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International Research School of Water Resources

International PhD Course in
HYDROGEOPHYSICS

Limitations, challenges & emerging techniques

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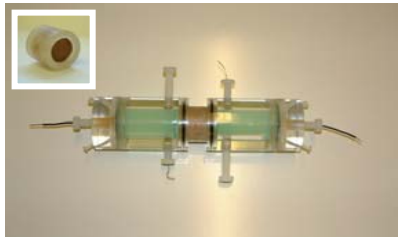
Limitations – hydrogeophysical relationships (1)

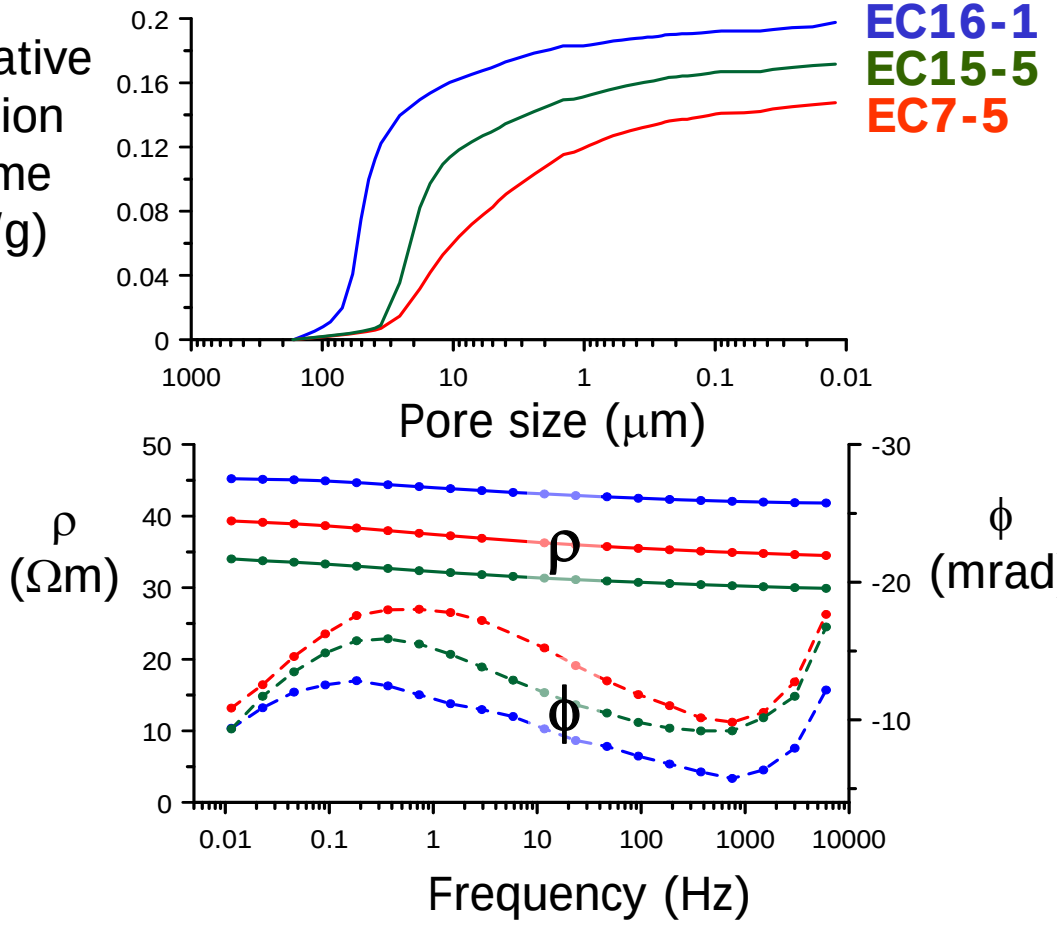
For static imaging there must be a contrast in a geophysical property that can be related to hydrological parameters

This may be site specific

Limitations – hydrogeophysical relationships (1)

Spectral induced polarisation of Triassic Sandstone

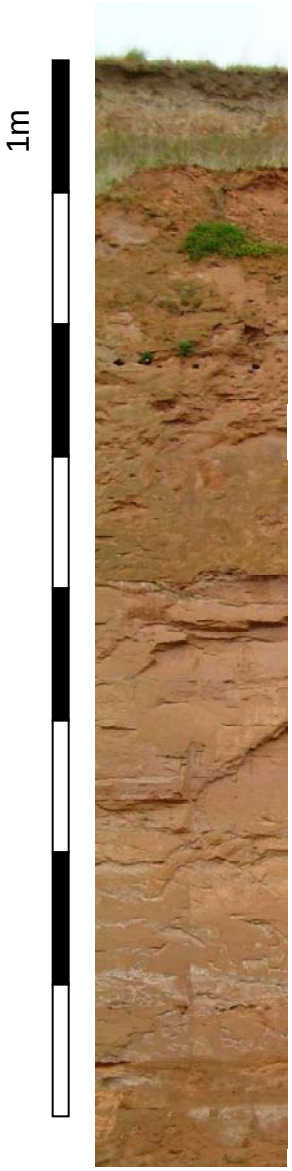




VEC16-1
depth = 17.61 m

VEC15-5
depth = 16.07 m

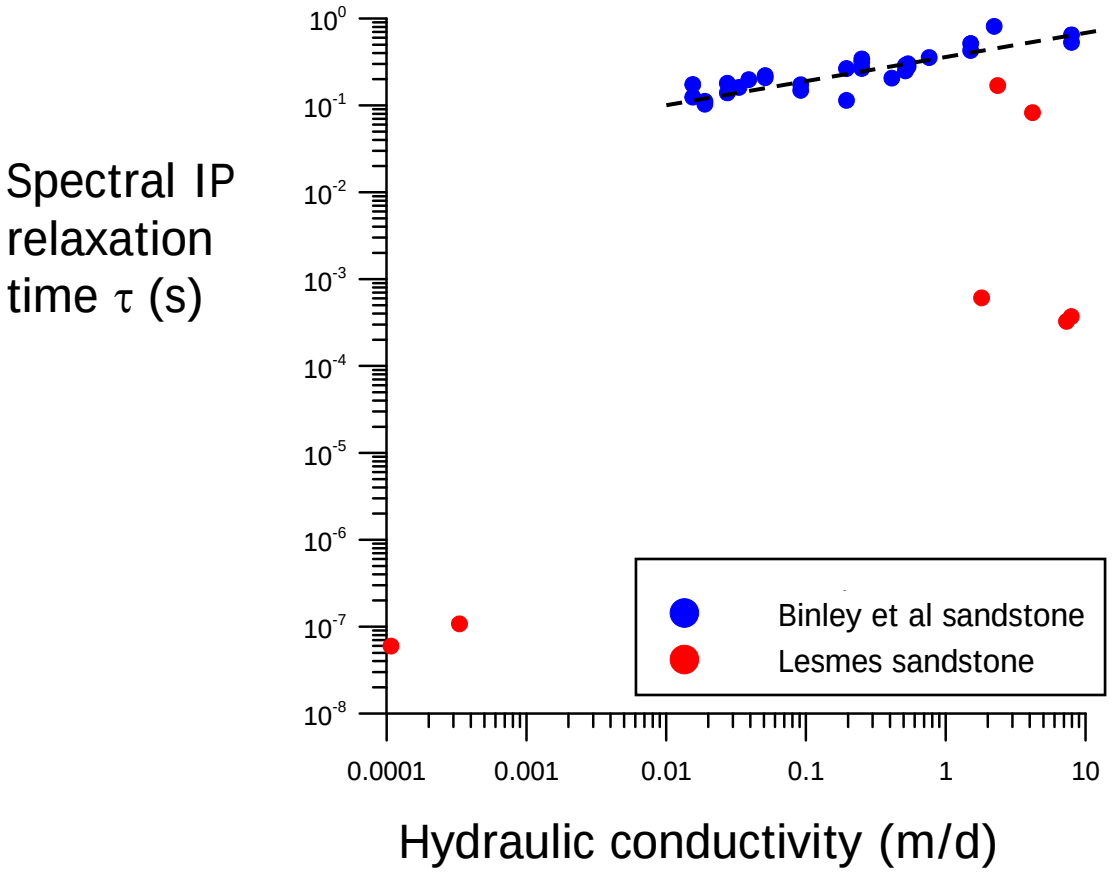
VEC7-5
depth = 8.22 m



Binley, Slater, Fukes and Cassiani (2005)

Limitations – hydrogeophysical relationships (1)

Is there a universal relationship ? Should there be one ?

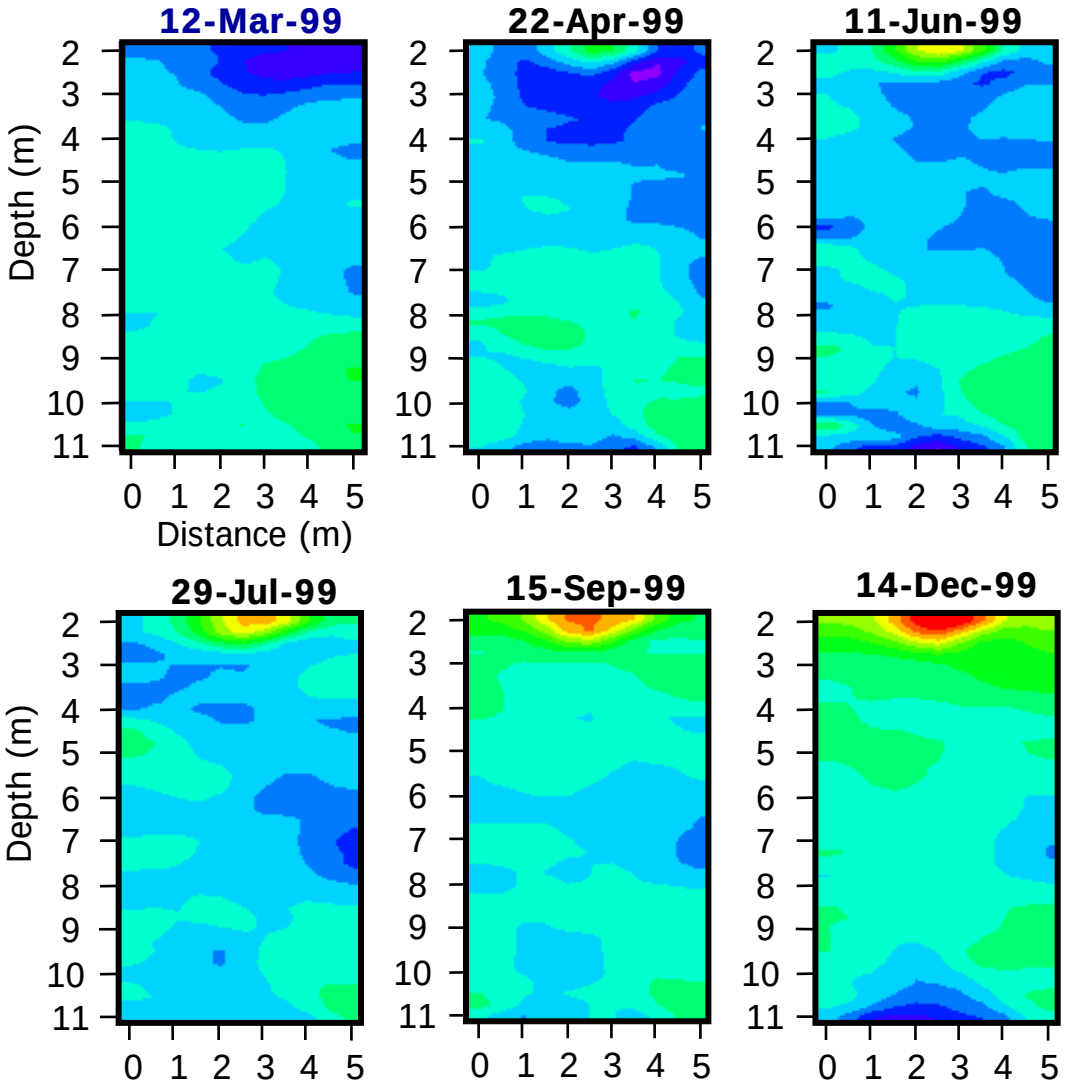


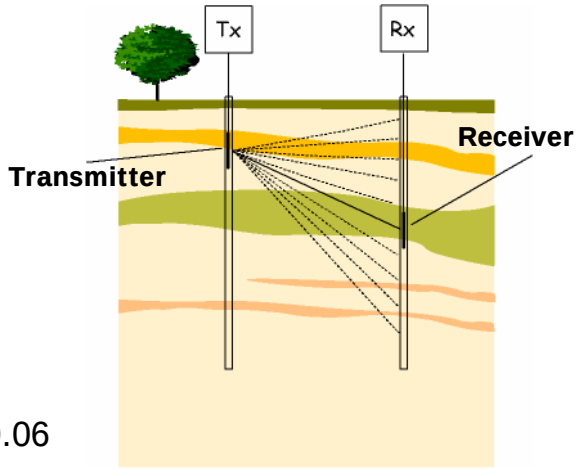
Limitations – hydrogeophysical relationships (2)

Time-lapse measurements may be easier to interpret in order to study processes but appropriate petrophysical relationships are needed

Limitations – hydrogeophysical relationships (2)

Moisture content changes due to natural inputs

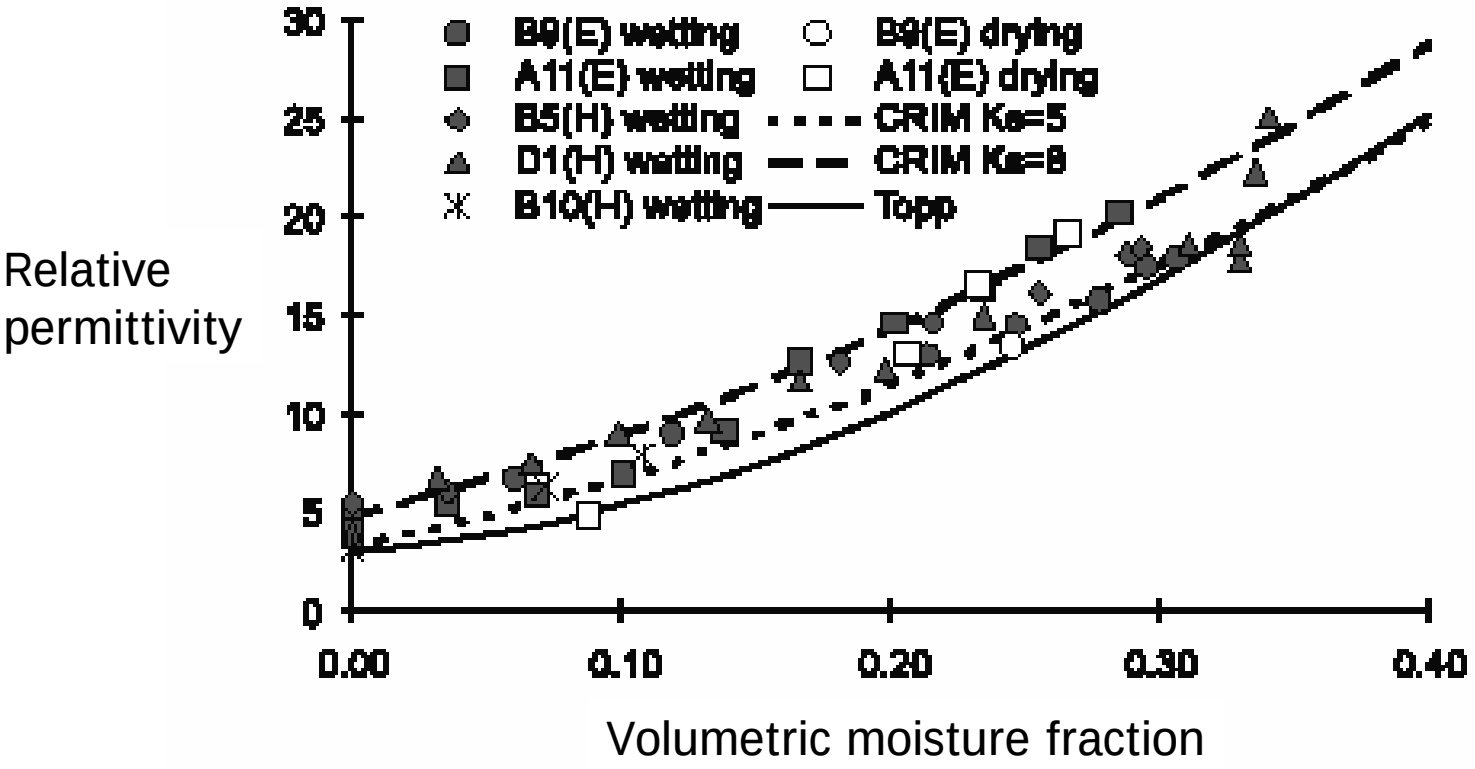




Binley, Winship, Middleton, Pokar and West (2001)

Limitations – hydrogeophysical relationships (2)

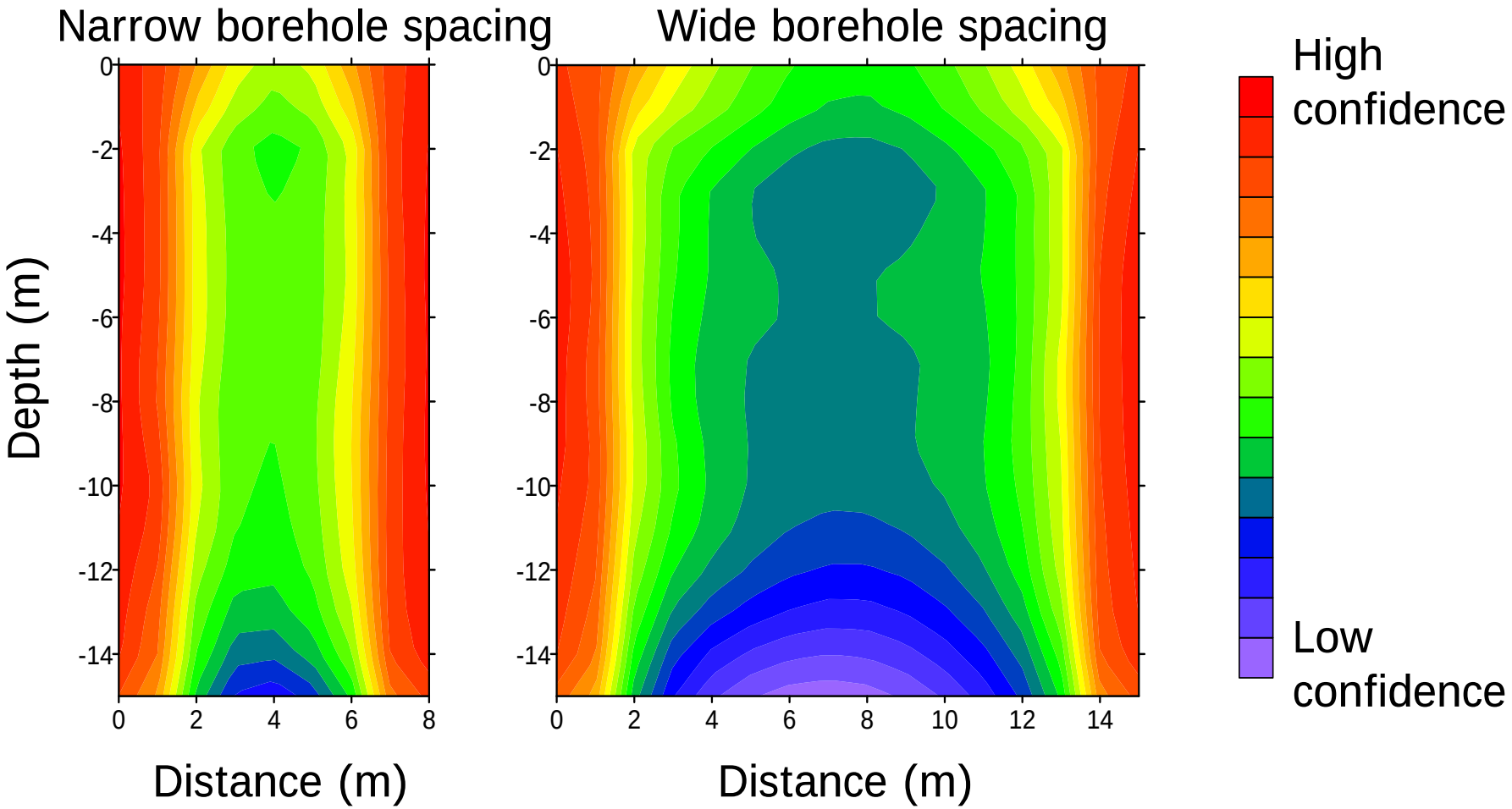
Petrophysical relationships may be site specific and also highly uncertain



West, Handley, Huang and Pokar (2002)

Limitations – variability of sensitivity in an image

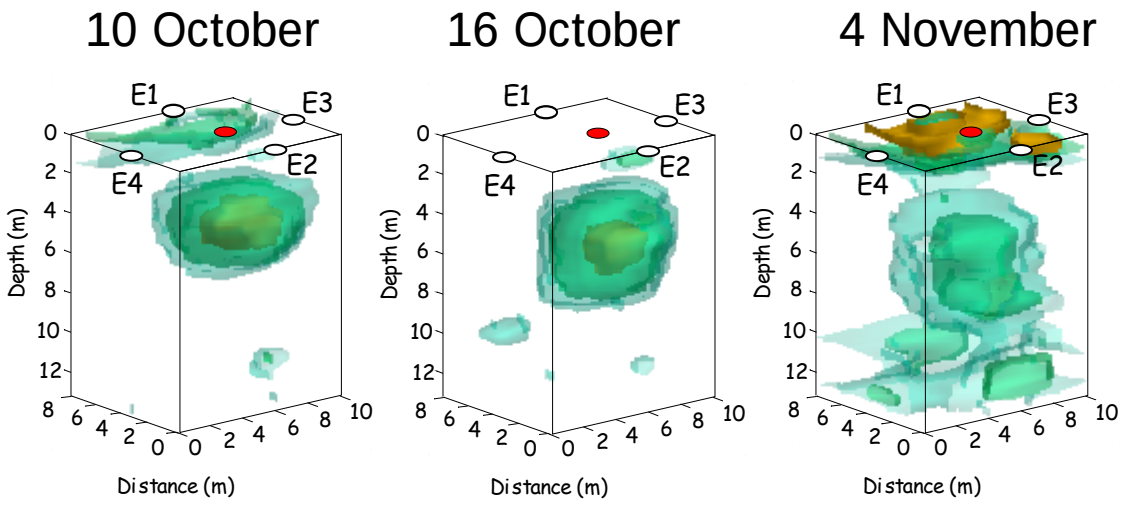
The sensitivity of the imaging varies within the image – in some areas uncertainty in the geophysical property is high – will lead to mass balance errors in tracer studies



Limitations – variability of sensitivity in an image

Vadose zone tracer experiment Hatfield, UK – ERT results

2000 litre water tracer injected 7 October

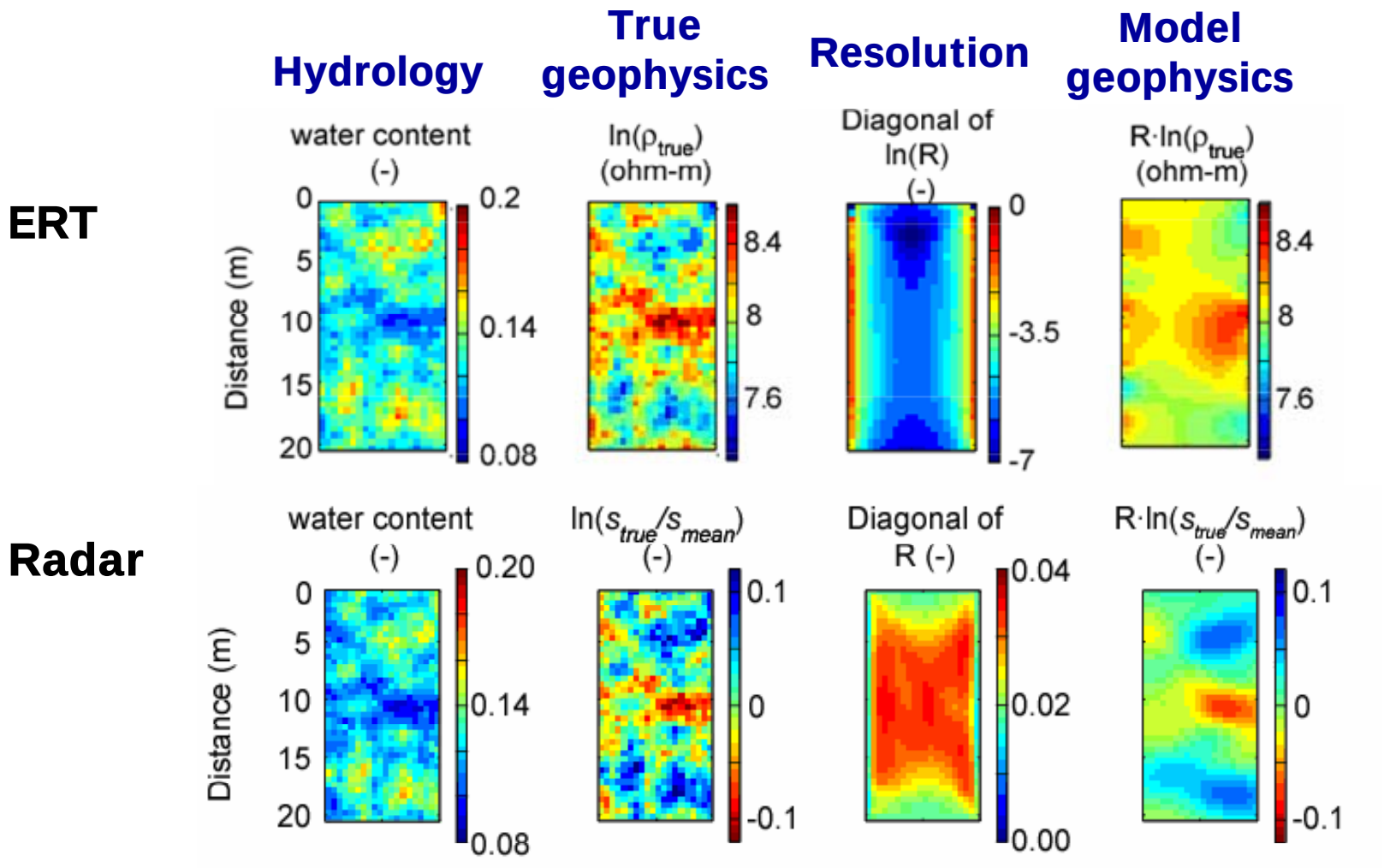


Only 50 % mass observed !

Binley, Cassiani, Middleton & Winship (2003)

Limitations – variability of sensitivity in an image

The sensitivity of the image varies within the image and is dependent on the technique and may be a function of the geophysical parameter

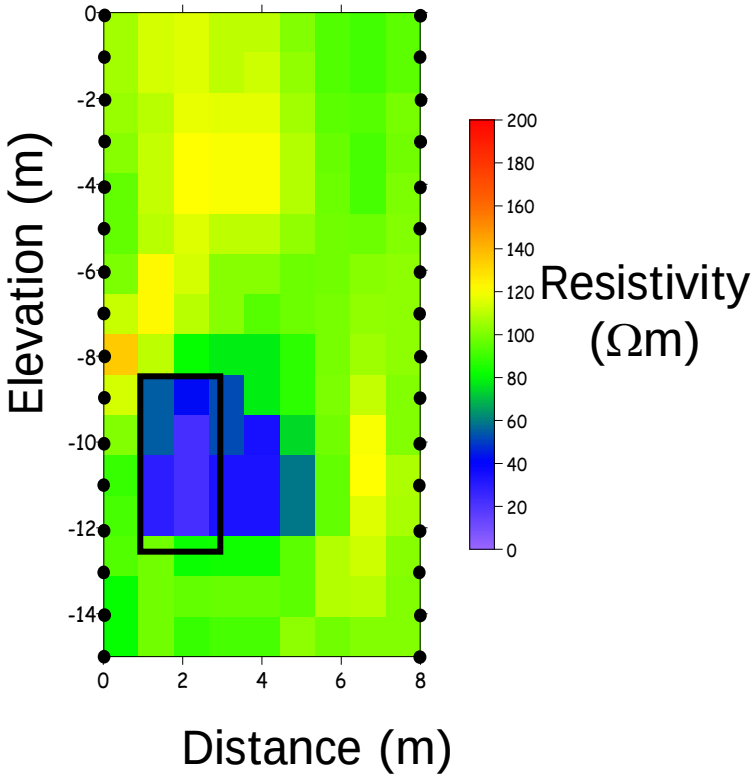


Day-Lewis, Singha and Binley (2005)

Limitations – imaging artefacts

Data inversions can be strongly affected by regularisation (needed to get stable solutions)

This may lead to hydrologically meaningless results or may give the false impression of something hydrologically meaningful

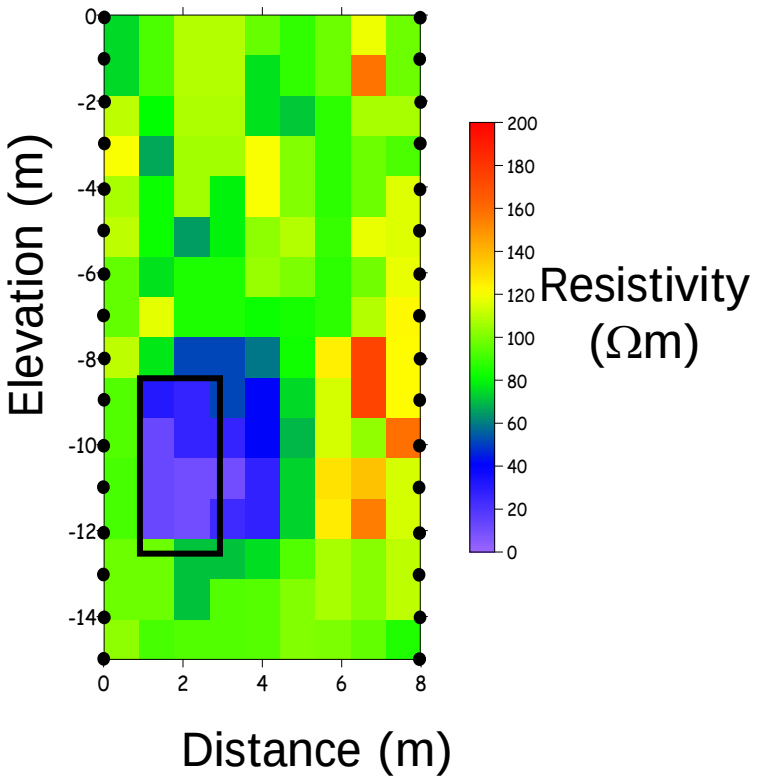


Limitations – impact of noise on images

Data inversions are strongly affected by data and modelling noise levels and these must be characterised for accurate assessment of geophysical properties

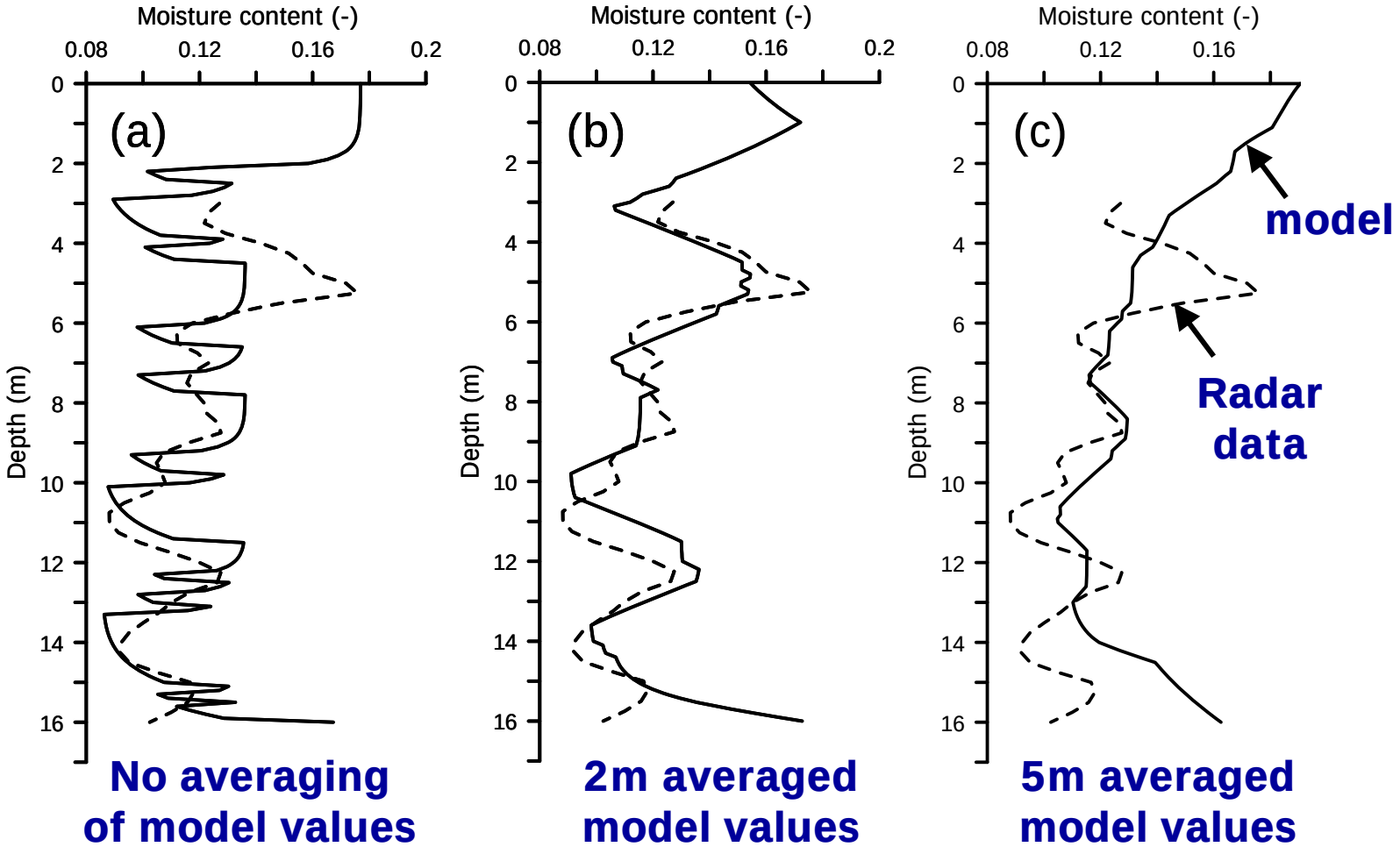
We can ignore this for ‘anomaly hunting’ but not if we want to get quantitative information from the images

Inversion of synthetic data with 5% error added but 2% error assumed



Limitations – measurement scale

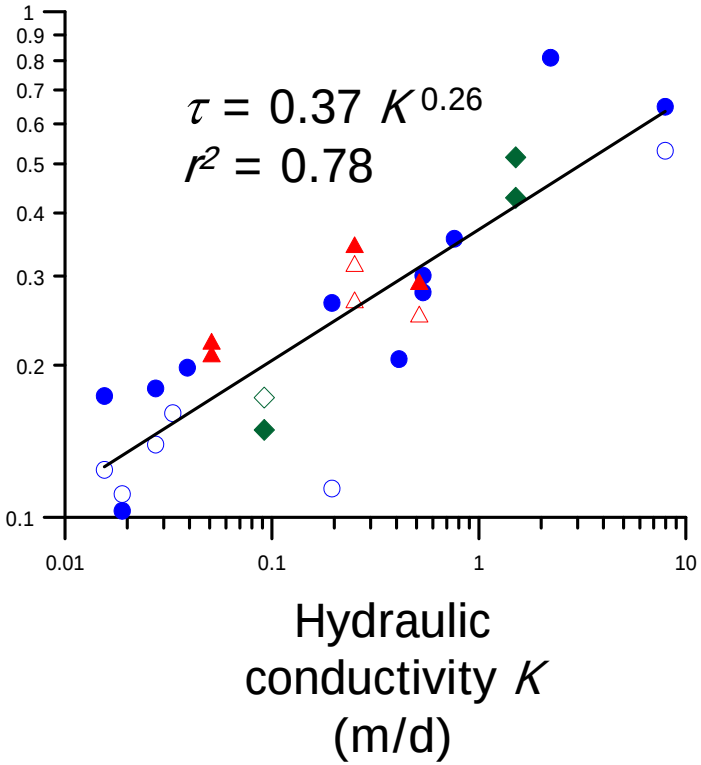
We need to ensure that measurement and model scales are comparable

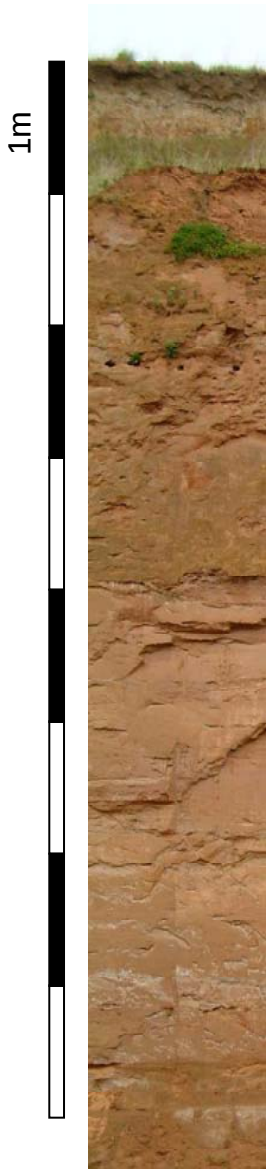


Cassiani and Binley (2005)

Challenges – better understanding of processes

A better understanding is needed of the processes that lead to some geophysical signals (e.g. induced polarisation)





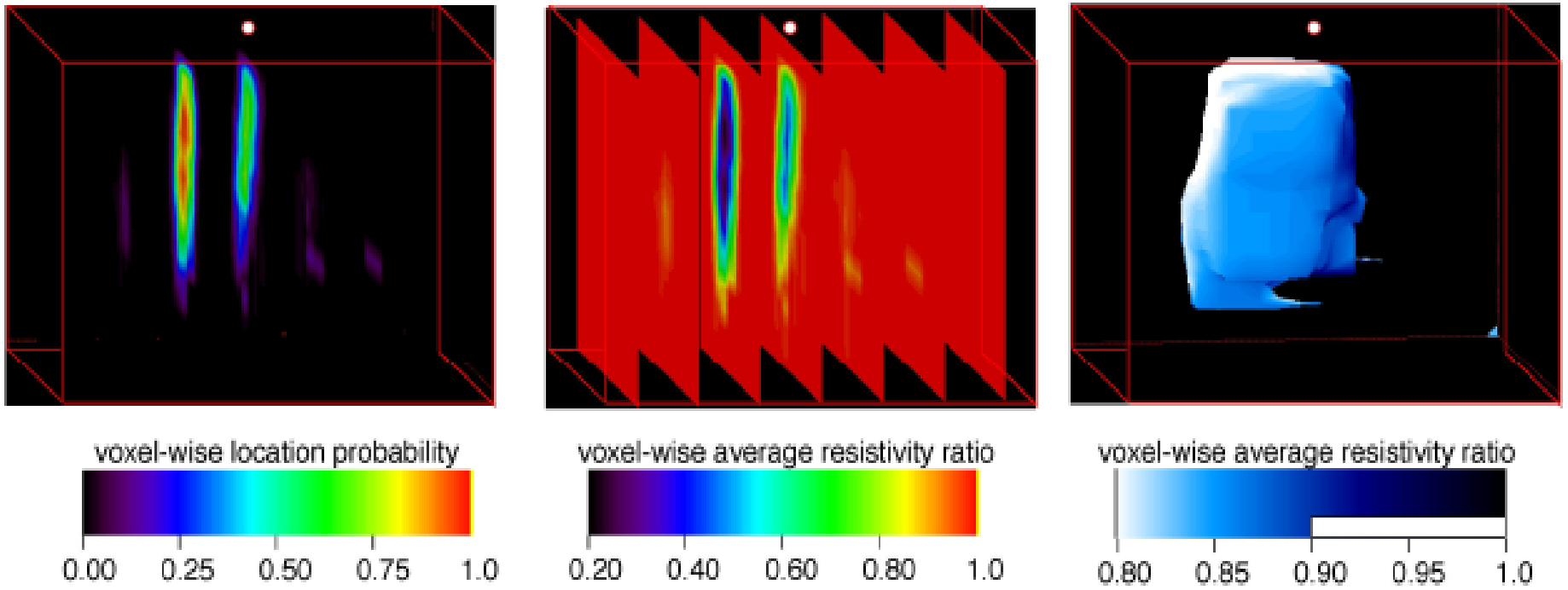
Challenges – data fusion methodologies

Do we need images ?

Can we setup inversions of hydrological variables rather than geophysical ones?

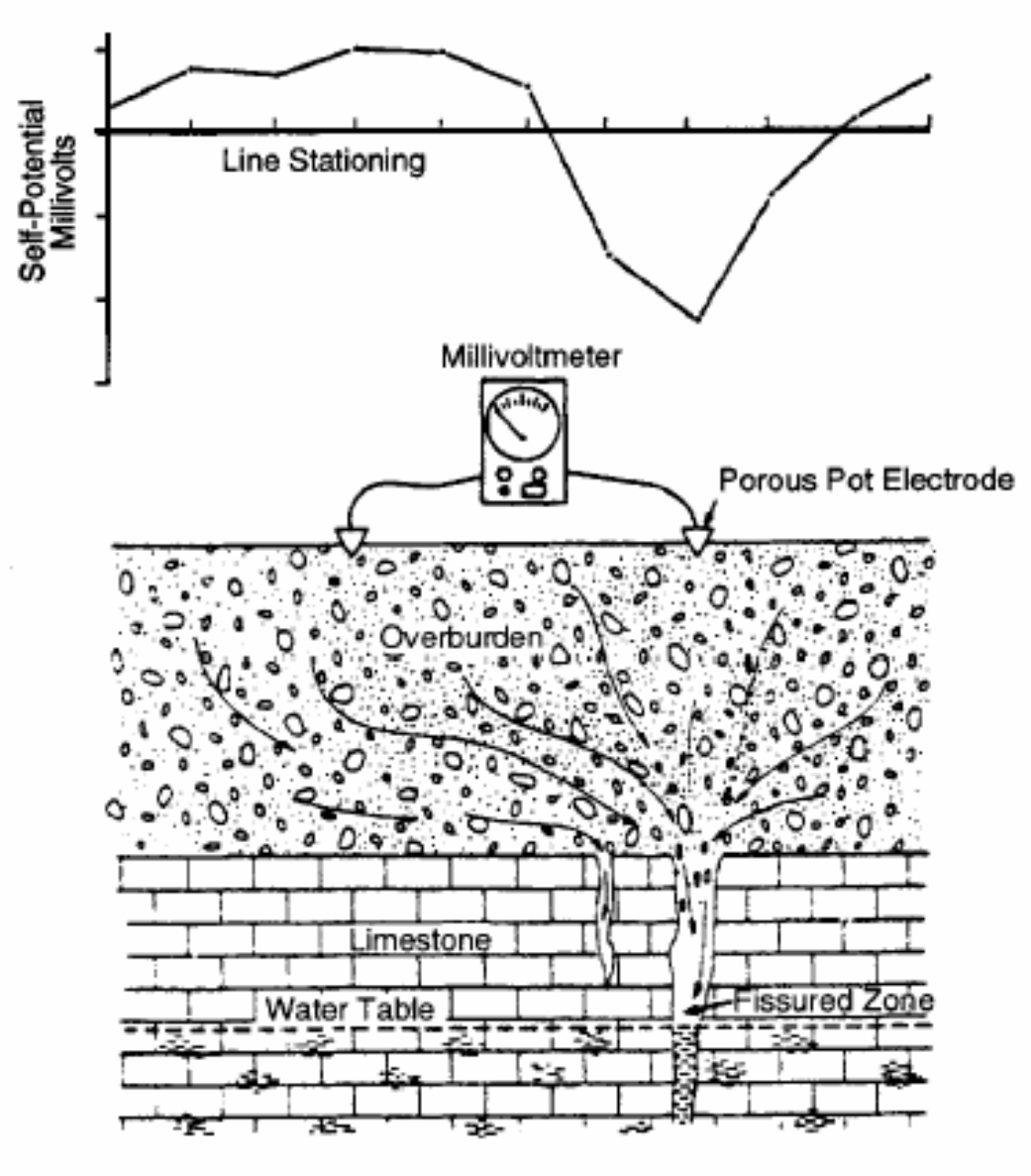
Challenges – uncertainty in geophysical results

We need an assessment of uncertainty in geophysical and hydrogeophysical results



Ramirez et al (2003)

Emerging techniques – Self Potential (but not really new)



Ogilvy & Bogoslovsky (1979)

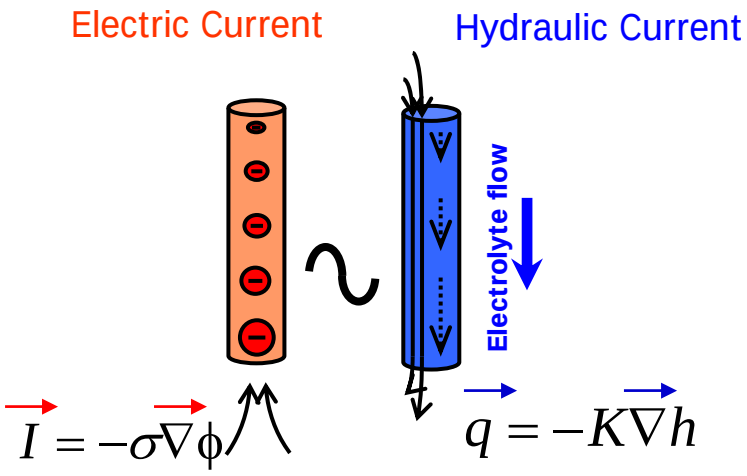
Emerging techniques – Self Potential (but not really new)

	Hydraulic modelling	Electric modelling
Flux	$\vec{q} = -K\vec{\nabla}h$	$\vec{I} = -\sigma\vec{\nabla}\phi$
Conservation law	$\vec{\nabla}.\vec{q} = -S_h$	$\vec{\nabla}.\vec{I} = -S_e$

Electrokinetic coupling:

$$\begin{cases} \vec{q} = -K\vec{\nabla}h + C\sigma\vec{\nabla}\phi \\ \vec{I} = C\sigma\vec{\nabla}h - \sigma\vec{\nabla}\phi \end{cases}$$

where $C = \left.\frac{dh}{d\phi}\right|_{I=0}$

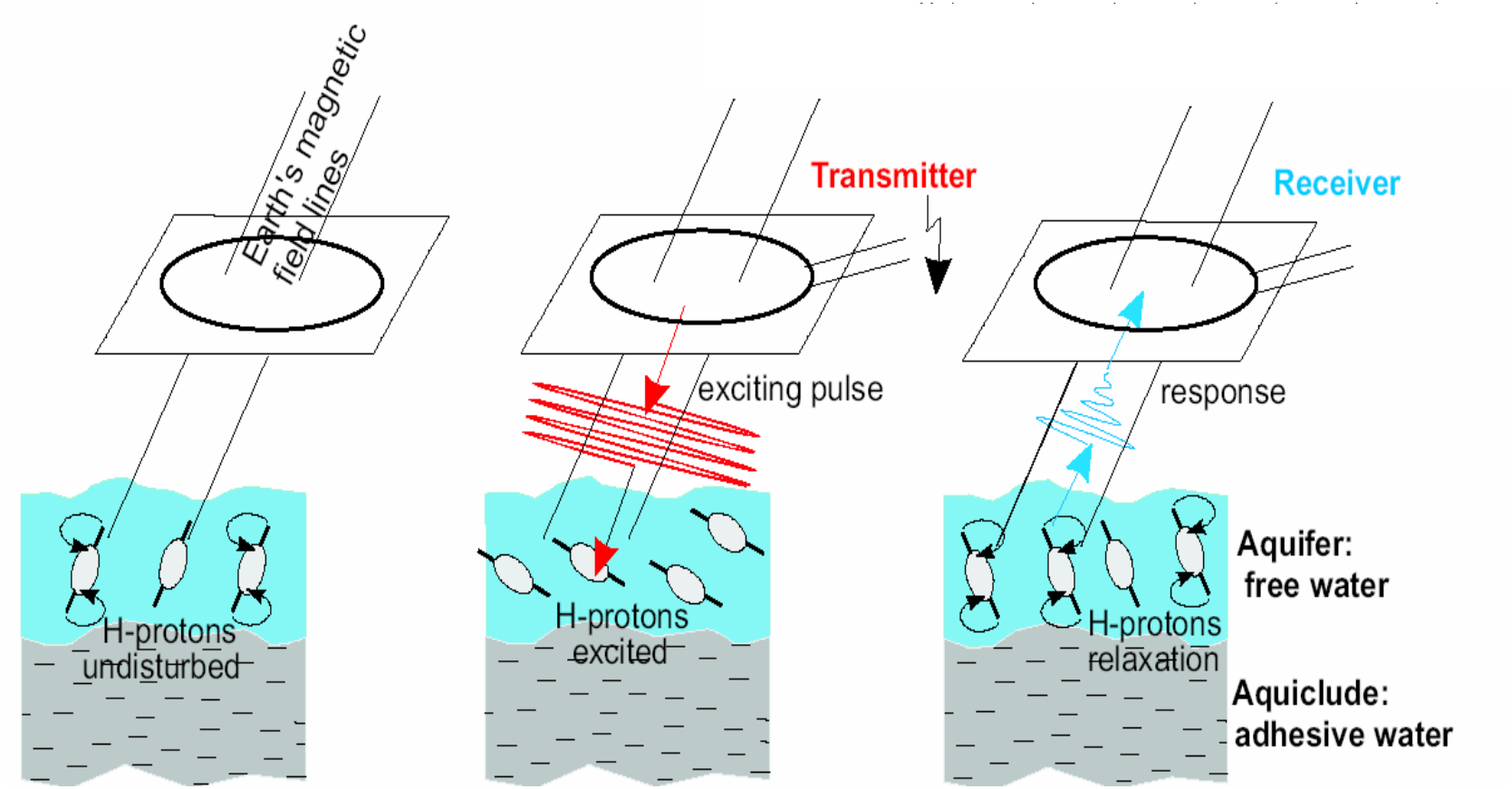


Sailhac (2005)

Emerging techniques – NMR

Nuclear Magnetic Resonance - ability to sense ‘free’ water

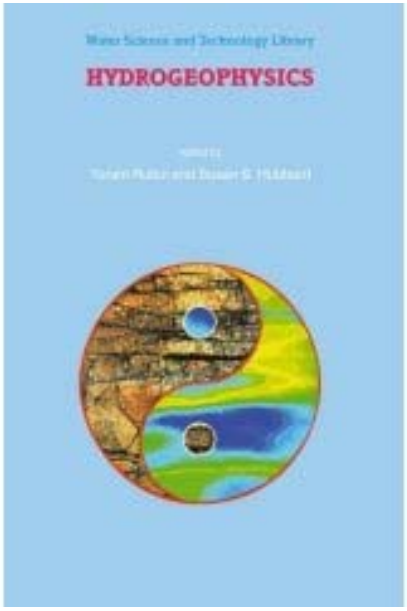
Excitation and relaxation of hydrogen protons



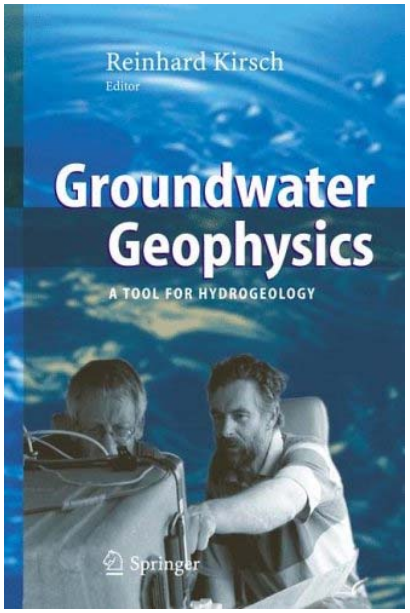
Yaramanci et al (2005)

For more information see:

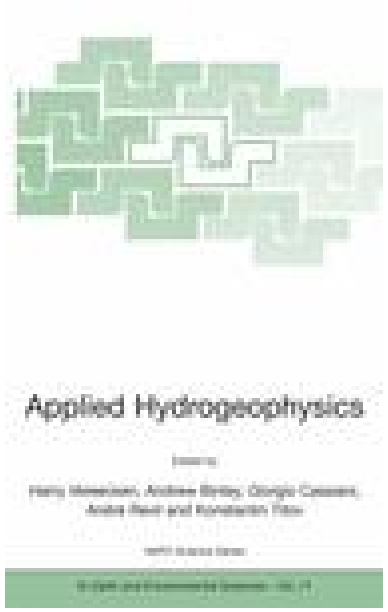
Hydrogeophysics **Rubin and Hubbard (Eds.), Springer, 2005.**



Groundwater Geophysics, **Reinhard Kirsch (Ed.), 493 pages, Springer-Verlag, 2006.**



Applied Hydrogeophysics, **H Vereecken, A Binley, G Cassiani, A Revil and K Titov (Eds.), 395 pages, Springer-Verlag, 2006.**



Enjoy the rest of the World Cup!