Magnetic Resonance Sounding

A new technique for hydrogeophysics

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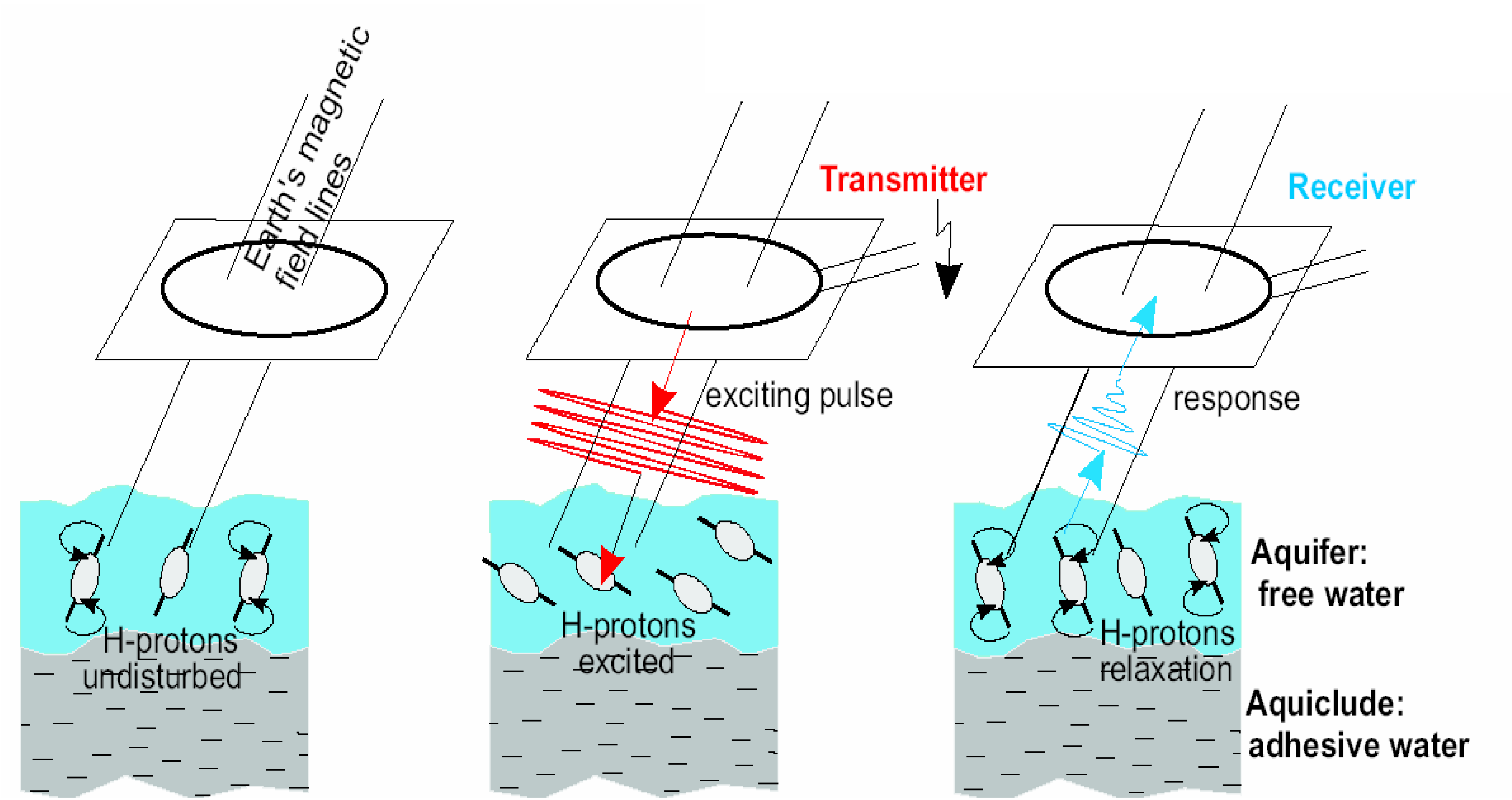
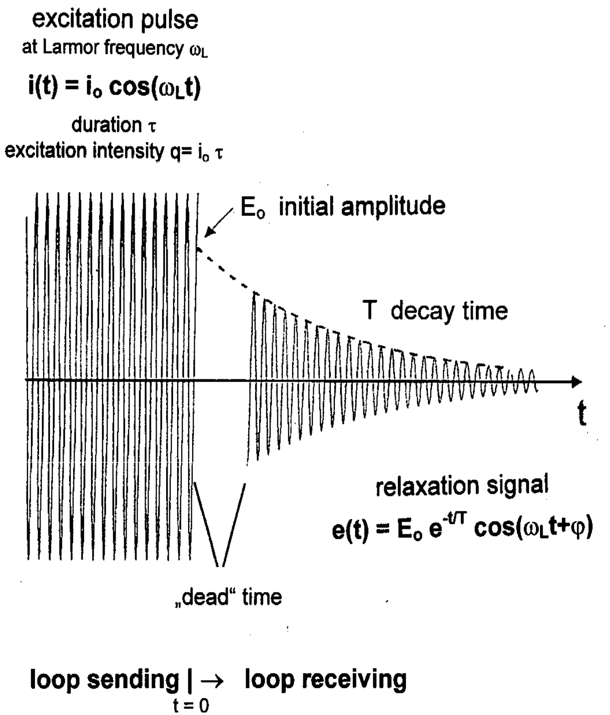
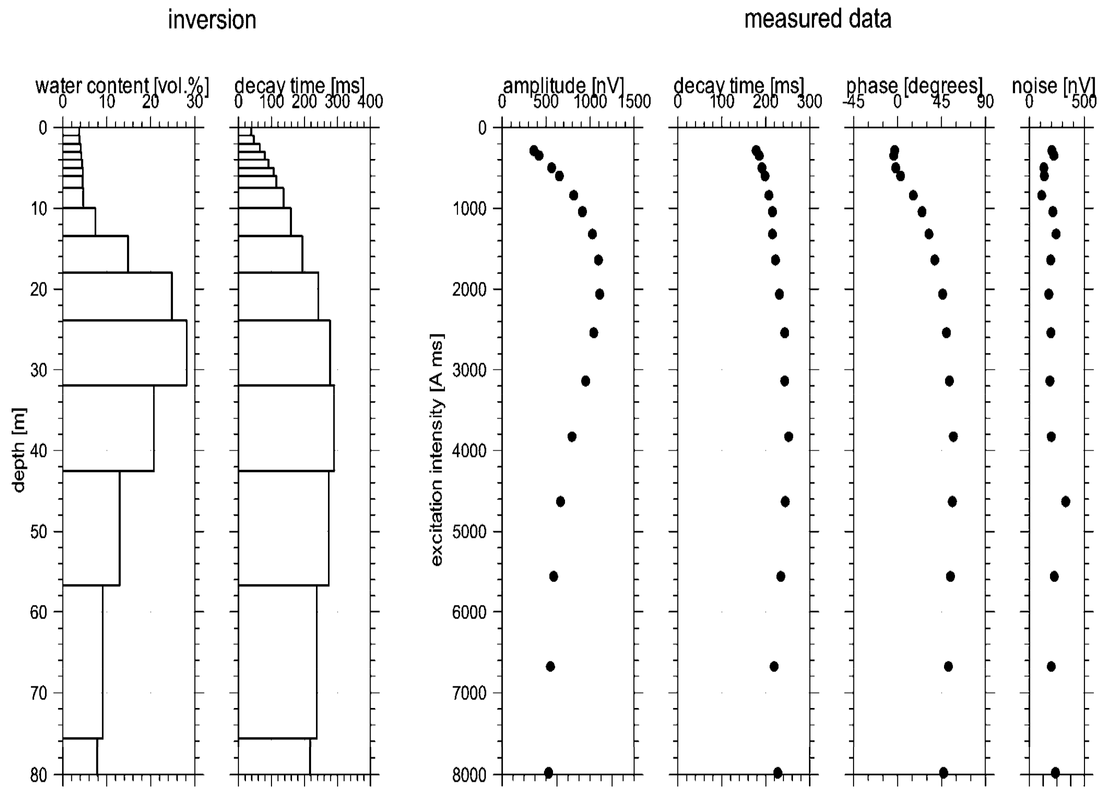
Excitation and relaxation of hydrogen protons



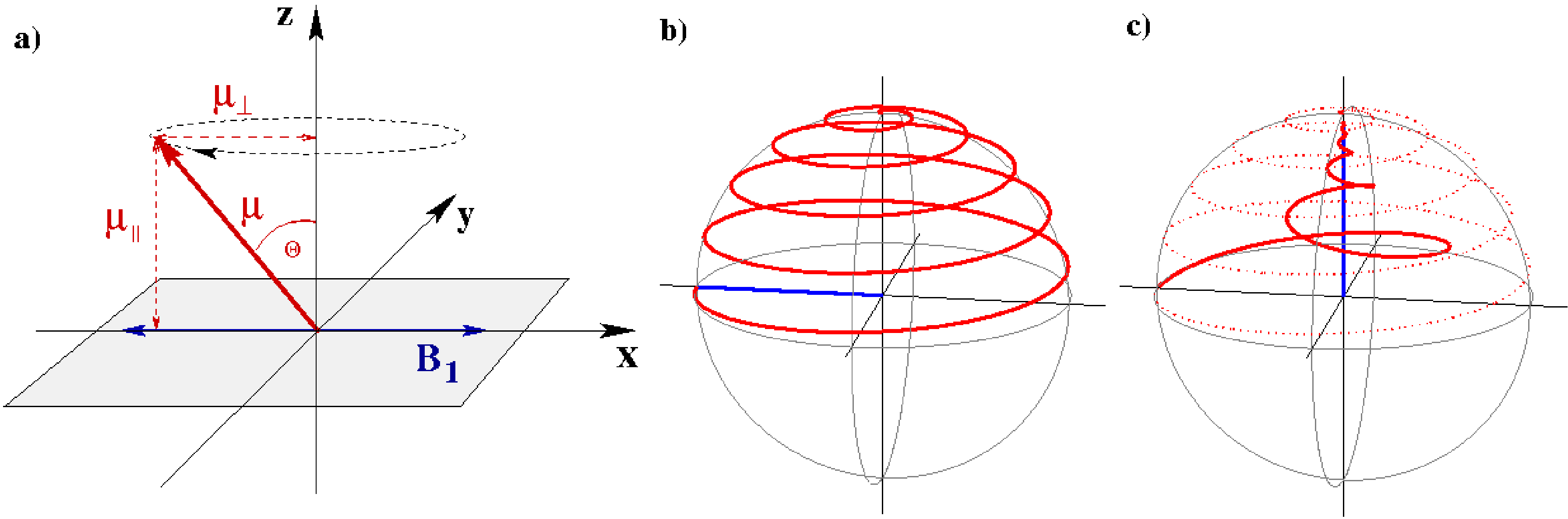
Basic principle of MRS measurements





<u>Measured quantity</u>	<u>Derived parameter</u>
E_o Initial Amplitude	~ layer water content
T Decay Time	~ layer decay time ~ pore size ~ hydraulic permeability
φ Phase	~ layer electrical conductivity

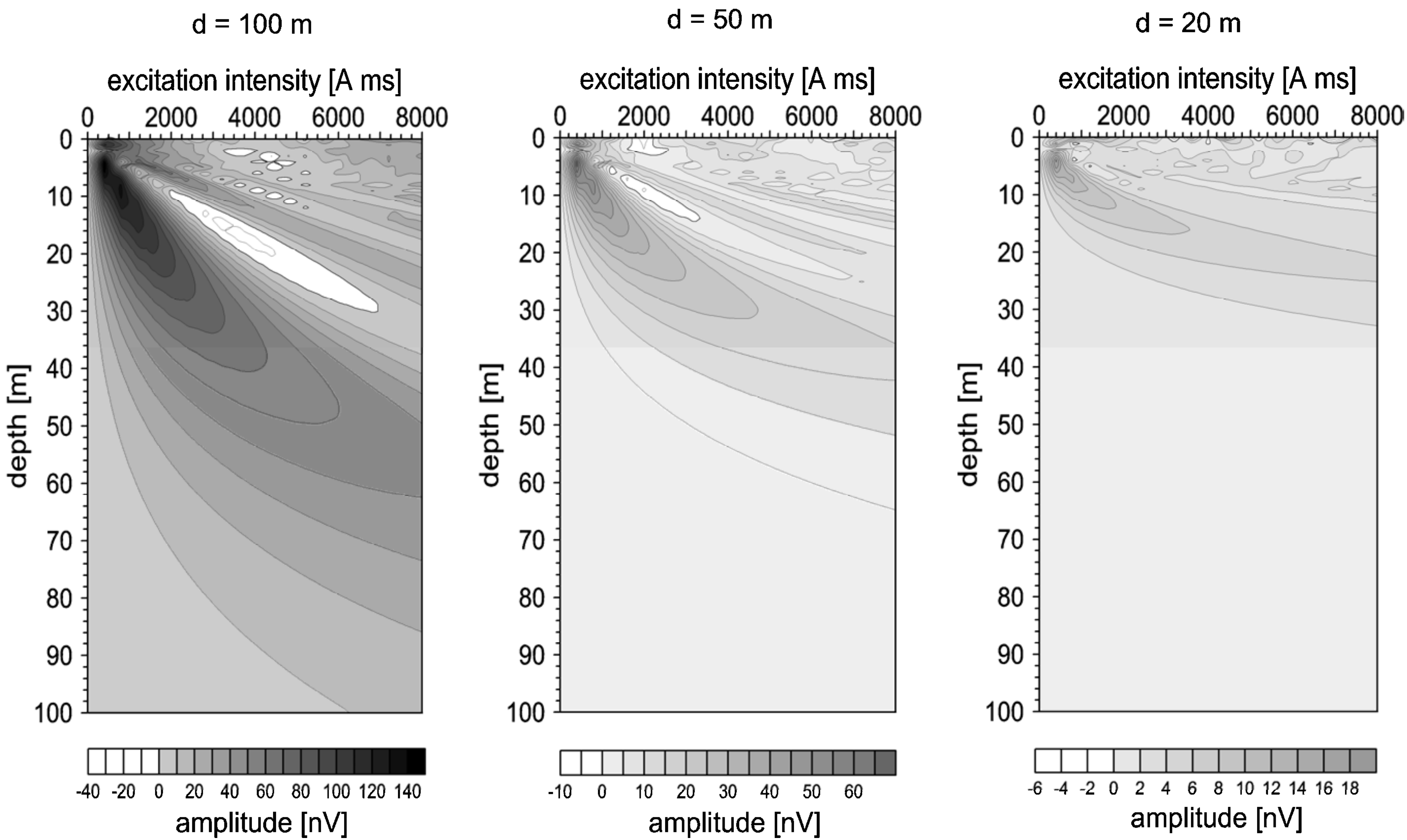
Spin behaviour during excitation and relaxation



(a) Components of the precessing magnetic moment of the Spin.
(b) Unit trajectory of the Spin magnetic moment during the excitation process
(c) and during the relaxation process

Direction of the static field B_0 is along the z-axis

Sensitivities at 1D soundings for different loop sizes



Basic equation for MRS response signal
Initial voltage in reciever loop

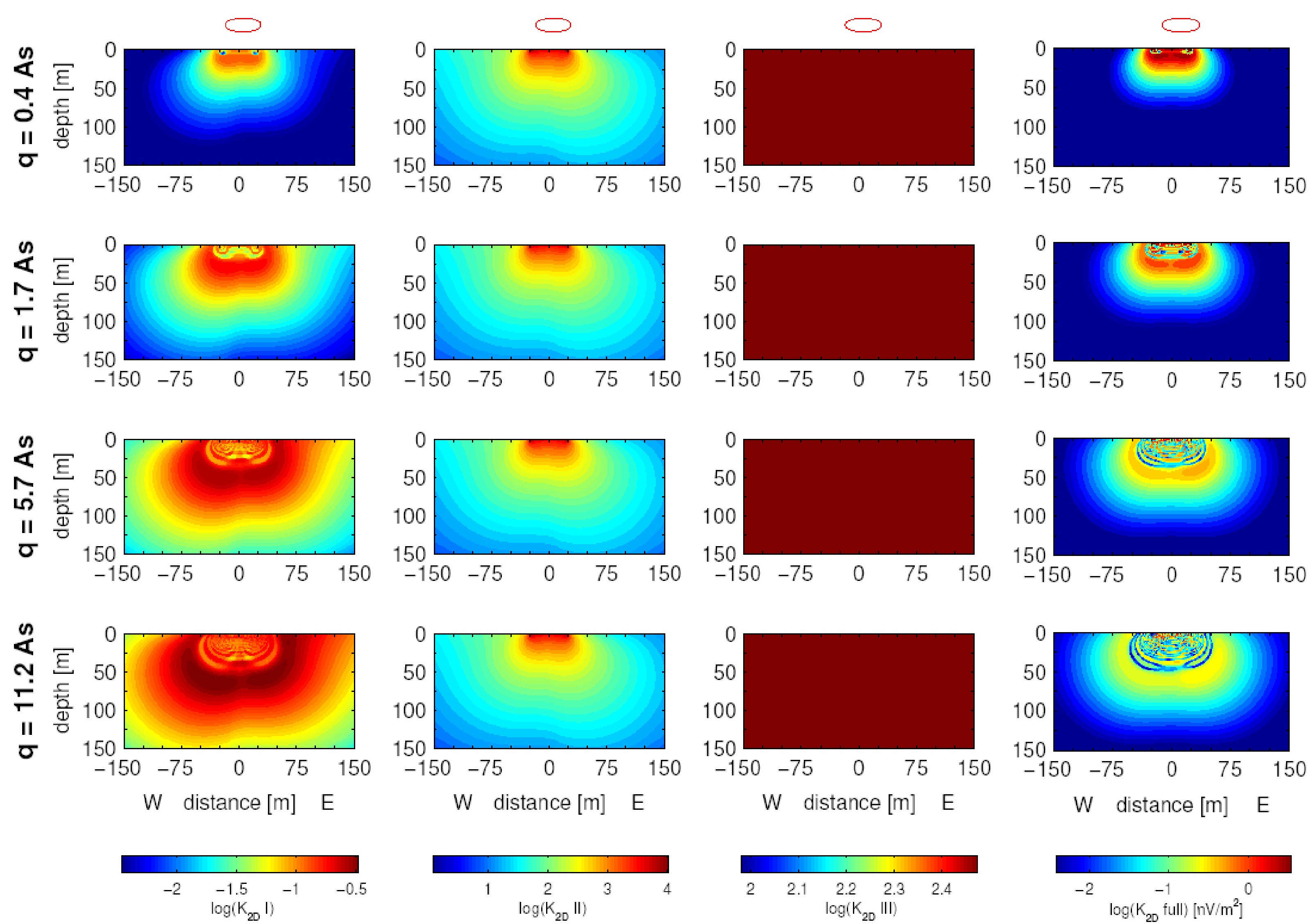
$$
\begin{aligned}
V_R(q) \;=\; & \omega_L \int d^3\mathbf{r} \left|\mathbf{M}_N^{(0)}(\mathbf{r})\right| \sin\left(q\mathbf{B}_T^{+}(\mathbf{r})\right) \\
& \times \mathbf{B}_R^{-}(\mathbf{r}) \cdot e^{i[\zeta_T(\mathbf{r})+\zeta_R(\mathbf{r})]} \\
& \times \left[\widehat{\mathbf{b}}_R(\mathbf{r}) \cdot \widehat{\mathbf{b}}_T(\mathbf{r}) + i\widehat{\mathbf{B}}_0 \cdot \widehat{\mathbf{b}}_R(\mathbf{r}) \times \widehat{\mathbf{b}}_T(\mathbf{r})\right]
\end{aligned}
$$

(I) The Spin signal excitation induced by the transmitter loop

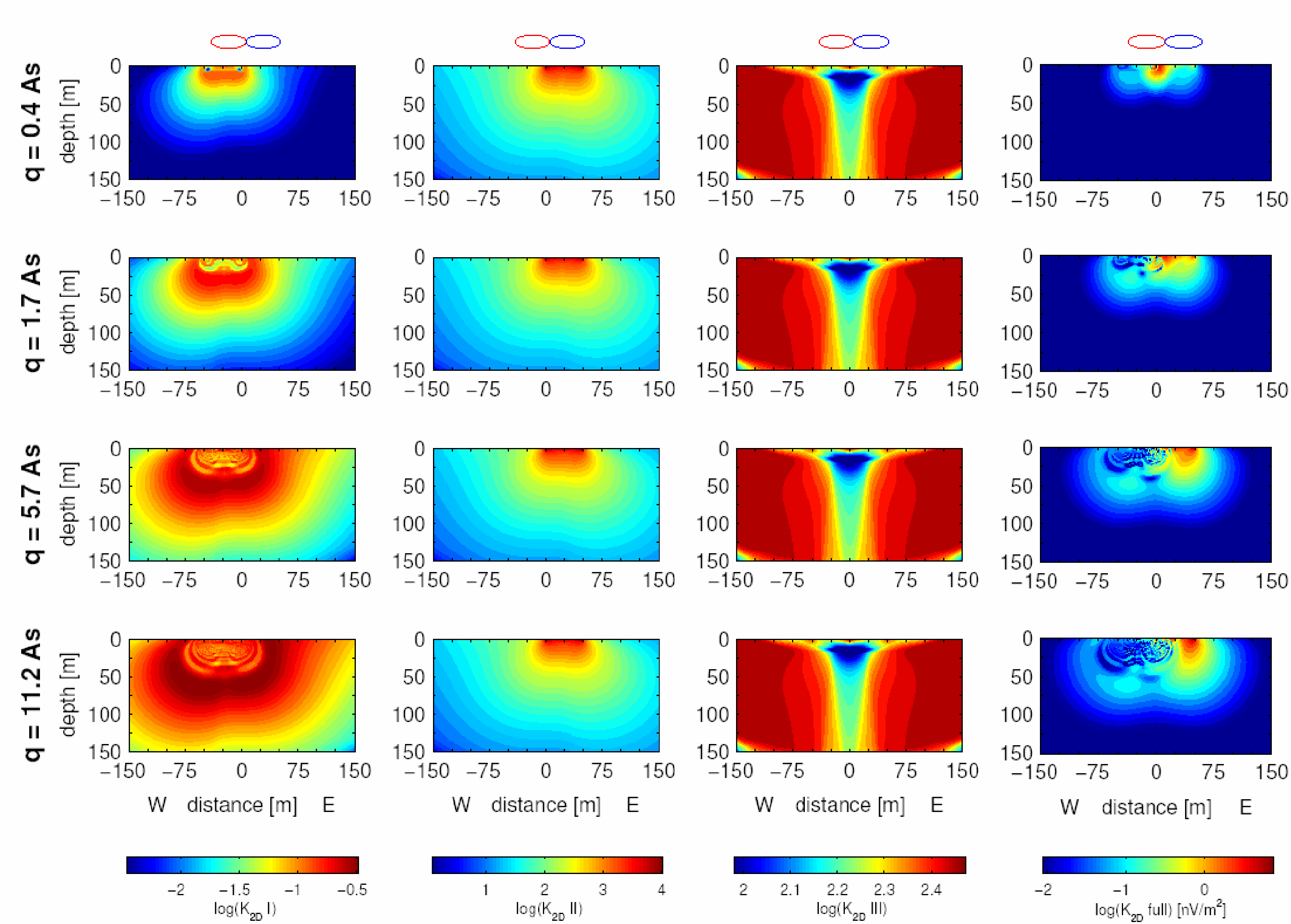
(II) The sensitivity of the receiver loop to the excited Spin

(III) The geometric relation of the magnetic fields of both loops

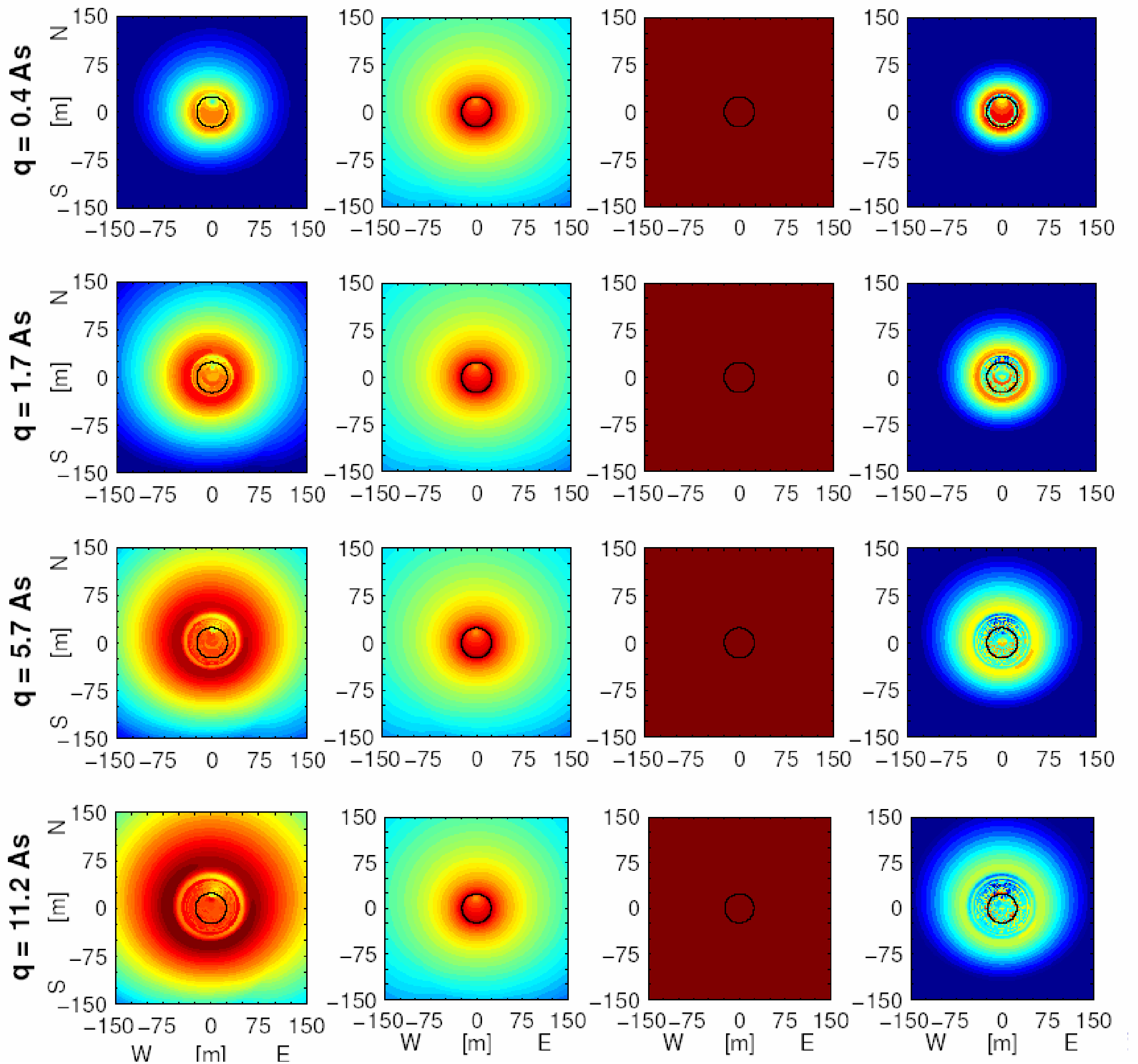
2d-sensitivities for coinciding receiver and transmitter



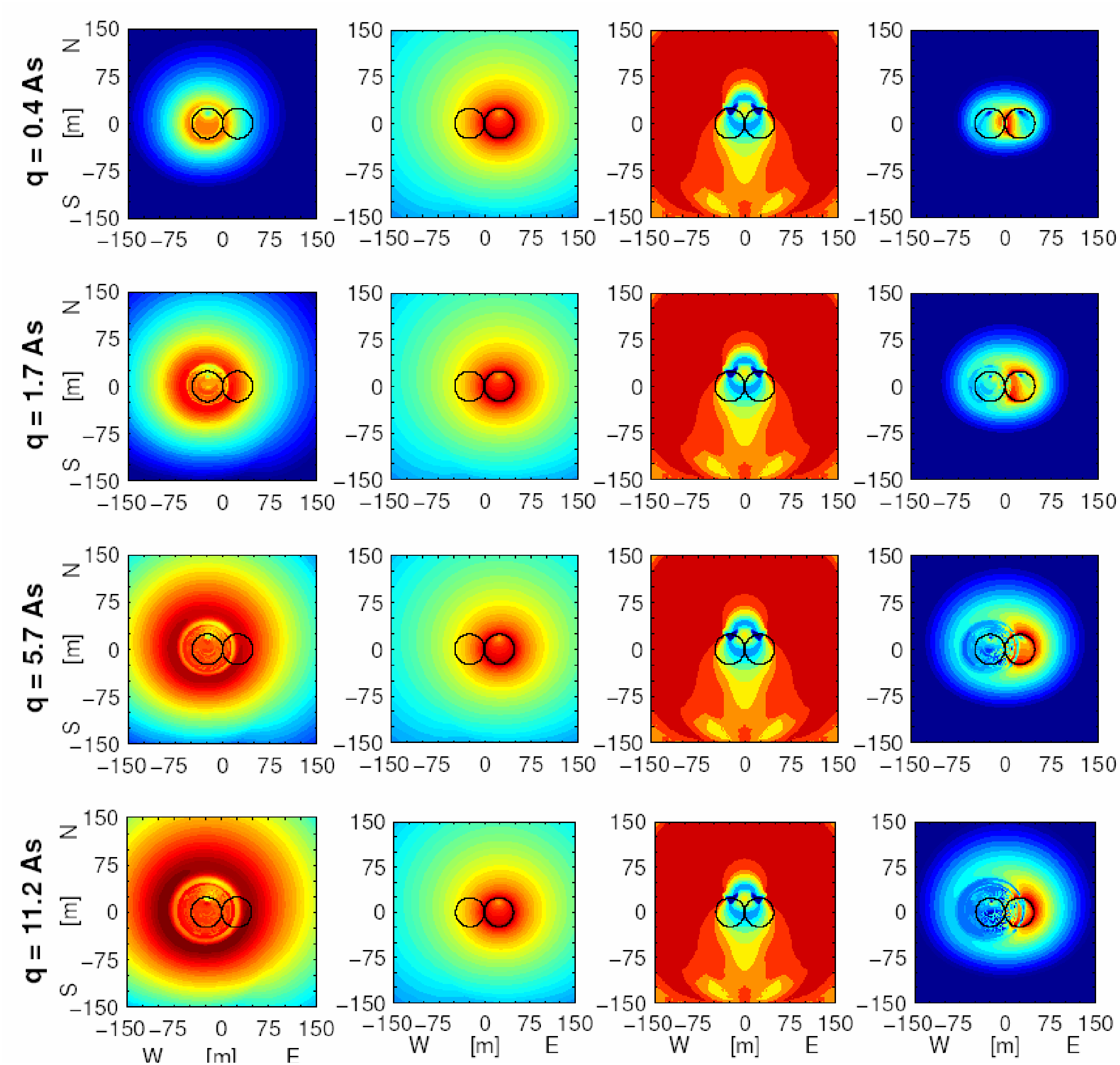
2d-sensitivities for seperated receiver and transmitter



2d-sensitivities for coincident receiver and transmitter

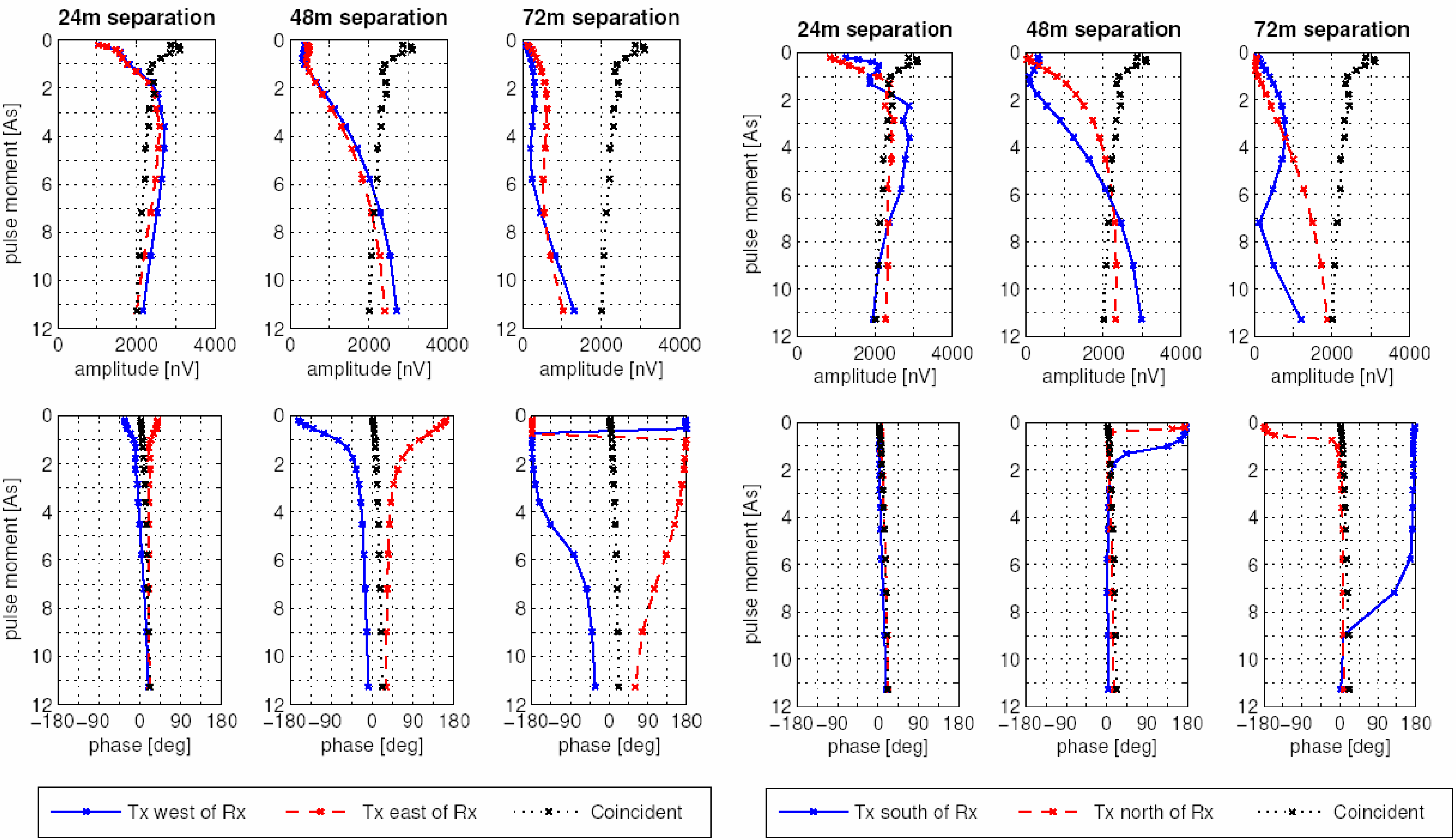


2d-sensitivities for seperate receiver and transmitter



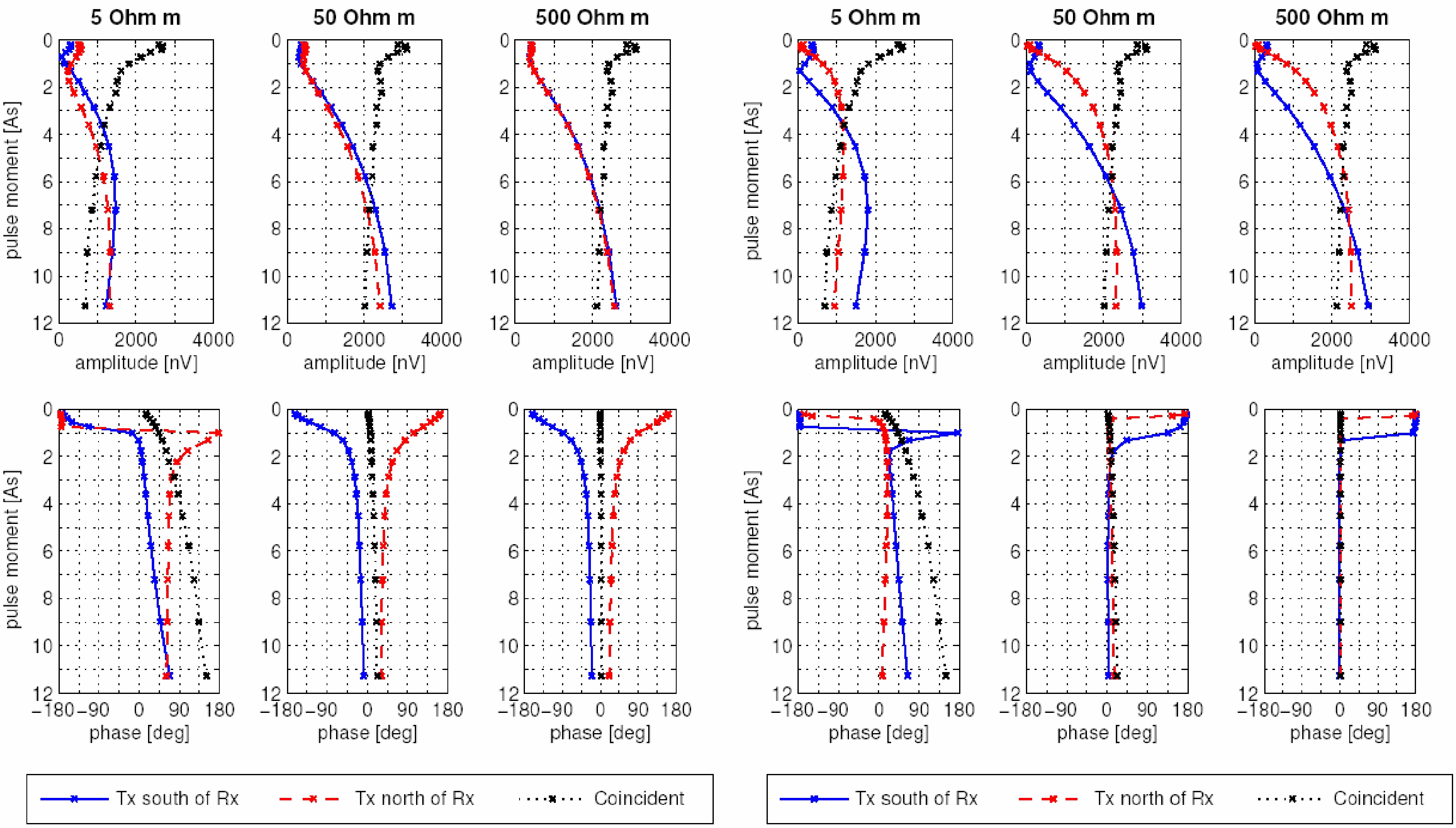
Synthetic data for homogeneous half space

effect of receiver and transmitter seperation and seperation direction

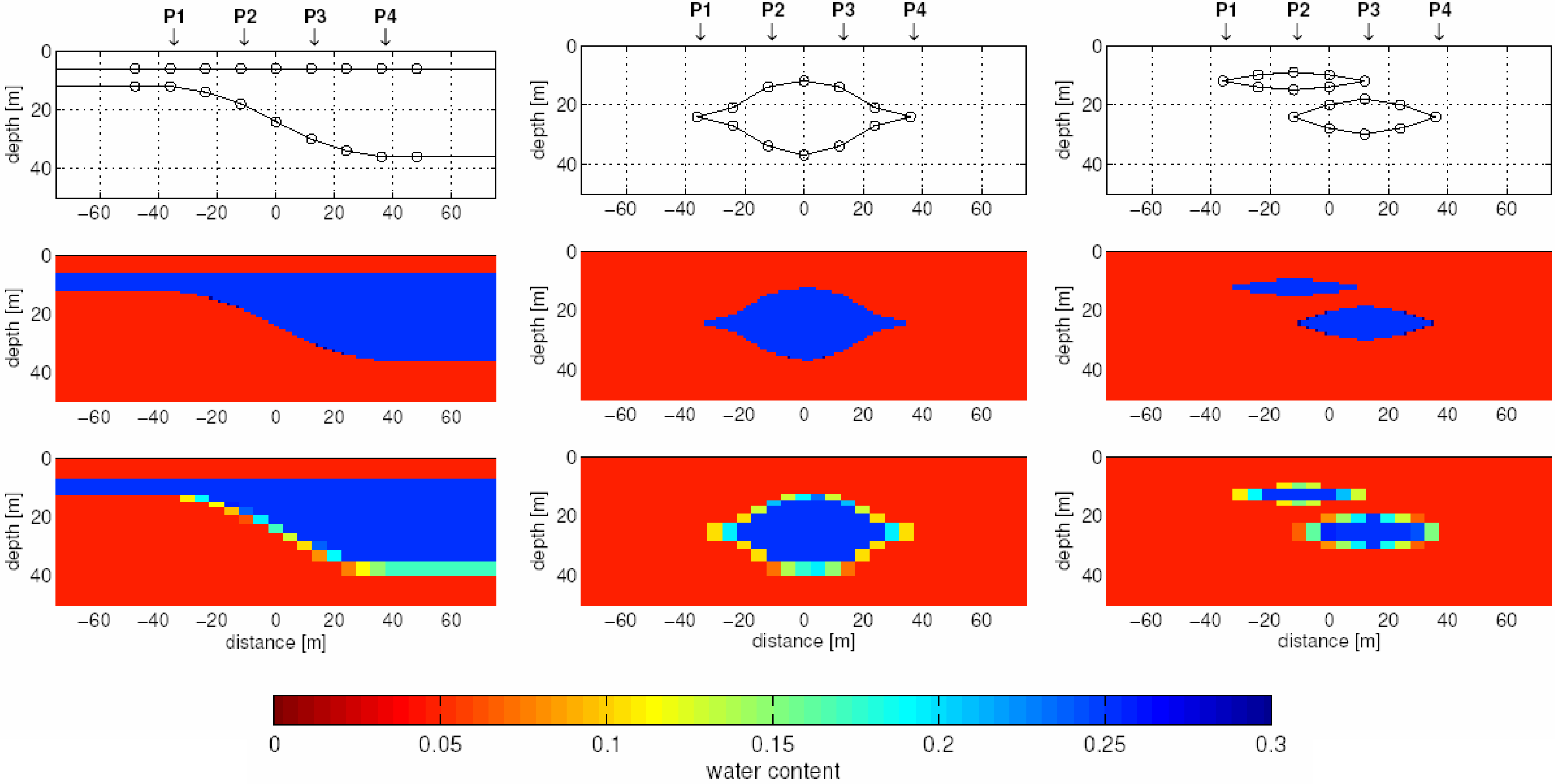


Synthetic data for homogeneous half space

effect of receiver and transmitter seperation and resistivity

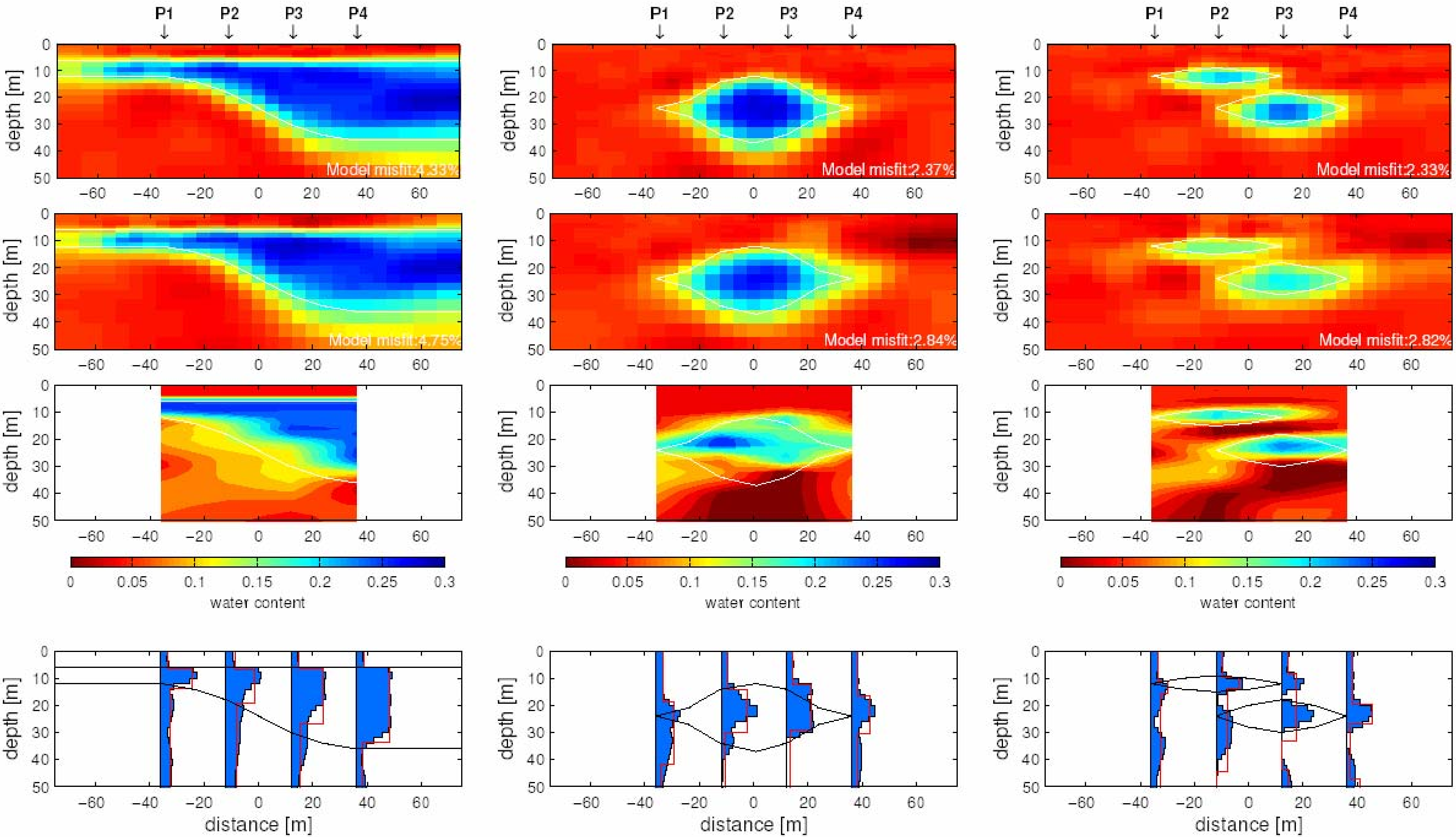


Models for tests with synthetic data



Results of inversion of synthetic data

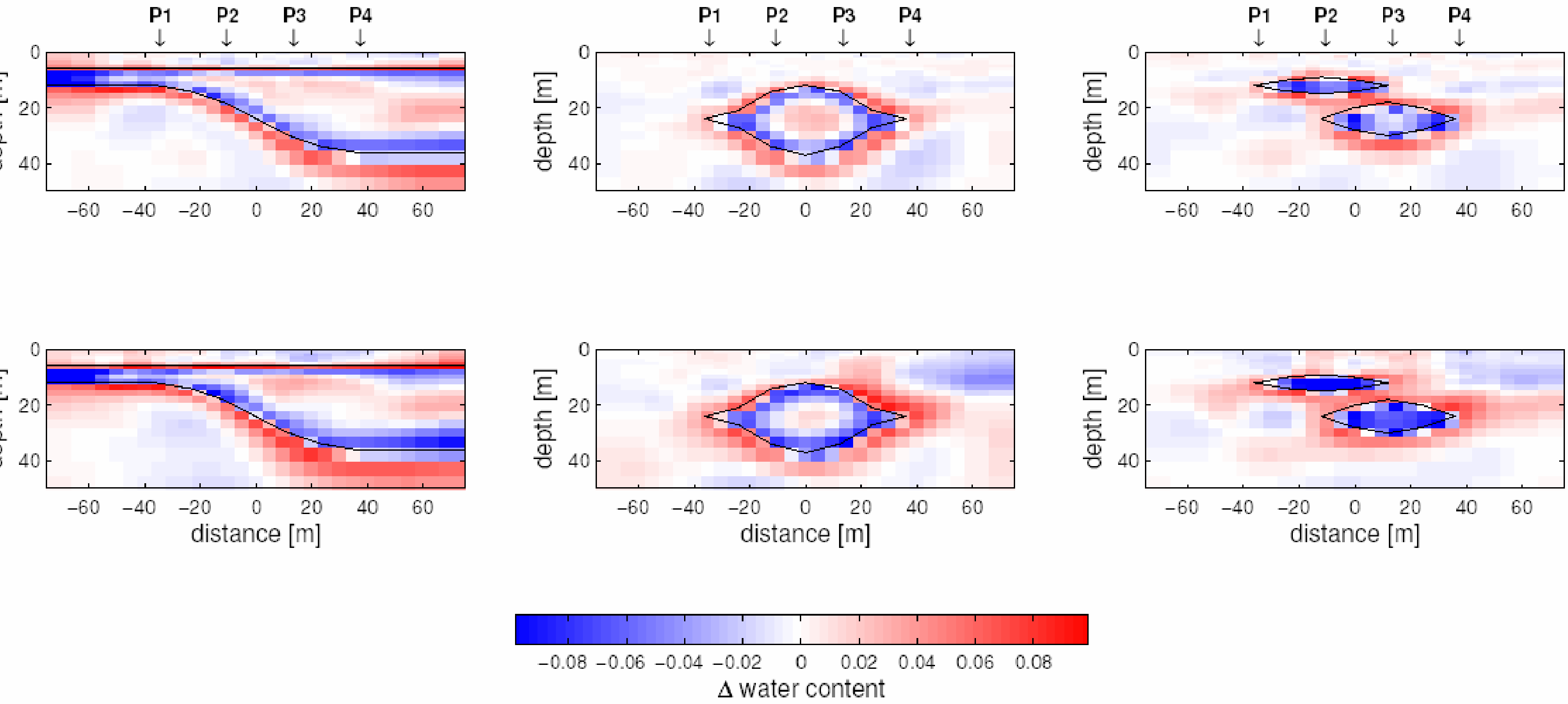
(a) 2D full inversion with full set data of seperated loops
(b) 2D full inversion with data of coincident loops
(c) 1D inversions in contourplot and (d) in usual sounding plots



Residuals of inversion of synthetic data

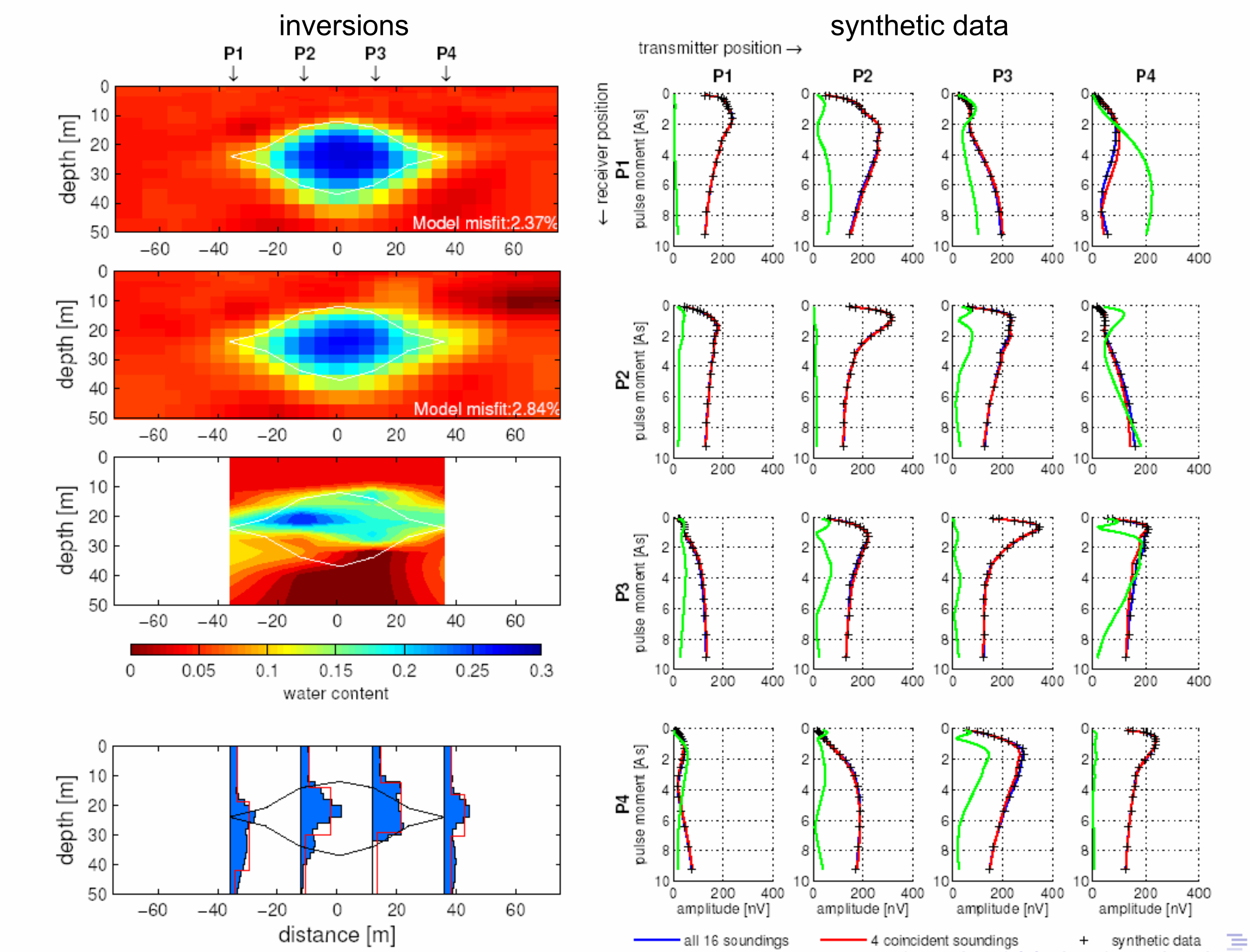
(a) 2D full inversion with full set data of seperated loops

(b) 2D full inversion with data of coincident loops



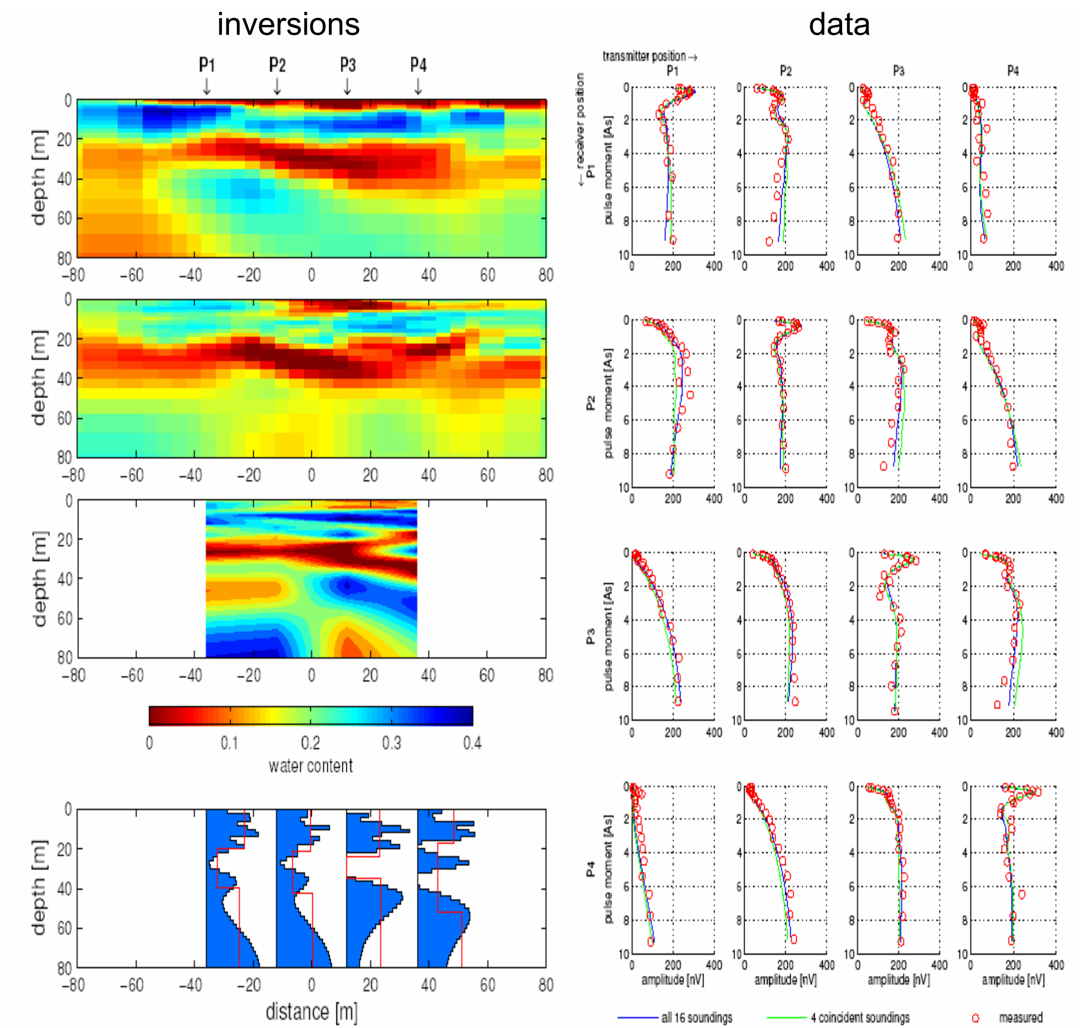
Synthetic data and inversion for a lens model

(a) 2D inversion with full set data of seperated loops
(b) 2D inversion with data of coincident loops
(c) 1D inversions in contourplot and (d) in usual sounding plots

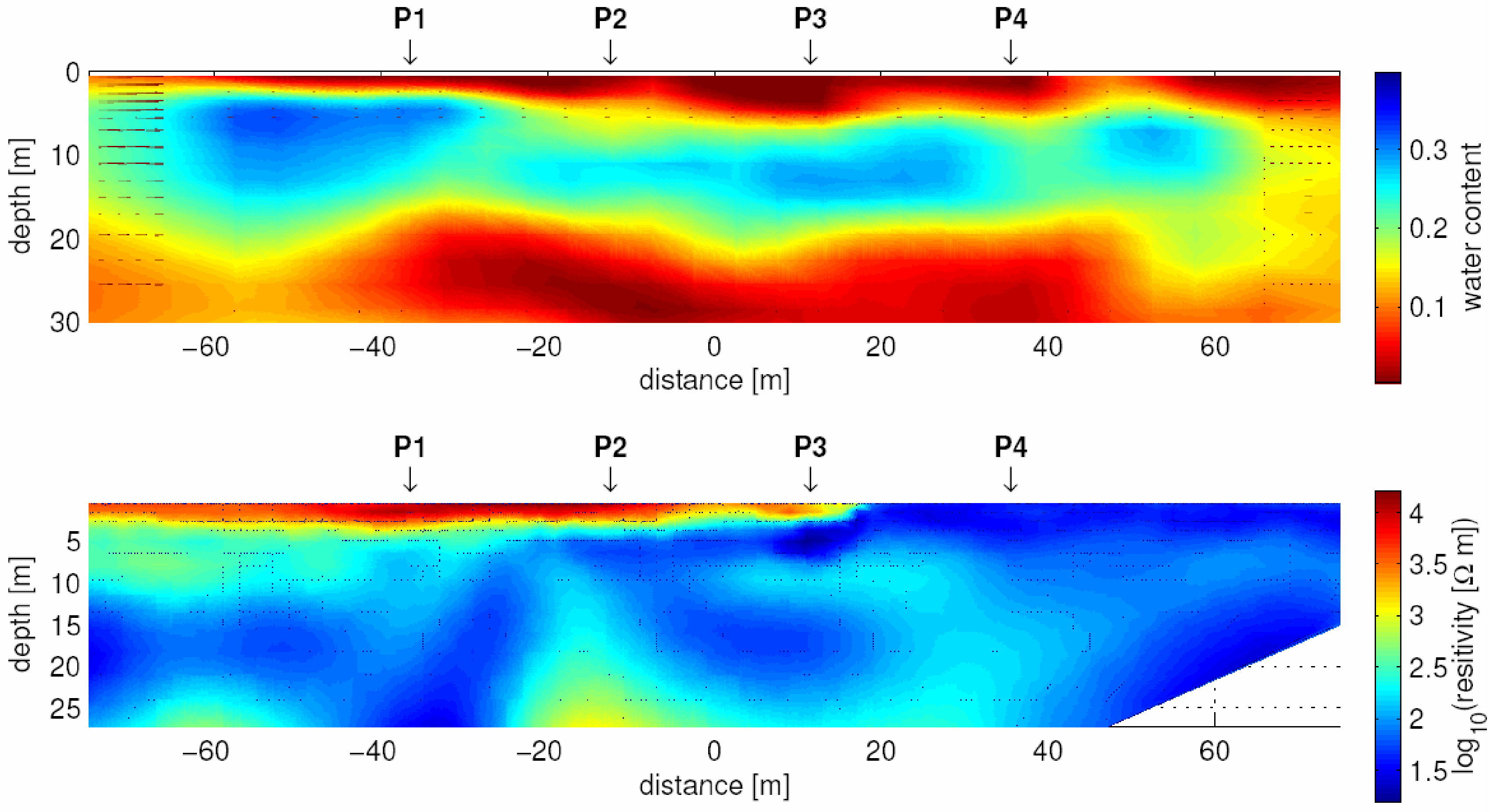


MRS measurements and inversion at test site 2

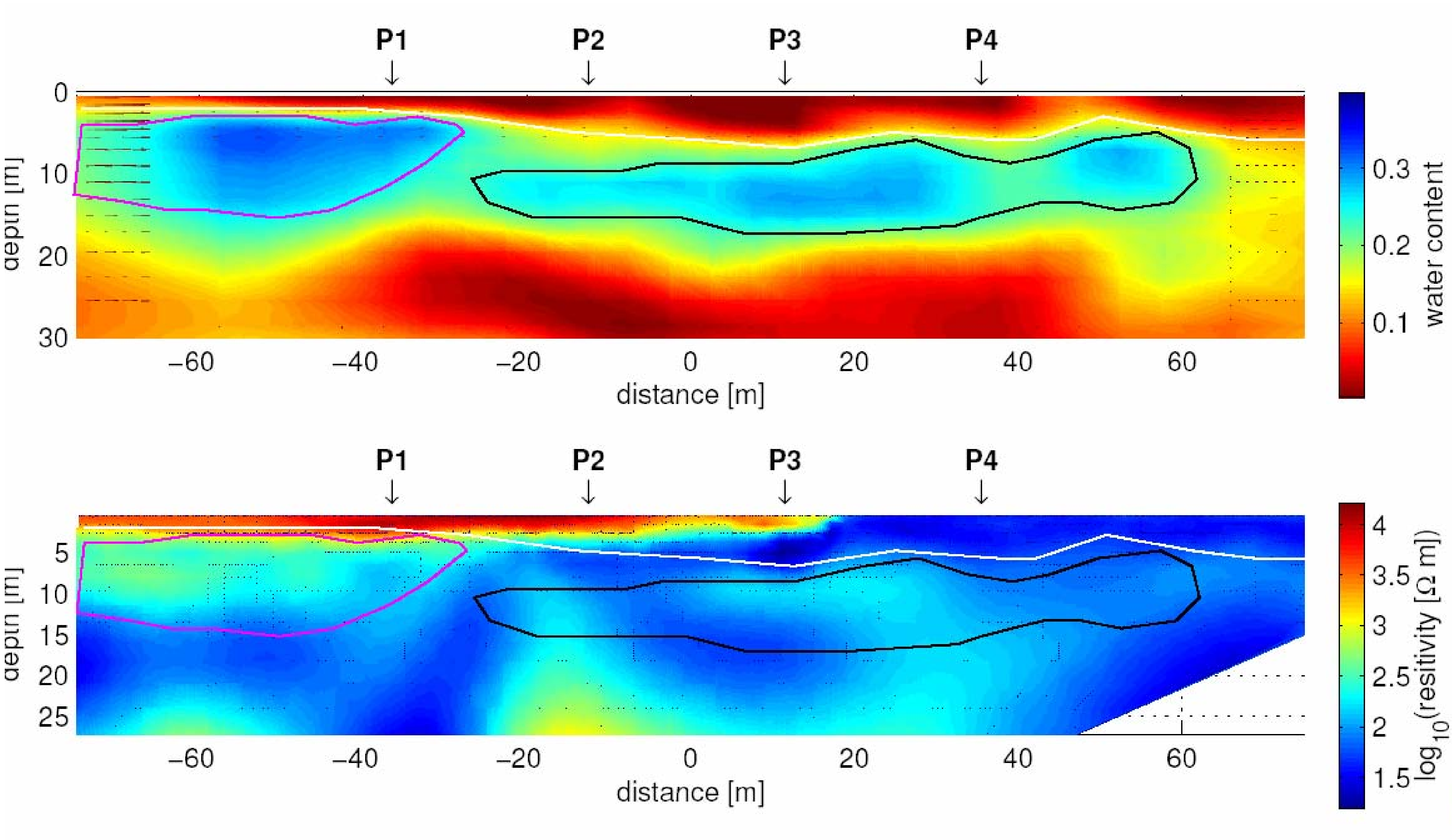
(a) 2D inversion with full set data of seperated loops
(b) 2D inversion with data of coincident loops
(c) 1D inversions in contourplot and (d) in usual sounding plots



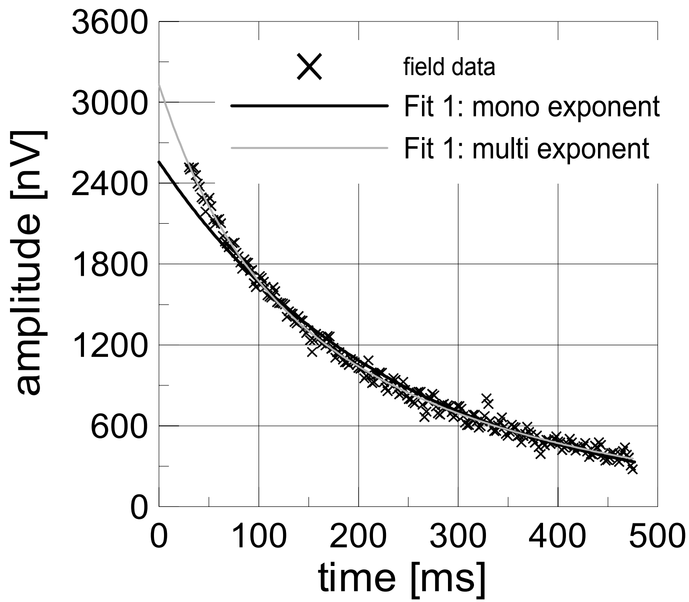
MRS and geoelectrics at test site 2

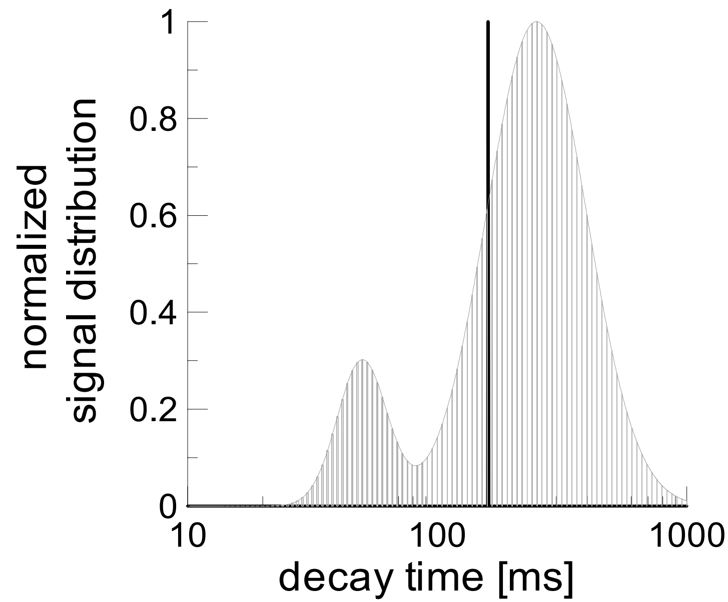


MRS and geoelectrics at test site 2



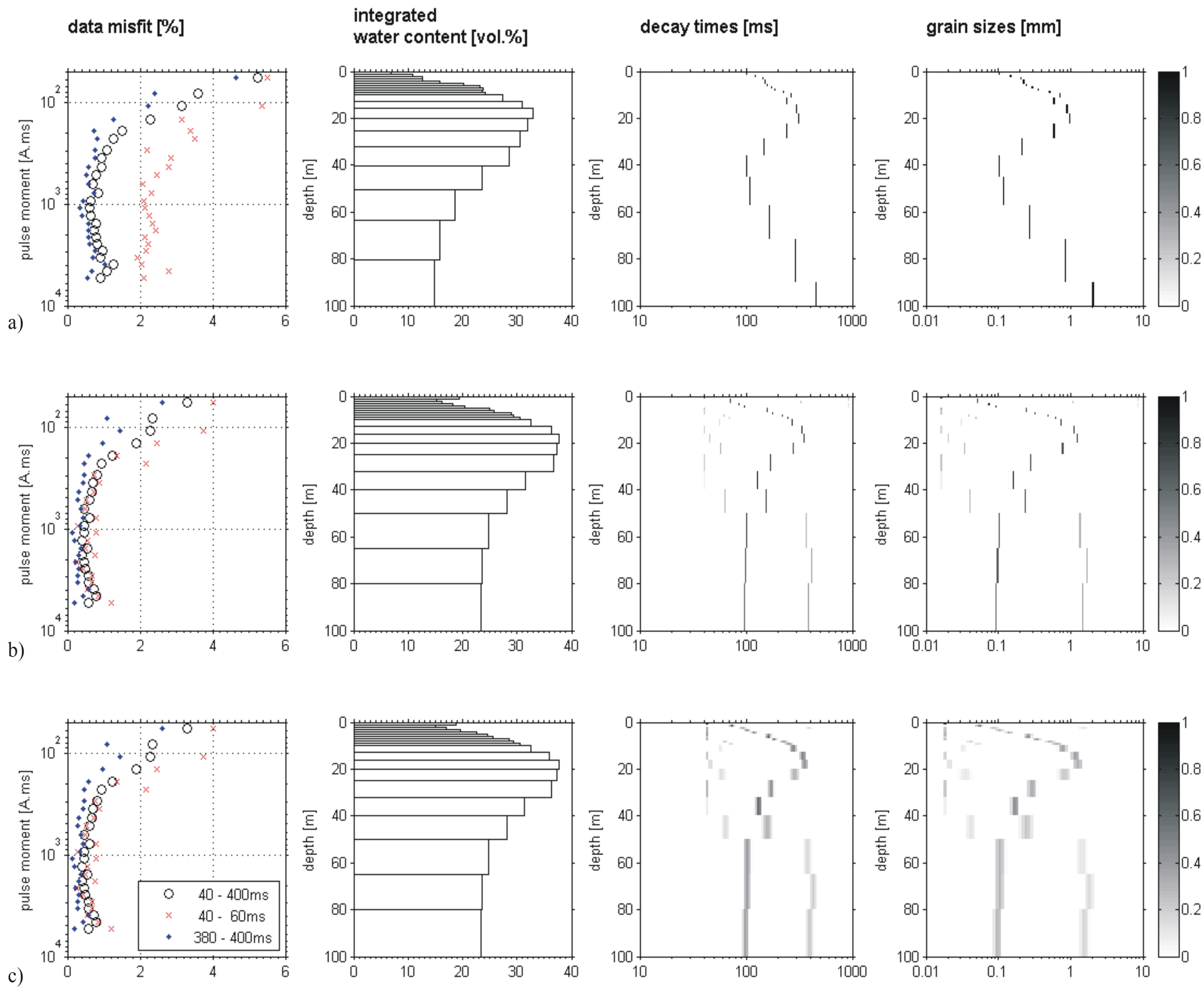
Decay times and distributions in MRS





Analysis of MRS decay times

(a) Monoexponential, (b) Biexponential, (c) Multiexponential



In conclusion

Magnetic Resonance Sounding (or – Tomography) (MRS and MRT) have passed the experimental stage and turned out to be a very useful method in particular for hydrogeophysics

Water content distribution can be detected explicitly and quantitavely

Effective pore sizes or even pore size distributions and followingly hydraulic permeabilities can be estimated

The potential of MRS can be increased in joint use, interpretation and inversion with other geophysical methods in particular with those of geoelectrics and electromagnetics