loop or grounded electrode)
Surface Data $(\mathbf{E}, \mathbf{H}, \frac{\partial \mathbf{B}}{\partial t})$
Borehole Data $(\mathbf{E}, \mathbf{H}, \frac{\partial \mathbf{B}}{\partial t})$
data
Depth

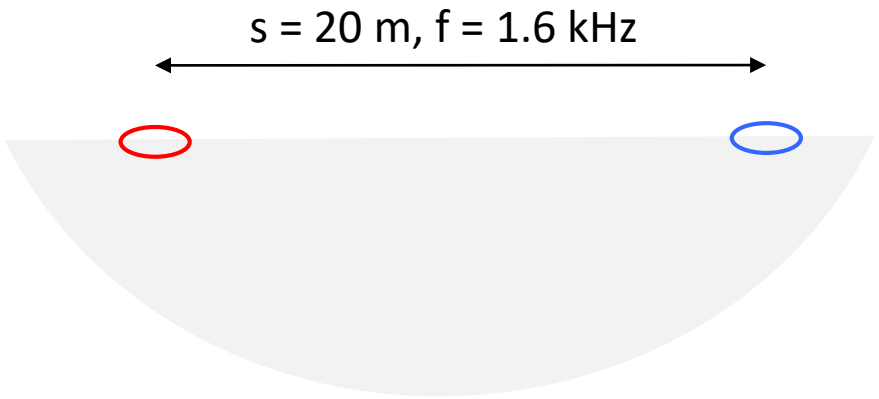
EM Surveys

- Type of source: magnetic dipole, electric dipole, plane wave (natural source)
- Frequency or time domain
- Source waveform: harmonics, square wave, pulse wave
- Operating frequencies or time channels
- Data: complex or real

EM-41

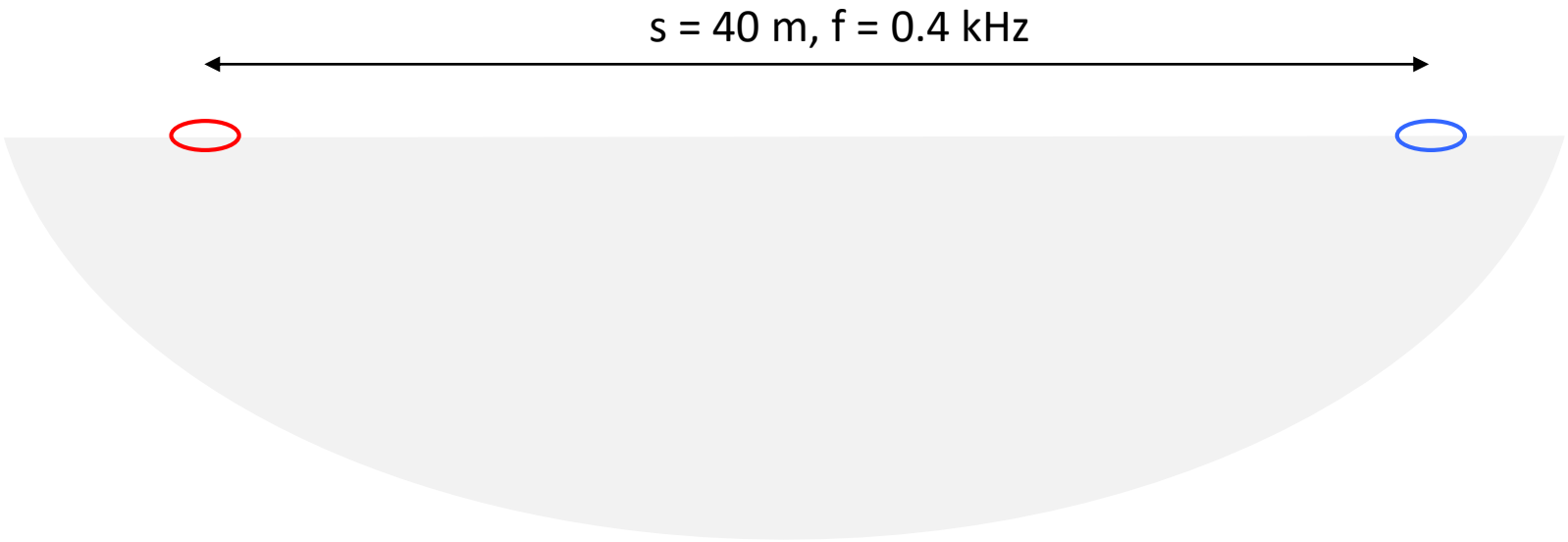


EM-41



EM-41

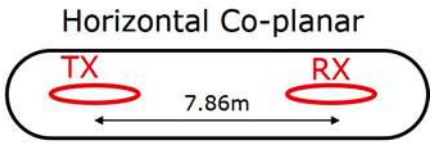
- Variable depth of exploration down to 60 m
- HCP or VCP coil configuration
- Groundwater exploration in fractured and faulted bedrock

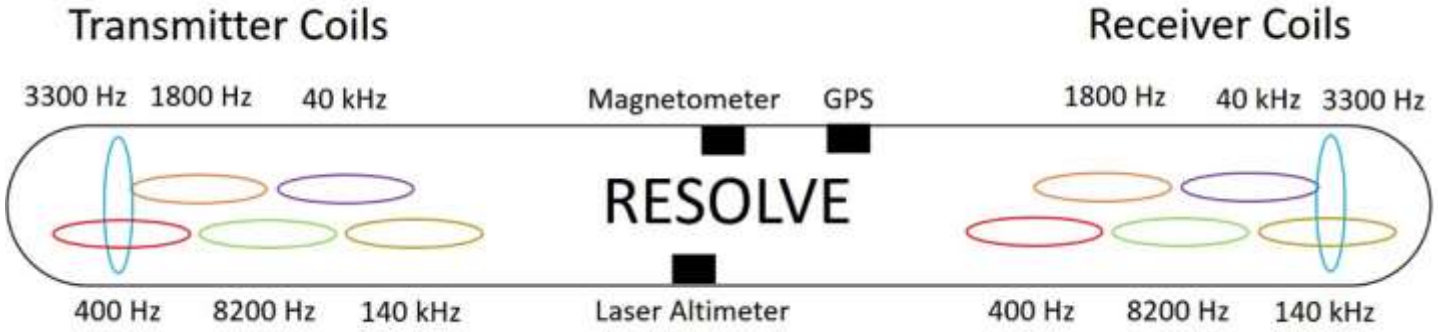


GEM3

- Concentric Tx-Rx
- Frequency 60 Hz to 24 kHz
- Identify an object based on its spectral fingerprints

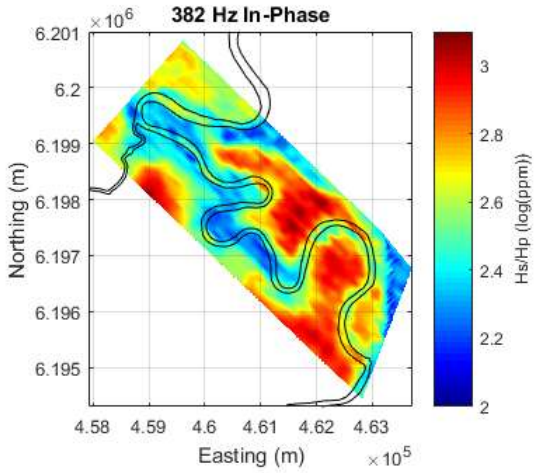
Airborne EM

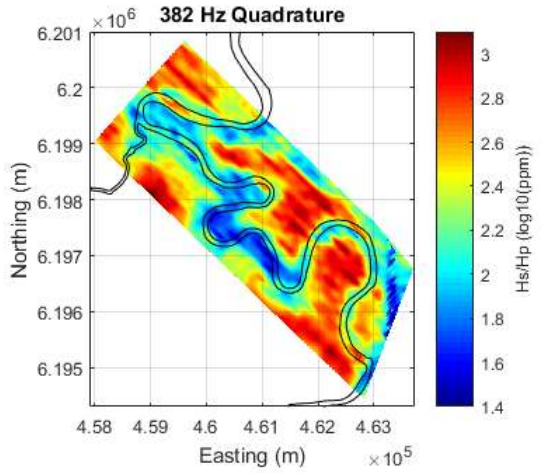


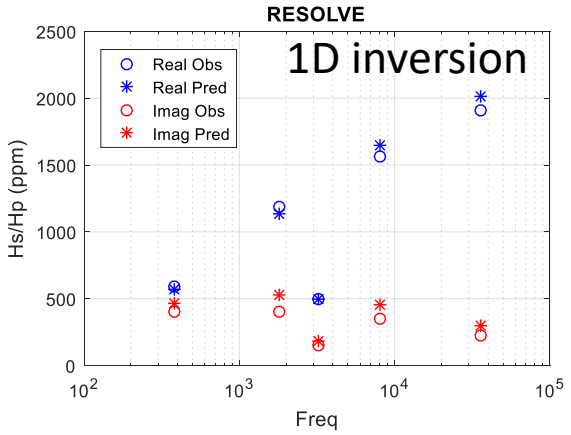


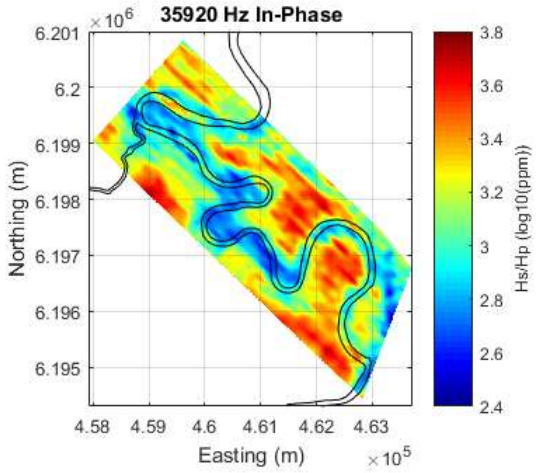
Skin depth: High frequency for shallow; low frequency for deep

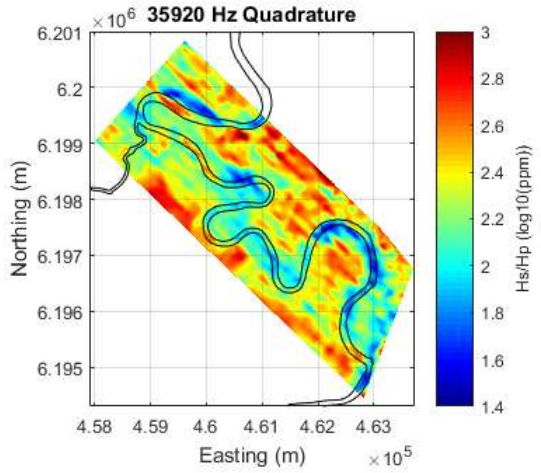
Airborne EM – Groundwater Flow

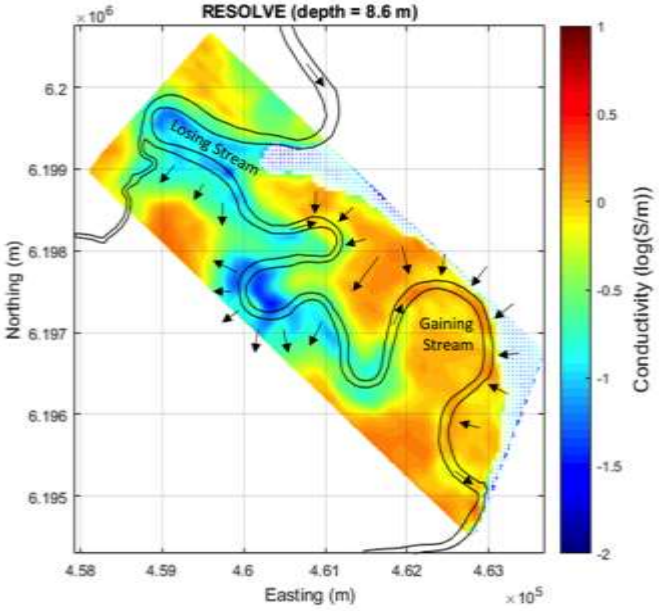




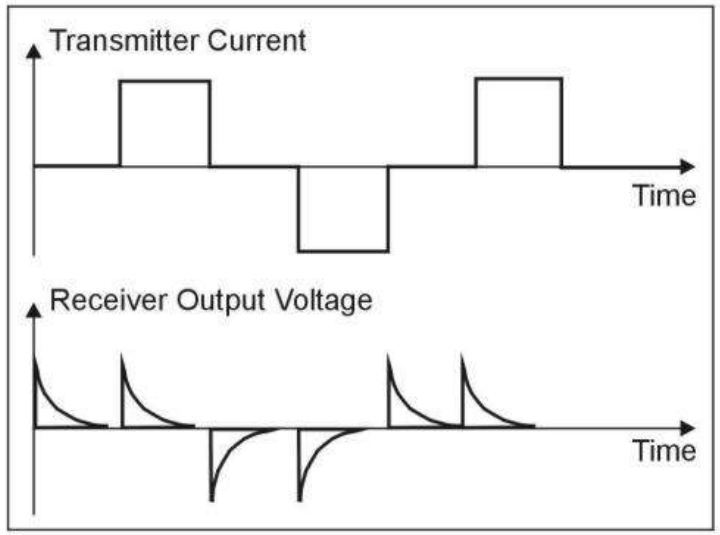


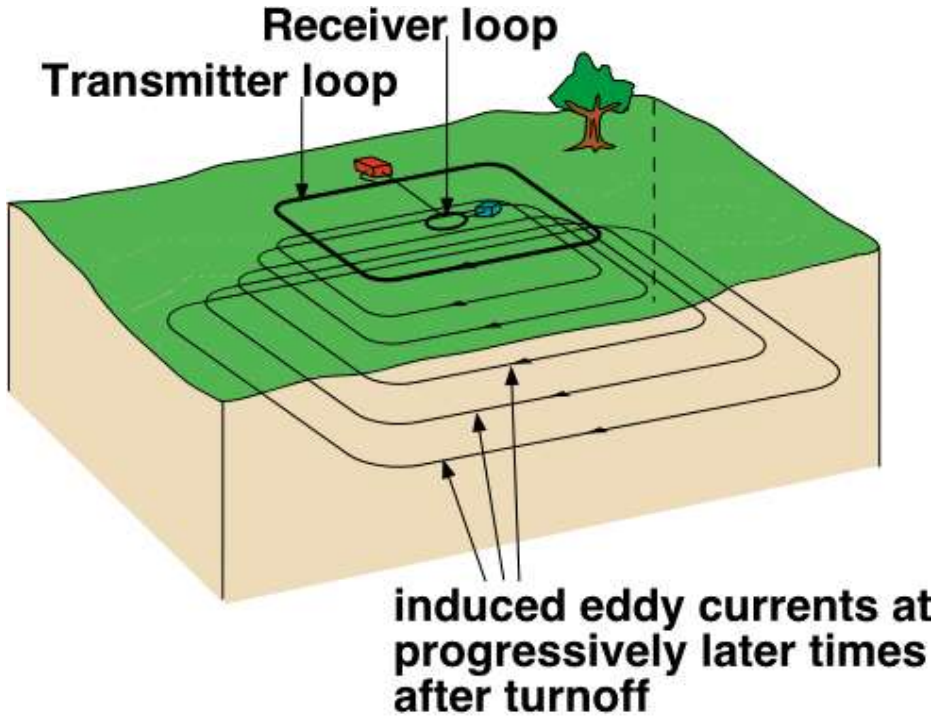


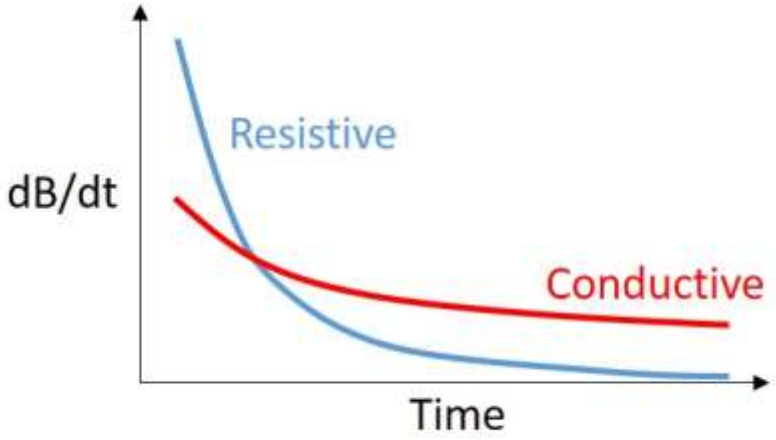




Time-domain (Transient) EM

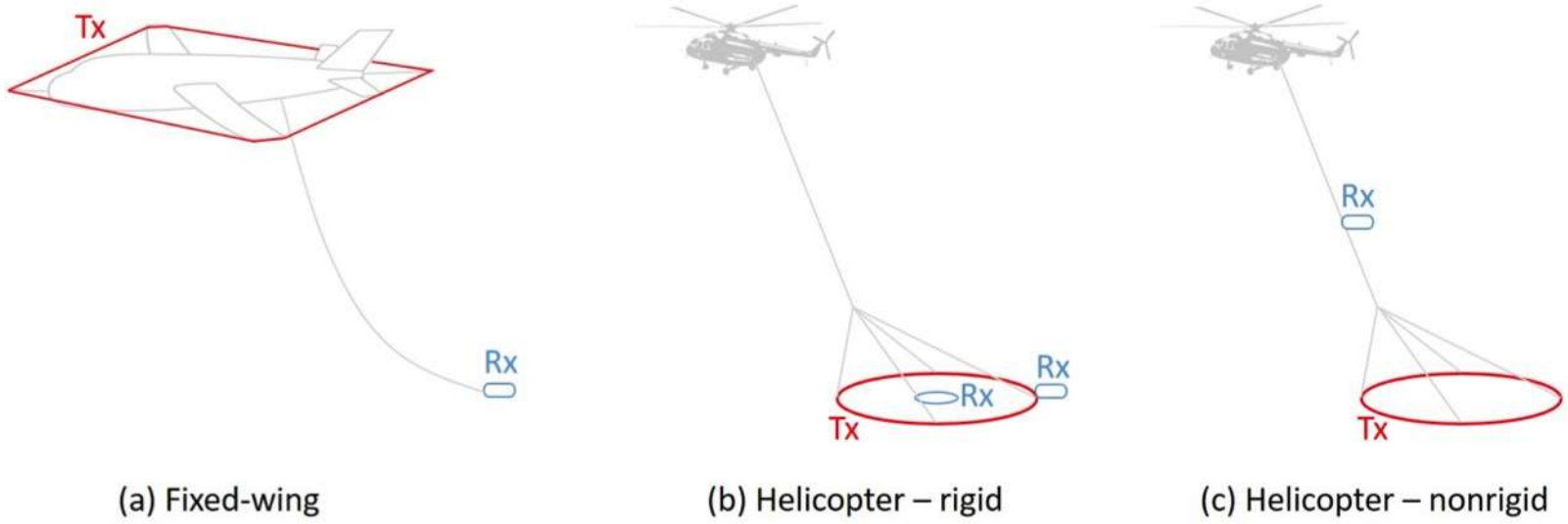






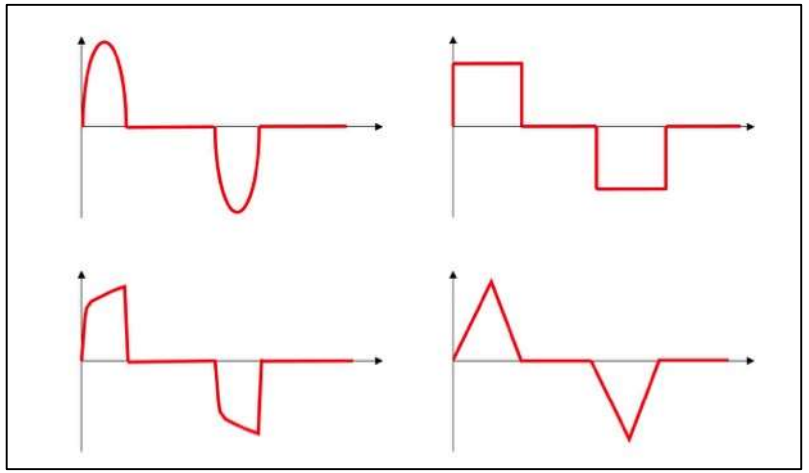
- Wider frequency bandwidth
- Deeper penetration
- Time channel: early for shallow, late for deep

Airborne Time-domain EM (TEM)



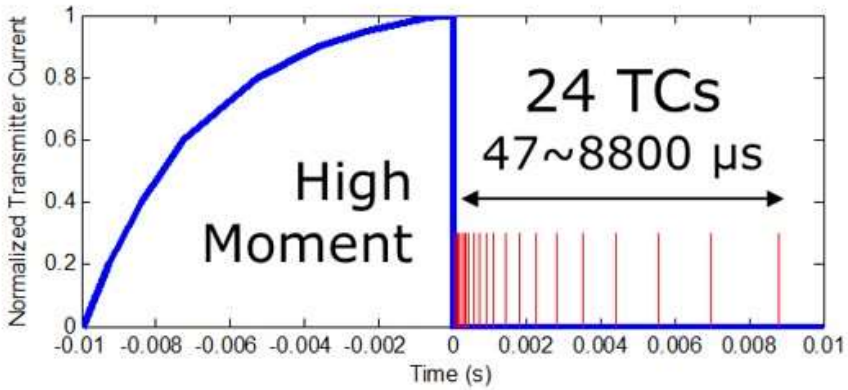
(a) Fixed-wing (b) Helicopter – rigid (c) Helicopter – nonrigid

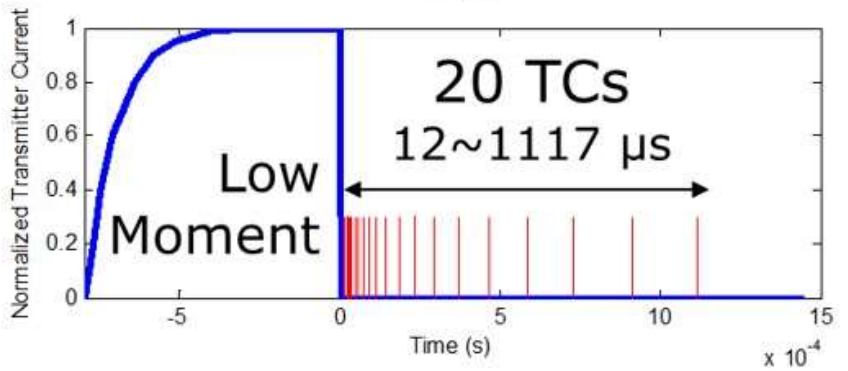
- Magnetic dipole Tx and Rx
- High efficiency
- Sensitive to conductors (water, minerals)
- Adjustable source moment
- Waveforms

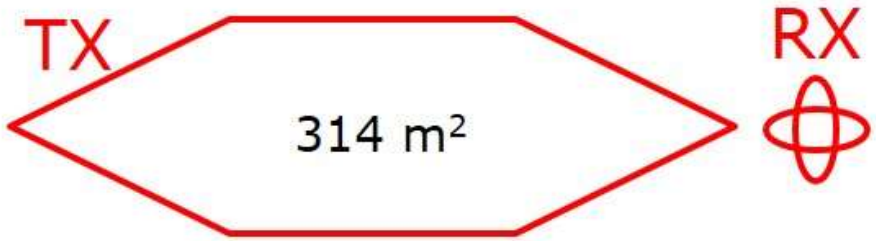


ATEM - SkyTEM

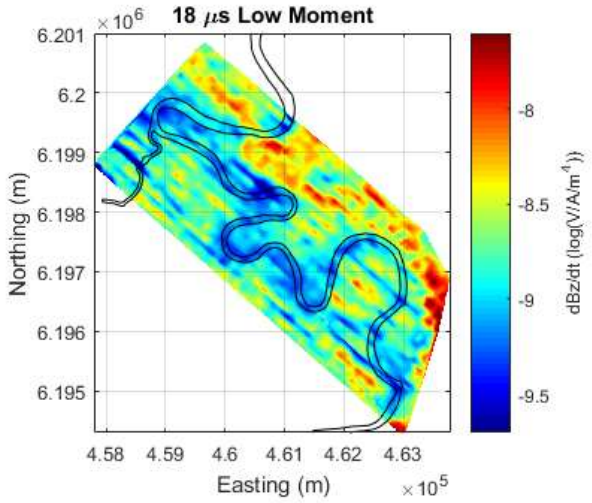

SkyTEM 2006

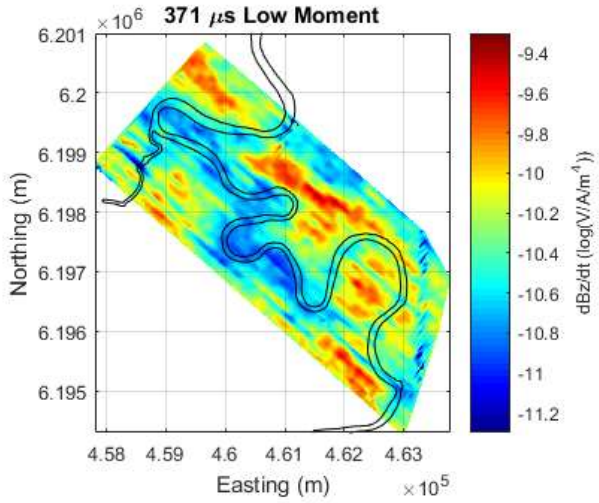

Normalized Transmitter Current
1
0.8
0.6
0.4
0.2
0
-0.01 -0.008 -0.006 -0.004 -0.002 0 0.002 0.004 0.006 0.008 0.01
Time (s)
24 TCs
47~8800 μs
High
Moment

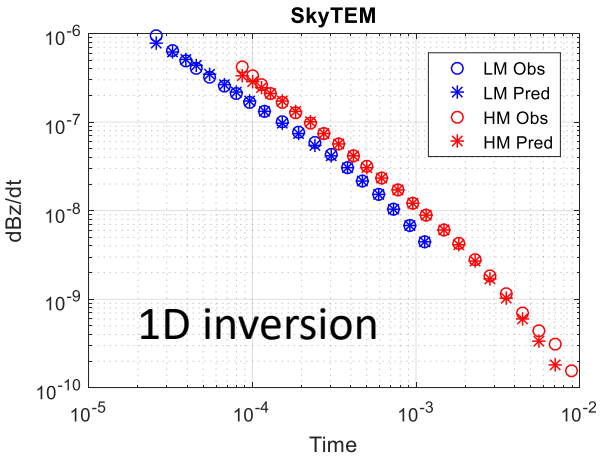

Normalized Transmitter Current
1
0.8
0.6
0.4
0.2
0
-5 0 5 10 15
Time (s)
x 10^-4
20 TCs
12~1117 μs
Low
Moment

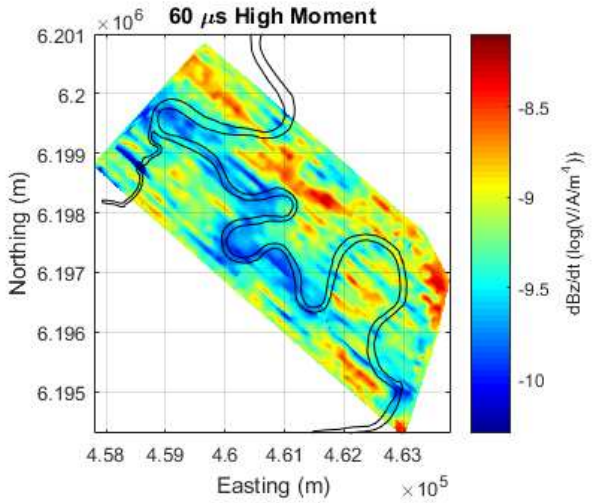

TX
RX
314 m²

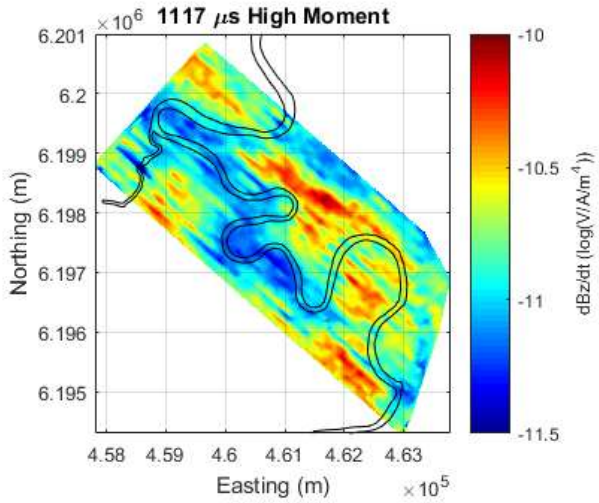
ATEM - Bookpurnong

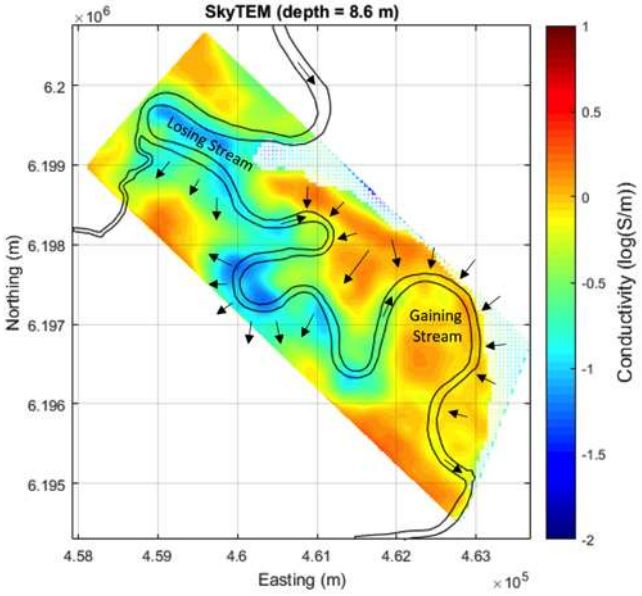


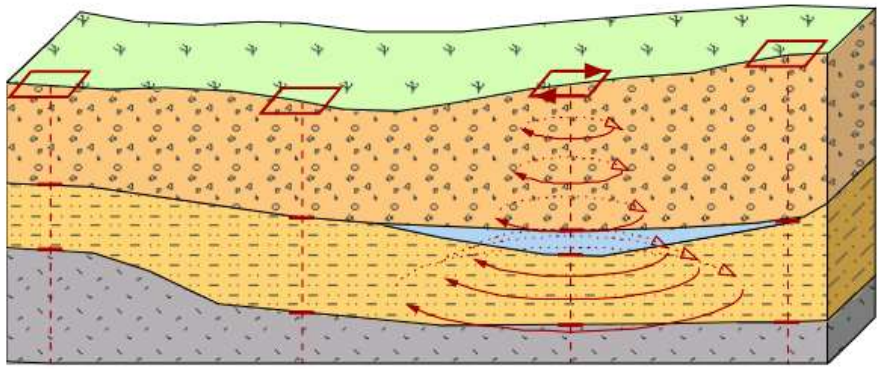






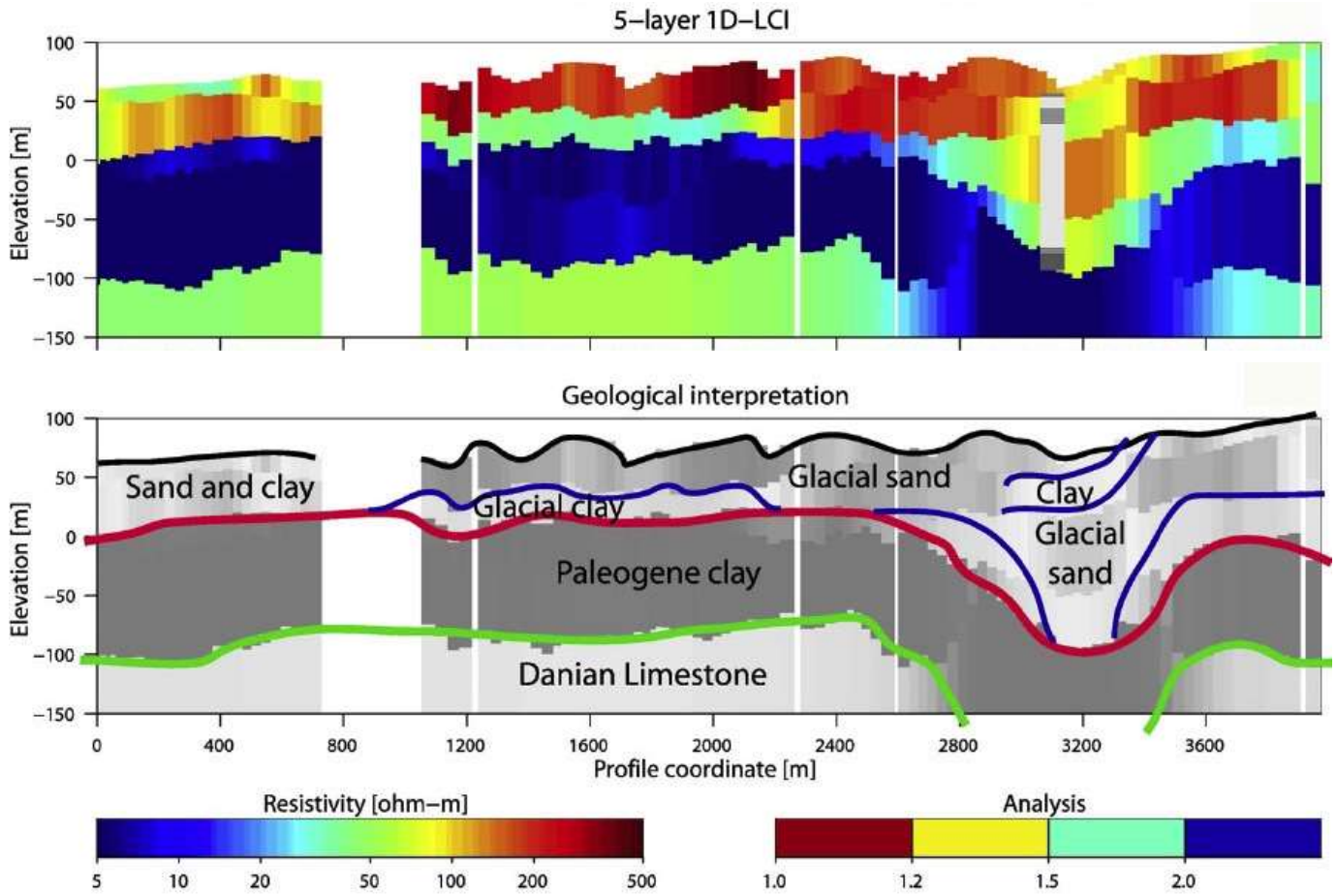






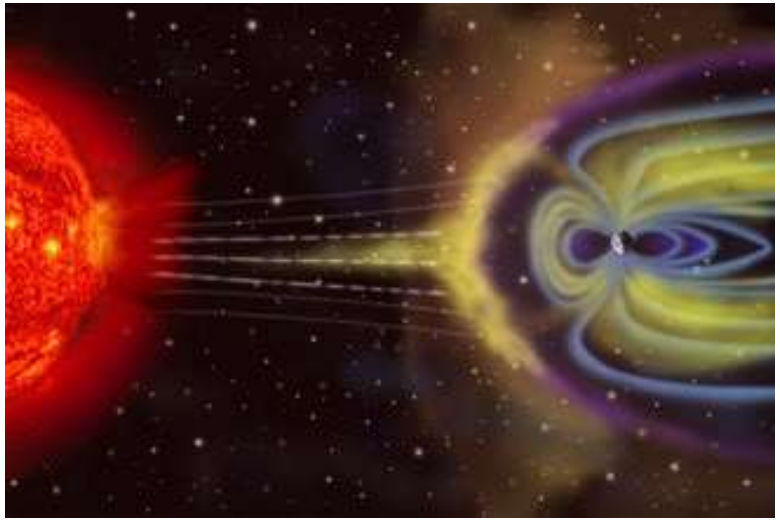
Surface TEM

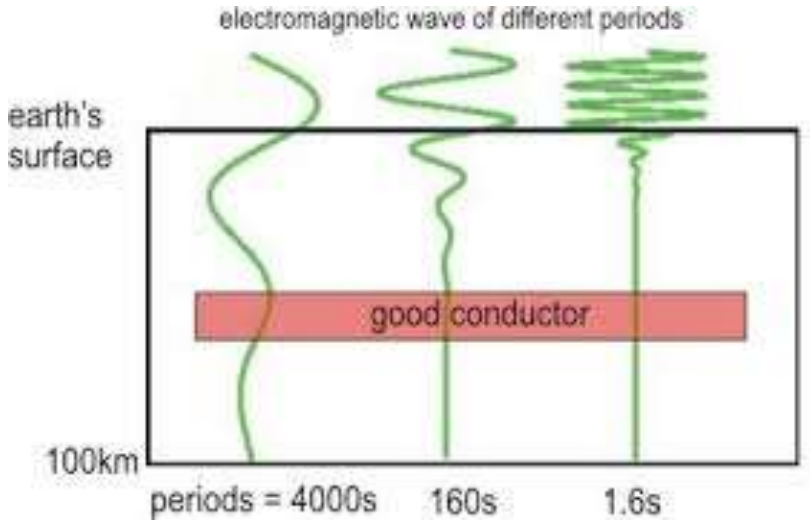
- Concentric Tx-Rx
- Time decay curve at each station
- 1D layered inversion at each station
- Stitch 1D models to form a 2D section



(NGA, EPA)

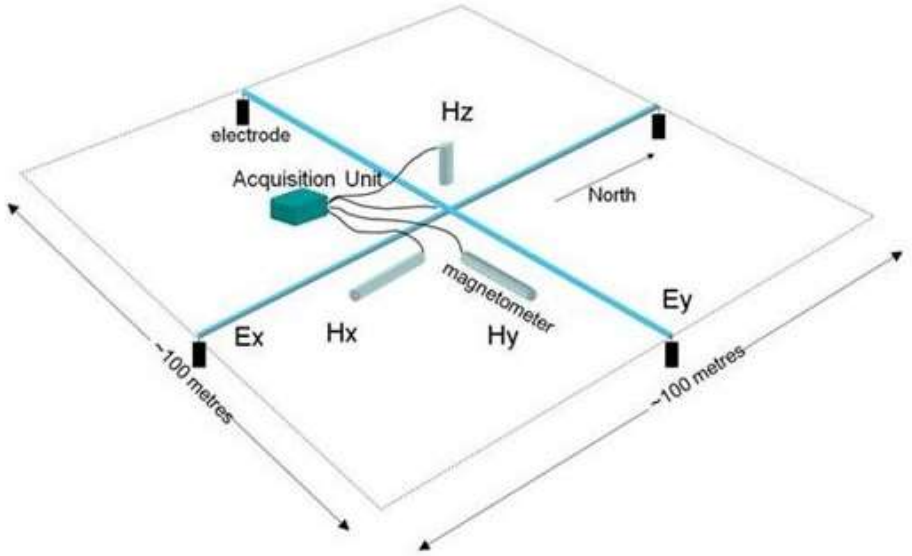
Natural Source EM





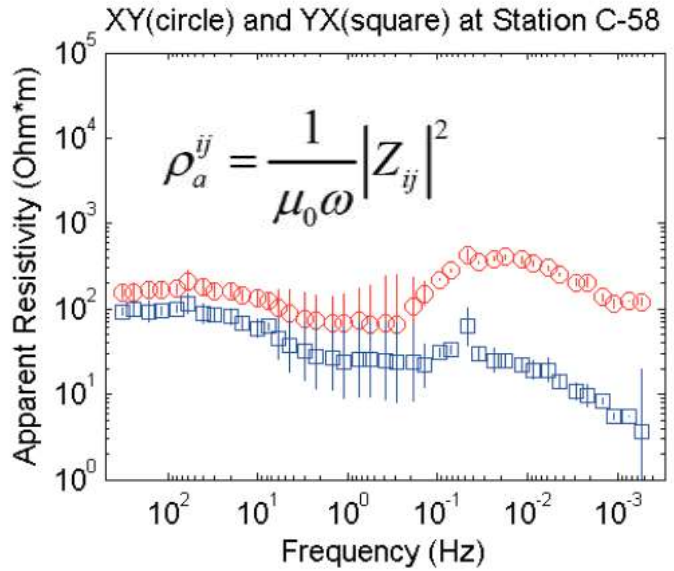
- Plane wave: horizontal E, H fields
- Frequency: 1 kHz – 10^{-4} Hz
- Depth of penetration: 10^{1} – 10^{5} m

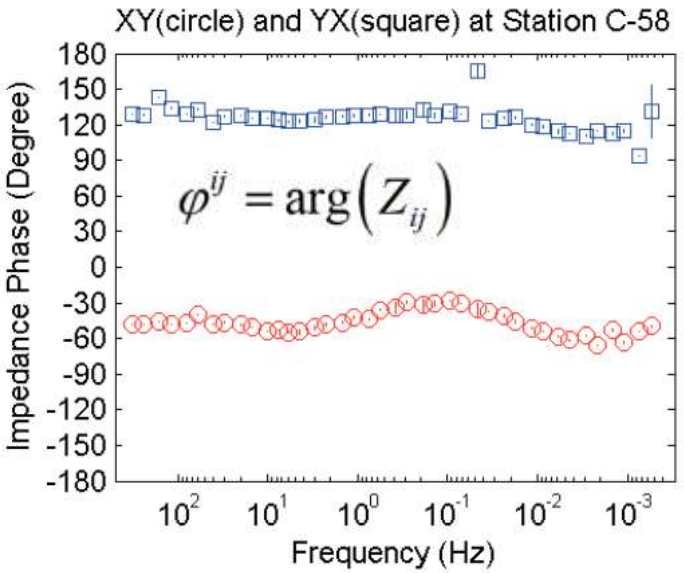
Magnetotellurics (MT)



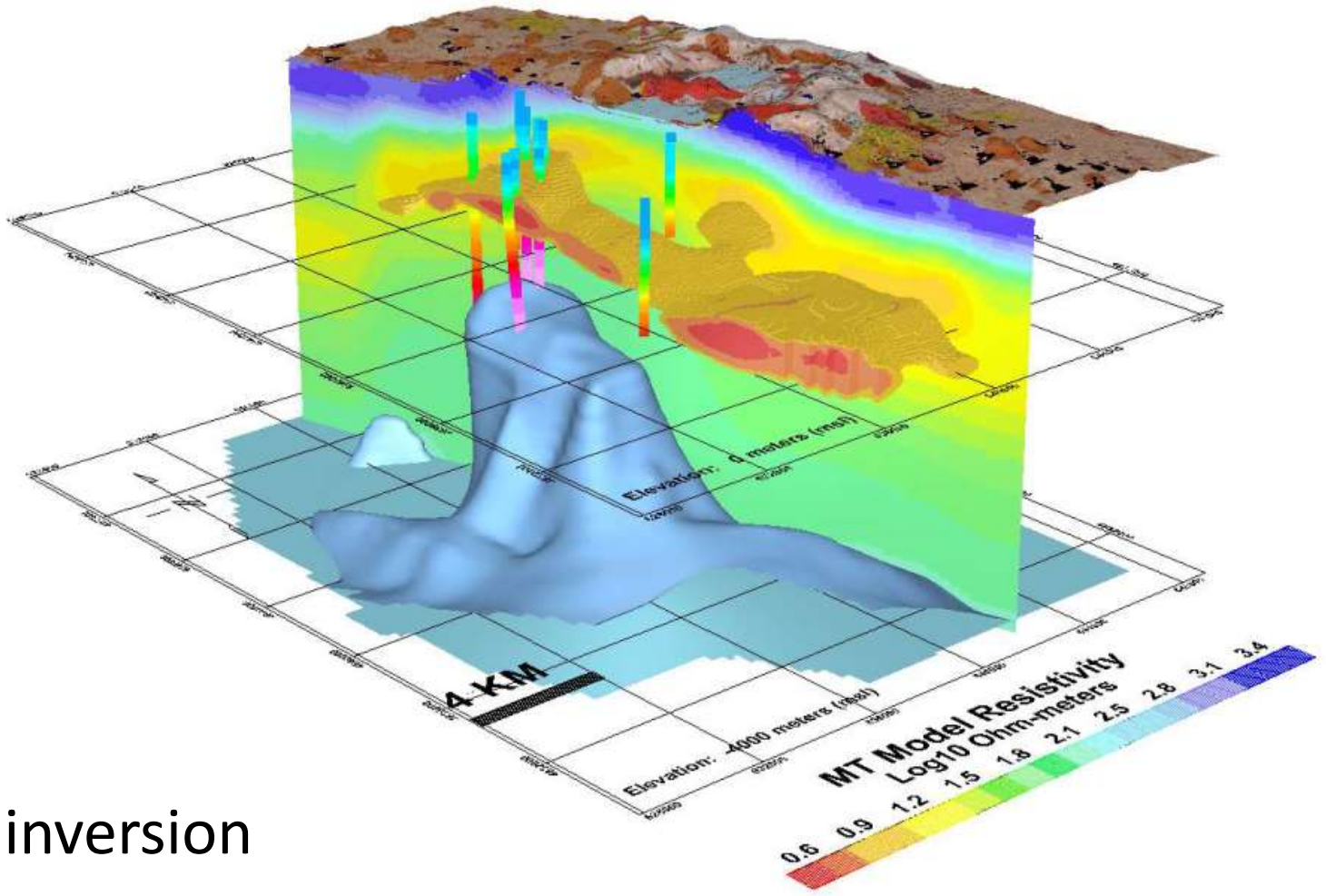
$$\begin{bmatrix} E_x \\ E_y \end{bmatrix} = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \begin{bmatrix} H_x \\ H_y \end{bmatrix}$$

Impedance tensor element Z_{ij} is complex and a function of sounding frequency and the earth's conductivity at different depths.





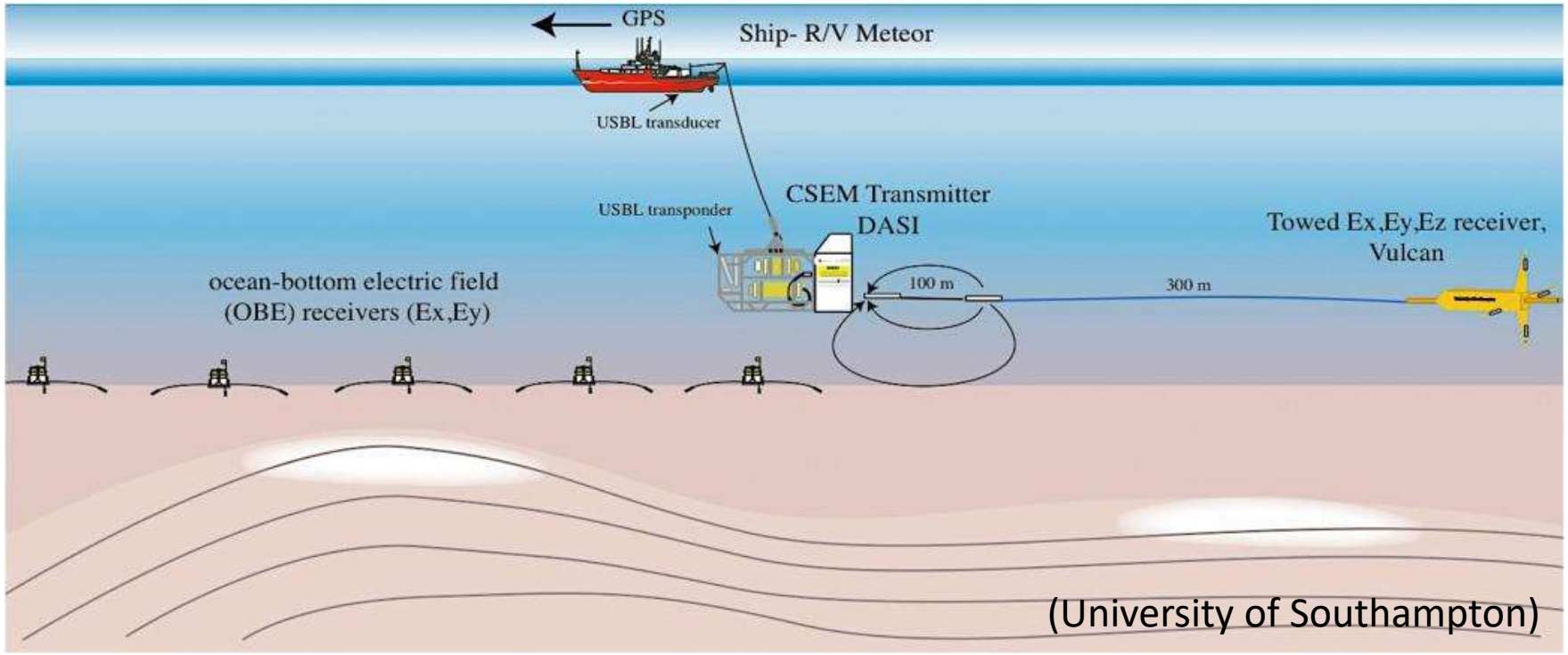
MT - Geothermal



3D inversion

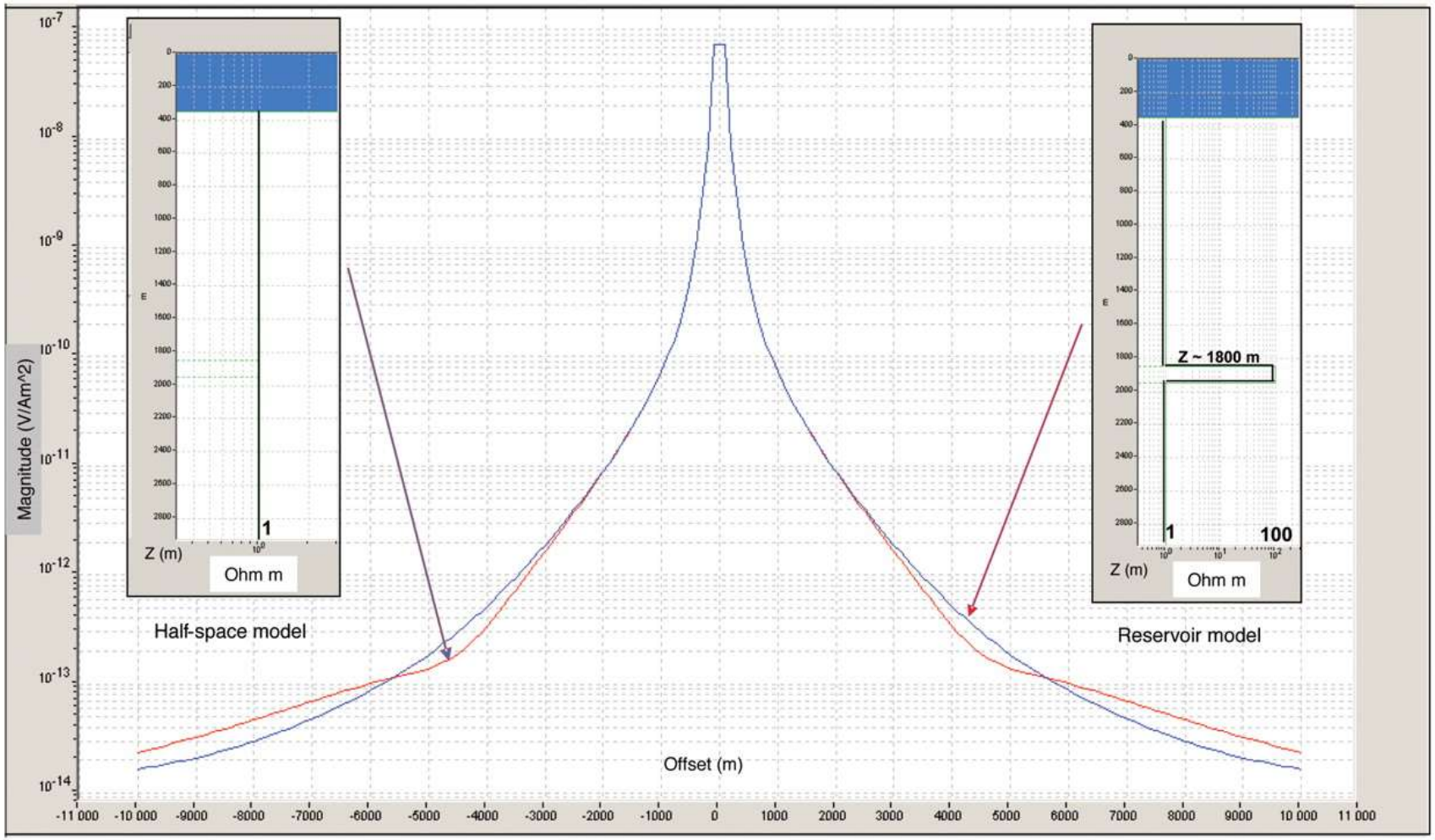
(Zonge)

Marine CSEM



- Electric dipole source
- Towed or ocean-bottom E-field receivers (electric dipoles too)
- Widely used in hydrocarbon exploration (resistors in a conductive background)

Marine CSEM



(Dell'Aversana)

Summary

- More EM surveys
  - Multi-frequency systems: EM-34, GEM3
  - Airborne EM: RESOLVE
  - Time domain EM: SkyTEM, concentric Tx-Rx
  - Natural source EM (MT)
  - Marine CSEM
- Applications
  - Groundwater/geothermal
  - Geologic mapping
  - Geotechnical, UXO
  - Petroleum