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Magnetotellurics

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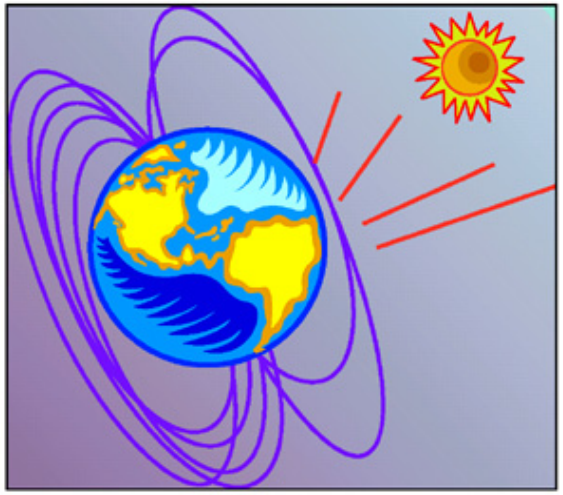
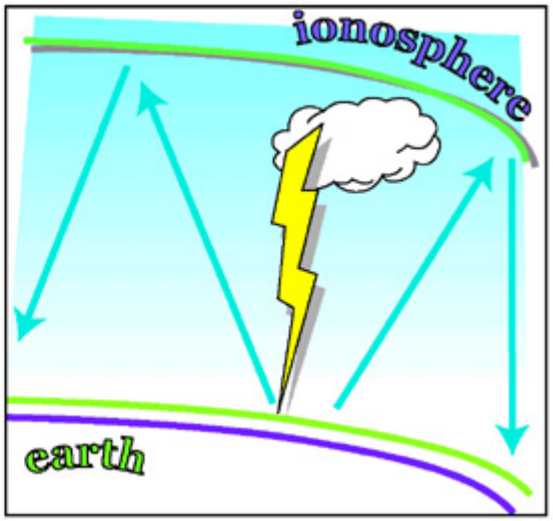
EarthScope Seminar Class

Figures and information referenced from various internet sources

Why Magnetotellurics?

- "Magneto" = magnetic
- "Telluric" = electrical Earth currents
- Magnetotellurics (MT) is a passive, electromagnetic depth-sounding technique that measures naturally occurring, time-varying magnetic and electric fields at the Earth's surface.
- **The Goal**: From these measurements we can derive conductivity (or resistivity) estimates for the subsurface.





http://www.SearchandDiscovery.net
Article #40025

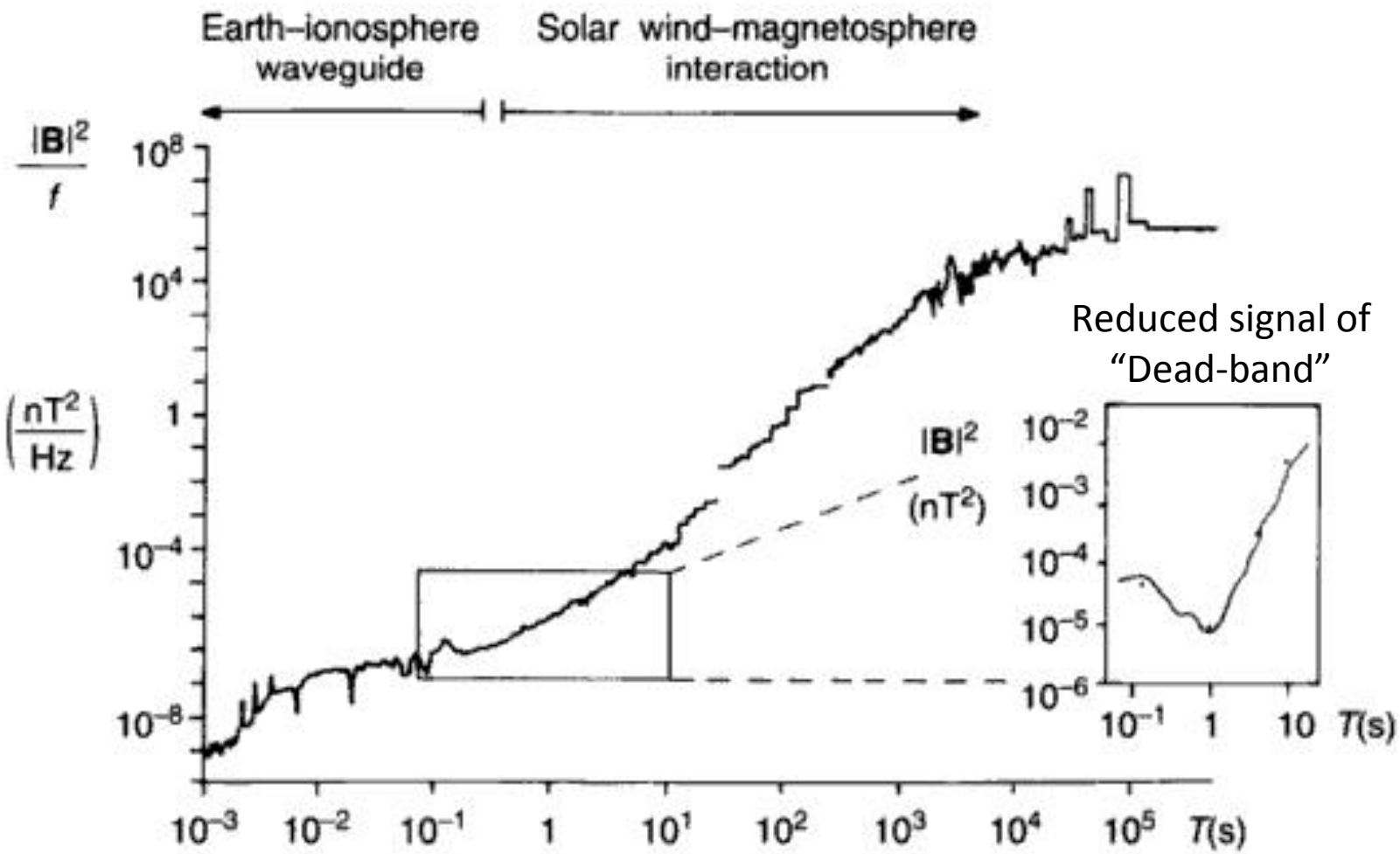
Passive MT Sources

1) **Solar Wind** - Charged particles from solar storms interact with the Earth's magnetic field.

   (Long period 1 — 0.0001Hz)

2) **Lightning** - Ionosphere acts as a wave-guide around the Earth.

   (Short period > 1 Hz)

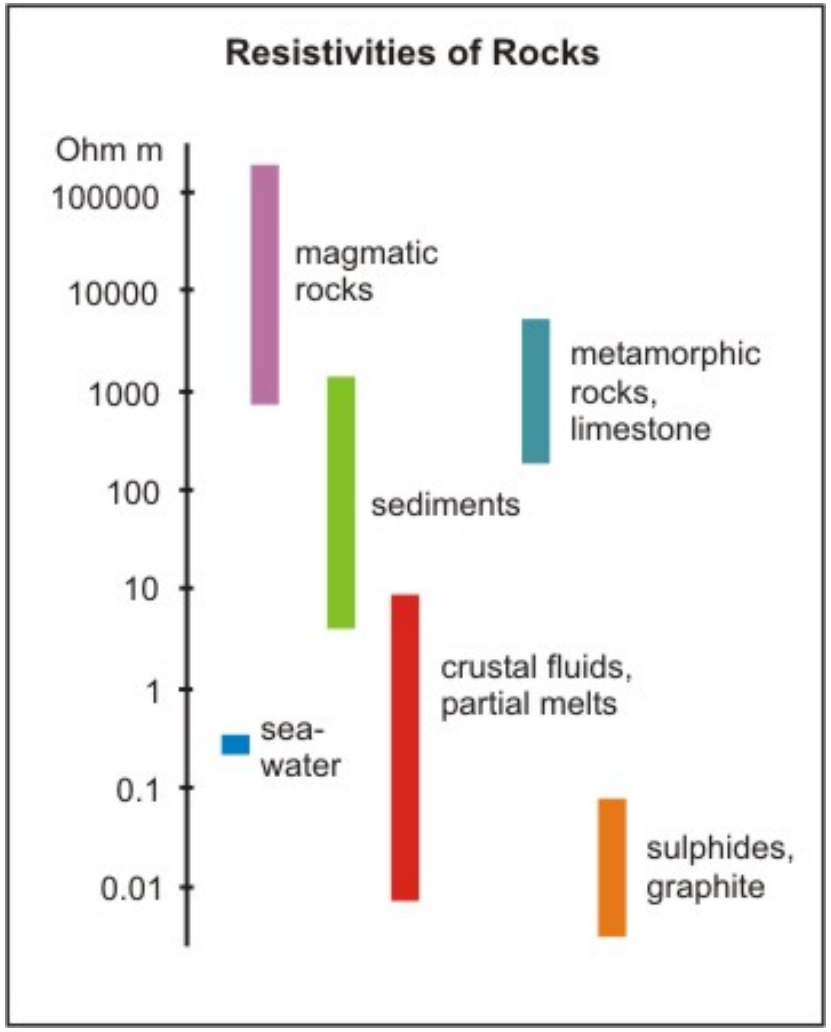


From Simpson & Bahr (2005)
Practical Magnetotellurics textbook

The Physics Behind MT
(A ***brief*** overview)

- We assume that the Earth follows Ohm's Law: $J = \sigma E$

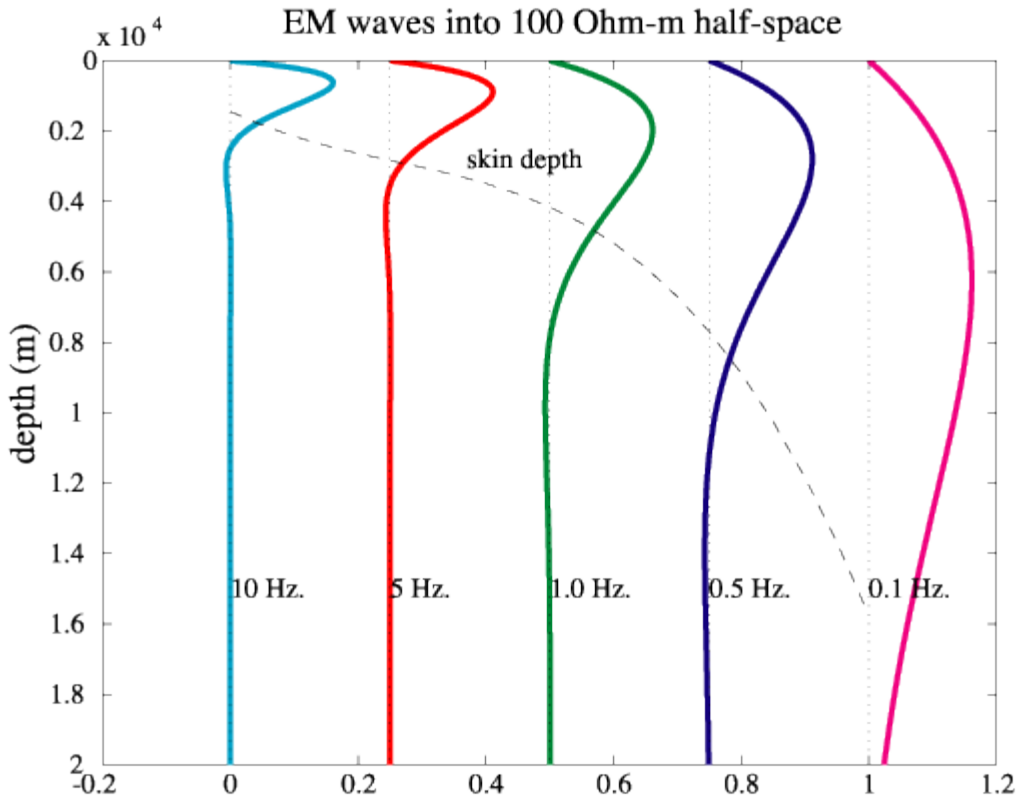
  (J = electric current density, σ = conductivity, E = electric field strength)
- We also assume that electric and magnetic waves propagate as plane waves vertically into the Earth inducing secondary currents.
- Therefore, we can use Maxwell's correction to Ampere's Law, which states that a changing magnetic field creates a electric field and a changing electric field creates a magnetic field.
- Now we can take our surficial measurements of E & M currents and use them to estimate impedance (Z) as a function of period.
- Impedance (Z) is the relation of electrical and magnetic field strength, normally represented as apparent resistivity and phase shift (or phase tensor ϕ) between both fields.

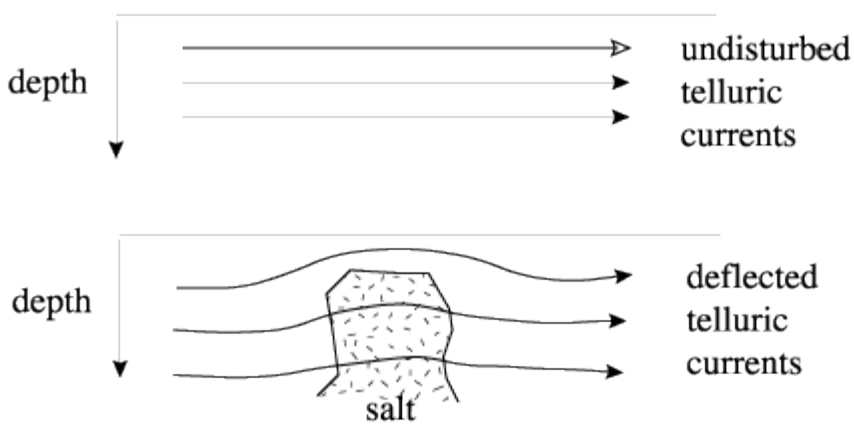


From MT Group @ FU Berlin
http://userpage.fu-berlin.de/~mtag/MT-principles.html

What Can Resistivity Tell Us?

- Resistivity in nature is very rock dependent and can vary by orders of magnitude.
- Remember that Resistivity (ρ) = $1/\sigma$, so low resistivity means high conductivity.





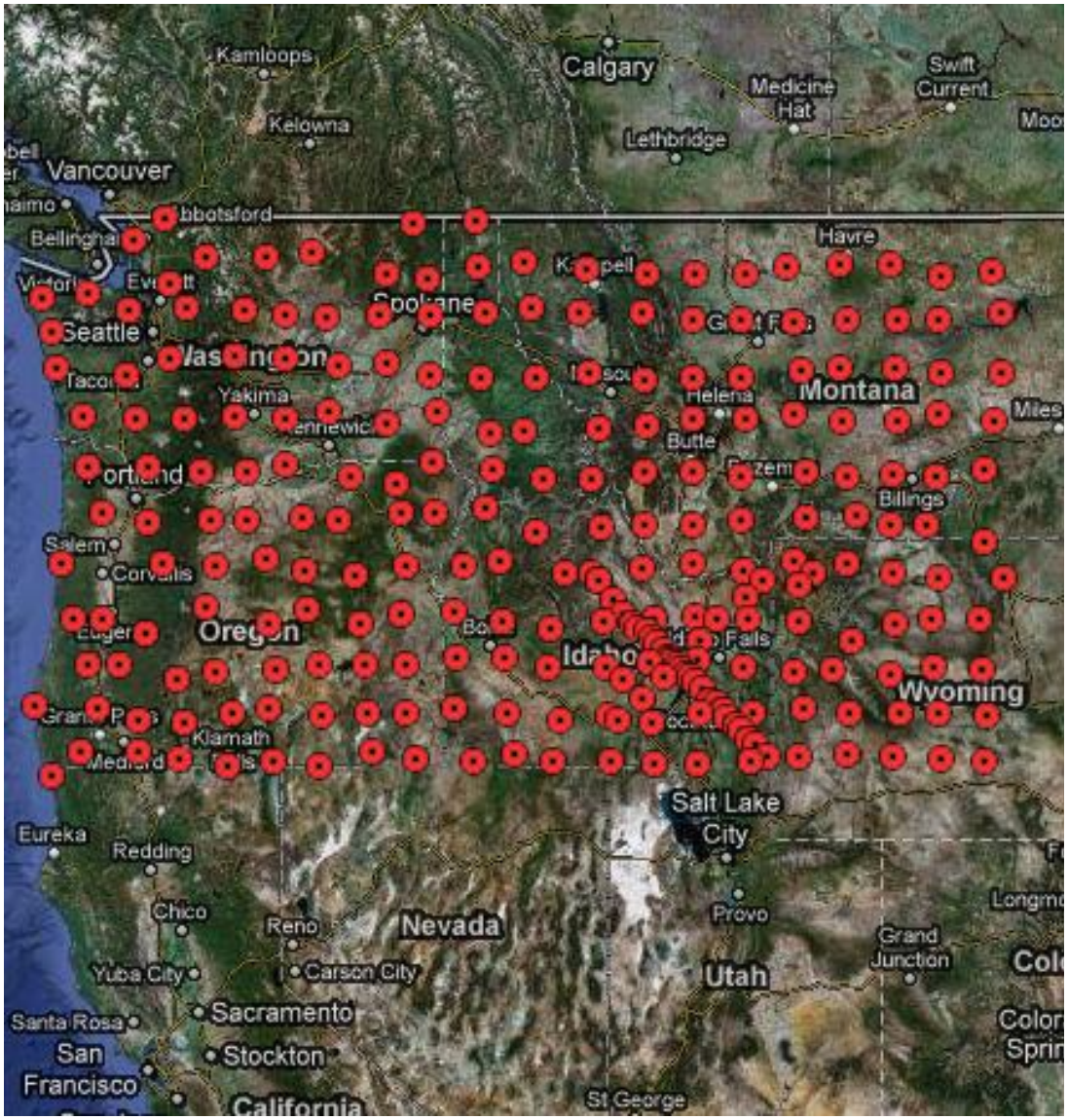
Skin effect is the tendency of an alternating electric current (AC) to distribute itself within a conductor so that the current density near the surface of the conductor is greater than that at its core.

The skin effect causes the effective resistance of the conductor to increase with the frequency of the current.

So in MT, detection depth or skin depth ≈ $0.5\sqrt{(\rho T)}$

From Livelybrooks (U. Oregon) web page http://hendrix2.uoregon.edu/~dlivelyb/LPE_talk/MT_intro.html

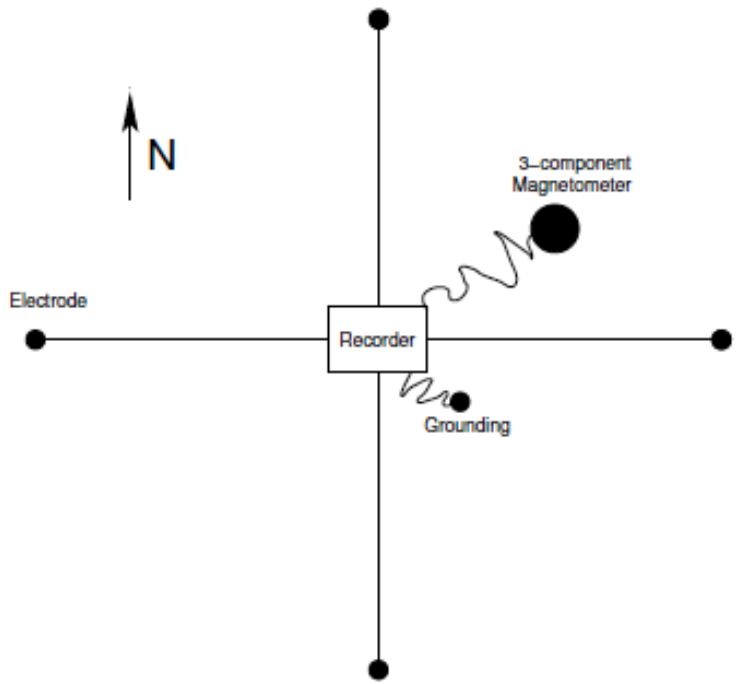
USArray MT Station Map



The magnetotelluric (MT) component of USArray consists of 7 (when fully deployed) permanent MT stations and a mobile array of 20 MT stations that will each be deployed for a period of about one month in regions of identified interest with a spacing of approximately 70 km.

From IRIS USArray web page
http://www.iris.edu/earthscope/usarray/

Typical MT Station Setup



- 4 electrodes for the North-South and East-West electric field ($\approx$ 50-100m apart)
- One ground connection (electrode or metal stake)
- For long periods ($>$ 1s) flux-gate magnetometer
- For short periods ($<$ 1000s) coils

From Max Moorkamp MT Intro ppt
www.dias.ie/~mm/mtintro.pdf

Typical MT Station Components

Electrodes

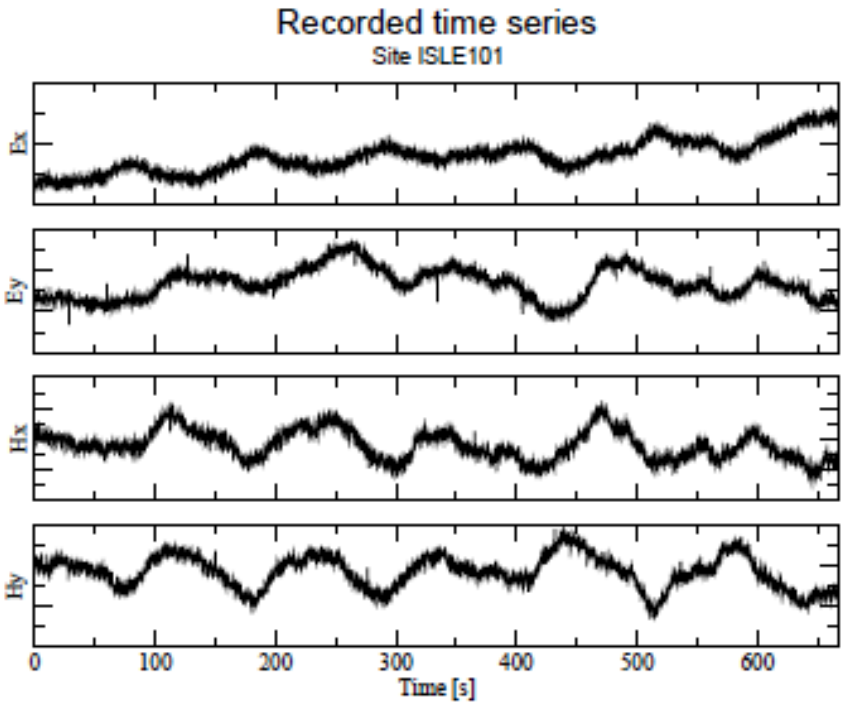
Coils

Flux-Gate

Recorder

From Max Moorkamp MT Intro ppt
www.dias.ie/~mm/mtintro.pdf

Recording Durations

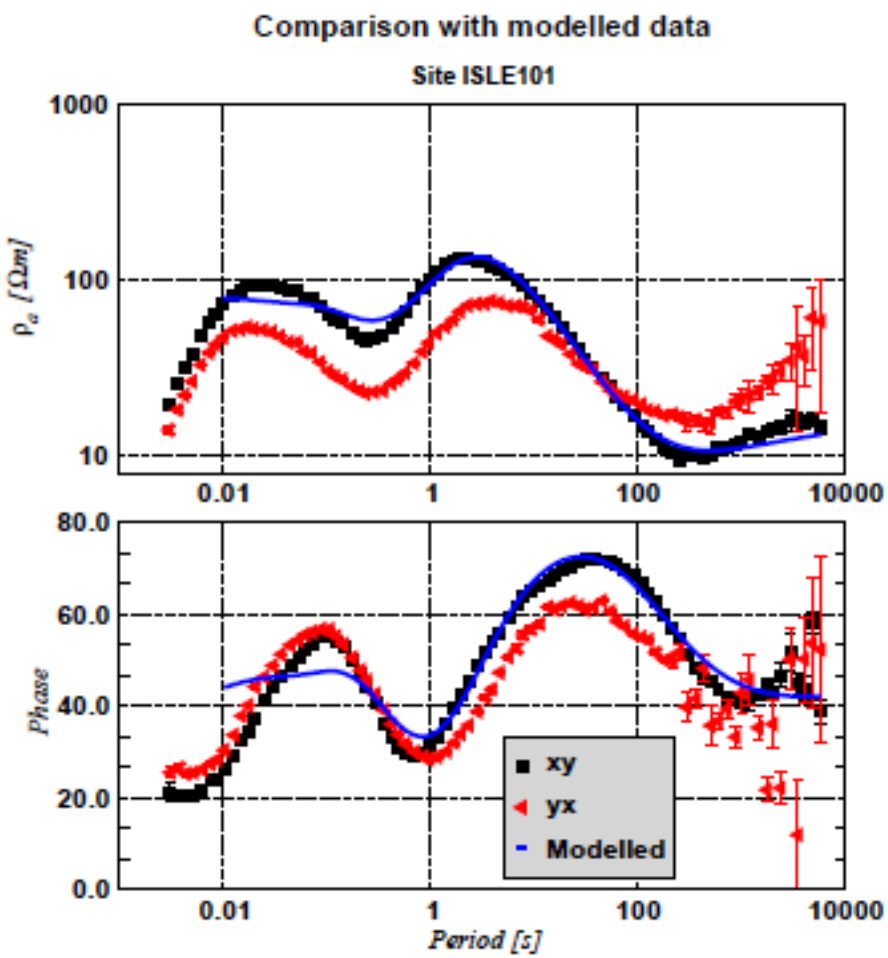


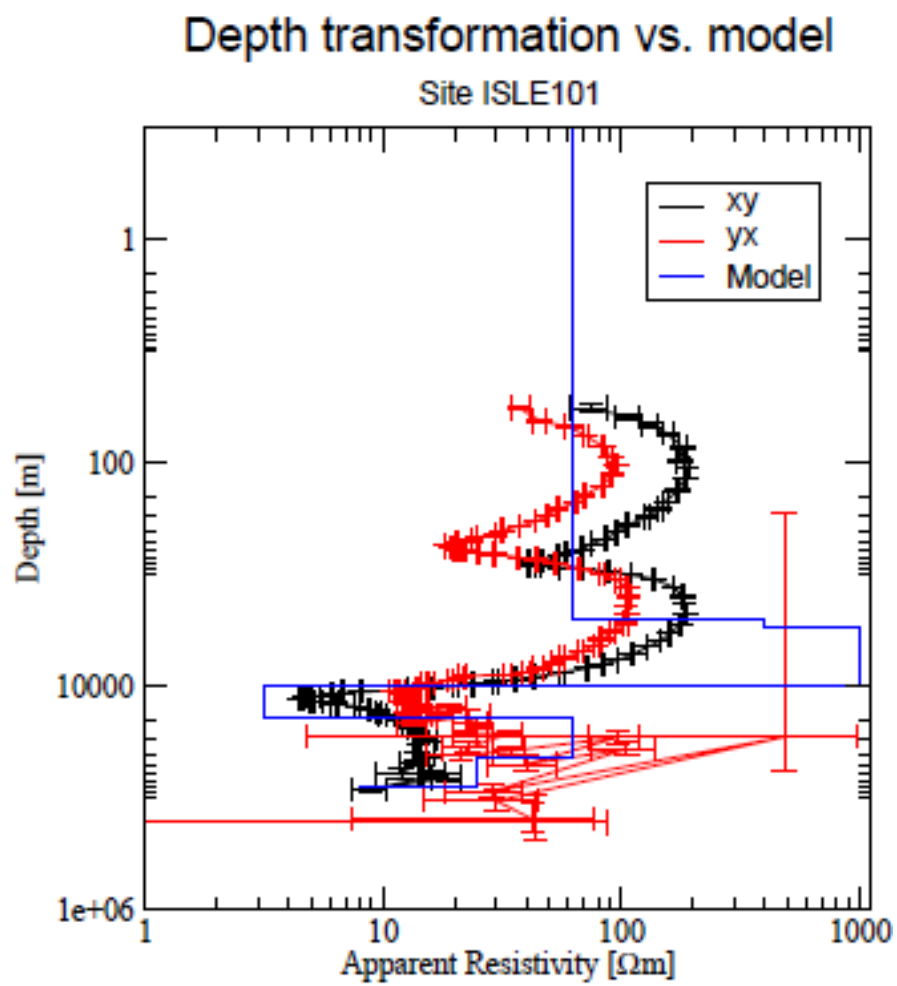
Recording length depends on target depth of investigation, typically:

Near surface	100,000Hz - 100Hz, a few minutes
Crust	100Hz - 1,000s, 3-4 days
Mantle	1s - 30,000s, several weeks

From Max Moorkamp MT Intro ppt
www.dias.ie/~mm/mtintro.pdf

Typical Data and Inversion

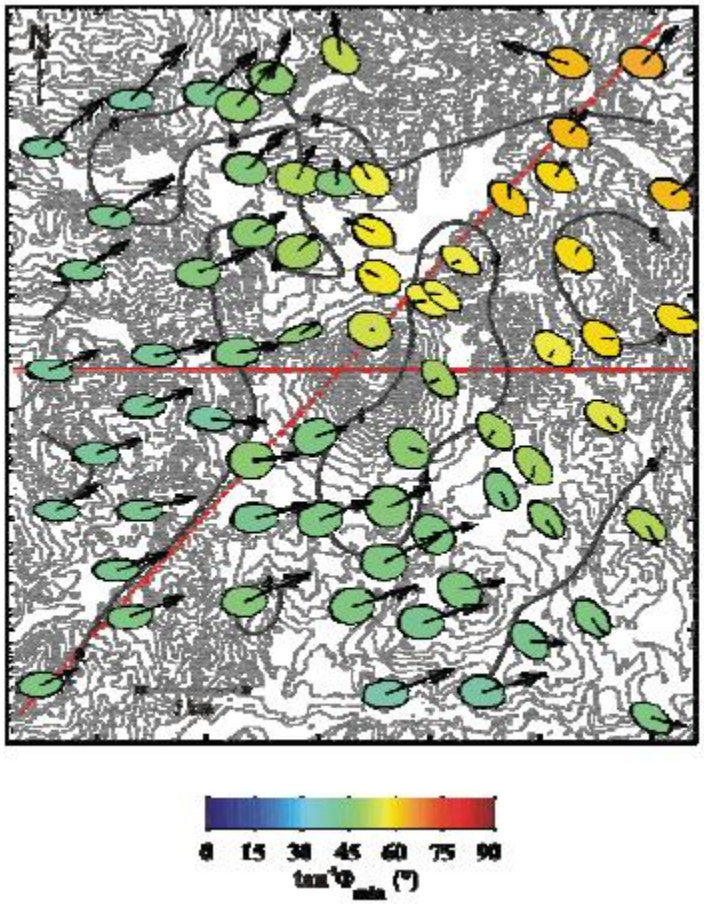




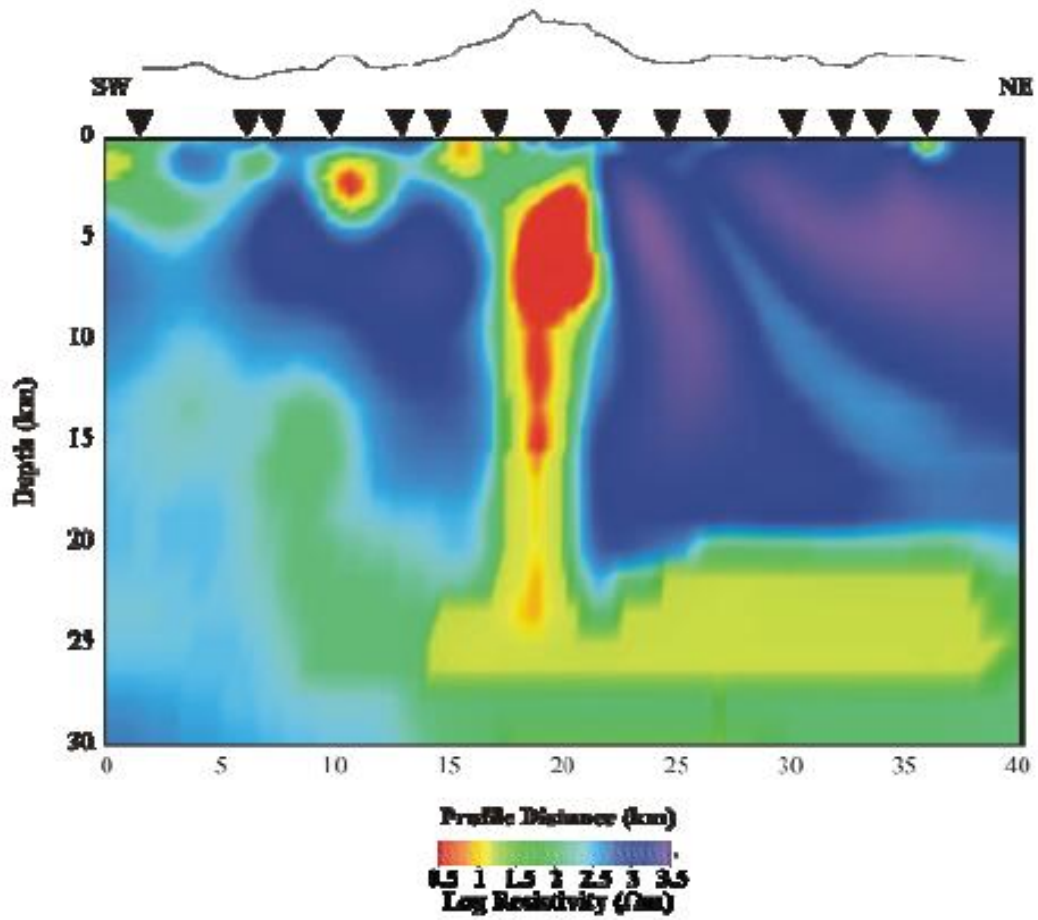
From Max Moorkamp MT Intro ppt
www.dias.ie/~mm/mtintro.pdf

Typical Results

Phase-tensor ellipses & induction vectors

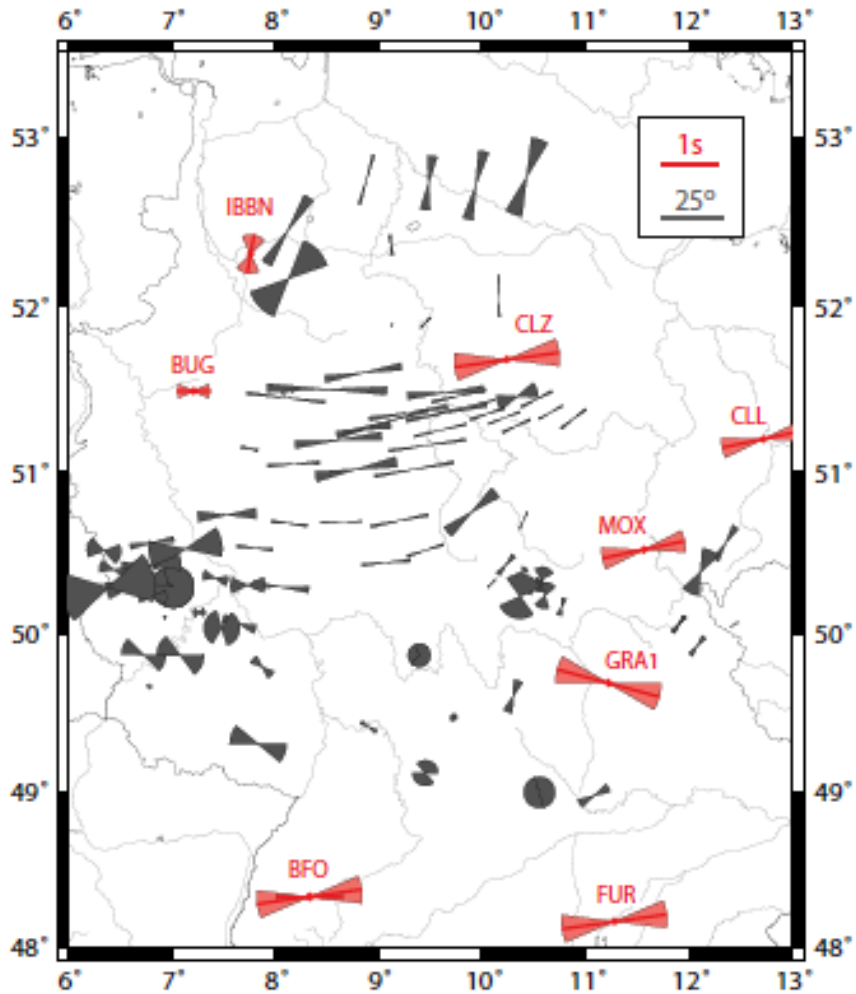


Phase-tensor based cross section



Hill, et al. (2009)

Typical Results



Maps of Geo-electric strike directions

From Max Moorkamp MT Intro ppt
www.dias.ie/~mm/mtintro.pdf