Simulation of Short and Normal Logging Measurements in the Presence of Tool Eccentricity Using Fourier Series Expansion in a New System of Coordinates and a Self-Adaptive hp-Finite Element Method

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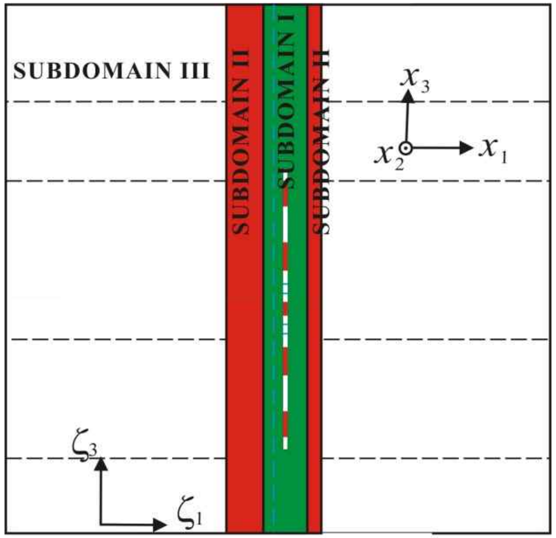
Overview

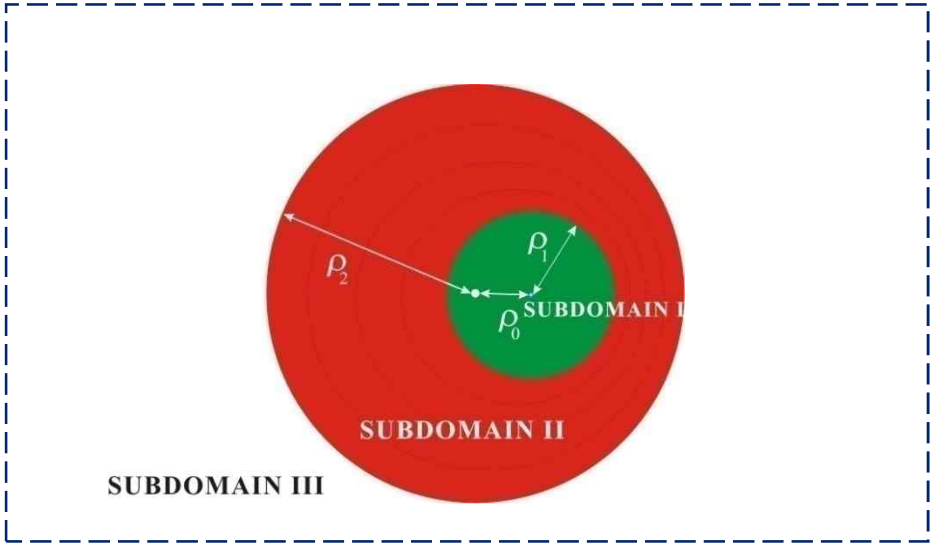
1. A Fourier Series Expansion in a New System of Coordinates
2. Short and Long Normal Instruments
3. Numerical Results
4. Conclusions

Eccentered Tool

Cartesian system of coordinates: (x_1, x_2, x_3)

New system of coordinates: $(\zeta_1, \zeta_2, \zeta_3)$





Subdomain I

$$\begin{cases} x_1 = \rho_0 + \zeta_1 \cos\zeta_2 \\ x_2 = \zeta_1 \sin\zeta_2 \\ x_3 = \zeta_3 \end{cases}$$

Subdomain II

$$\begin{cases} x_1 = \dfrac{\zeta_1 - \rho_2}{\rho_1 - \rho_2}\rho_0 + \zeta_1 \cos\zeta_2 \\ x_2 = \zeta_1 \sin\zeta_2 \\ x_3 = \zeta_3 \end{cases}$$

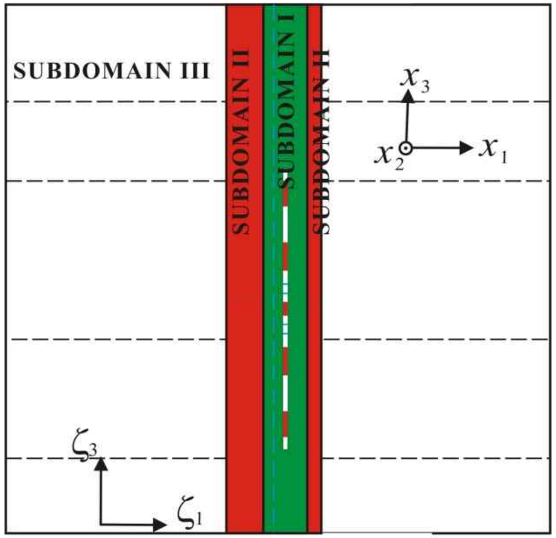
Subdomain III

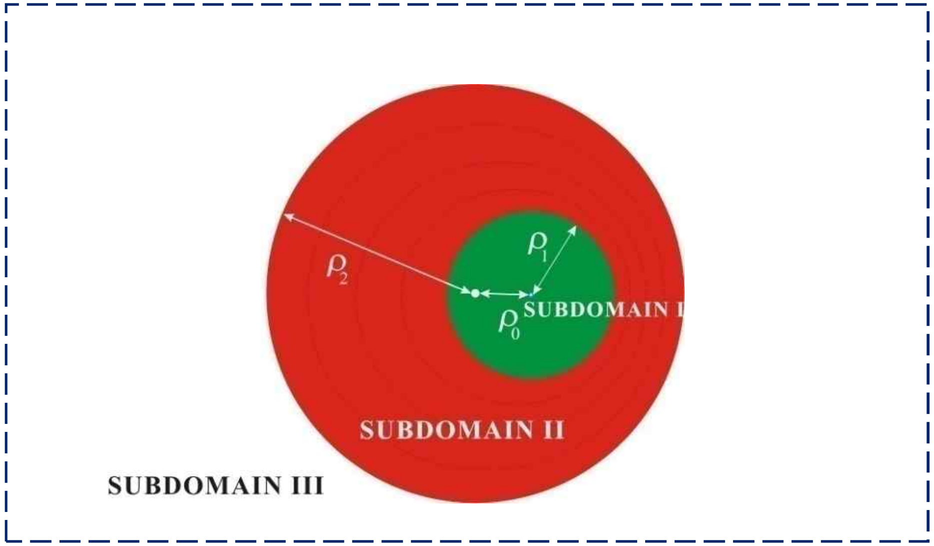
$$\begin{cases} x_1 = \zeta_1 \cos\zeta_2 \\ x_2 = \zeta_1 \sin\zeta_2 \\ x_3 = \zeta_3 \end{cases}$$

Eccentered Tool

Cartesian system of coordinates: (x_1, x_2, x_3)

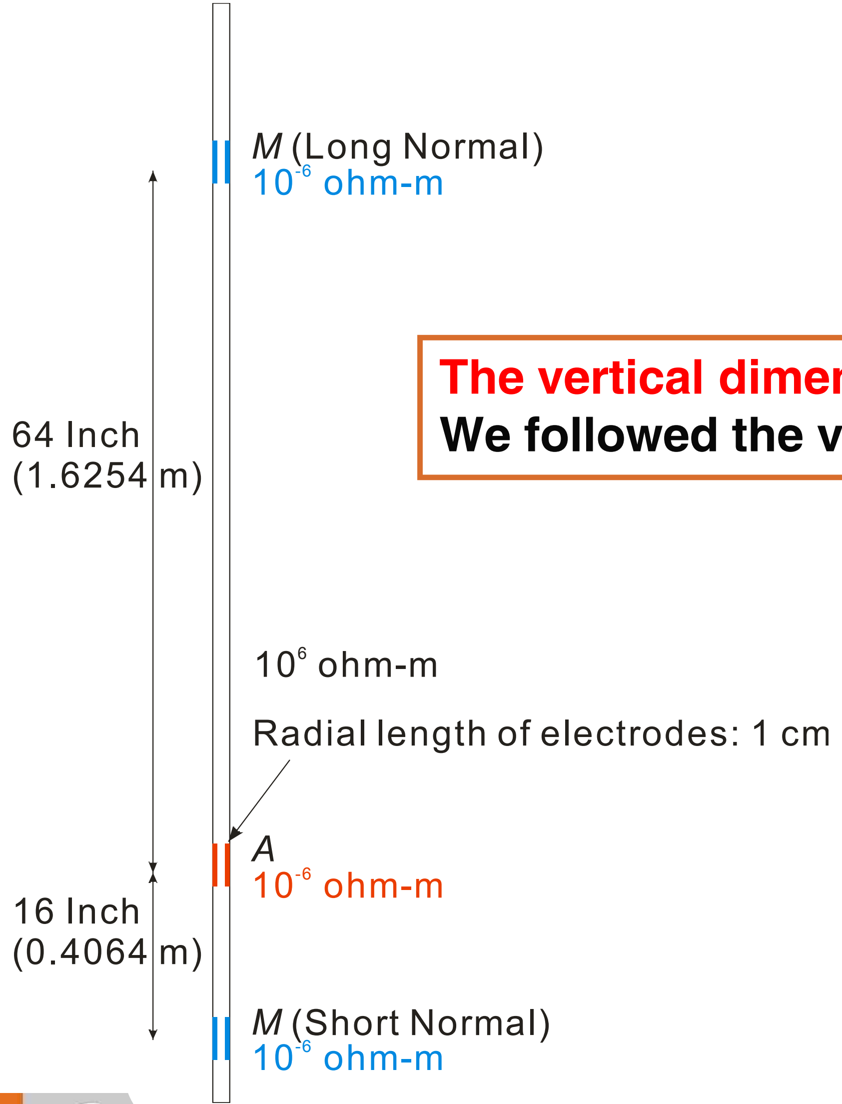
New system of coordinates: $(\zeta_1, \zeta_2, \zeta_3)$





Constant material coefficients in the quasi-azimuthal direction ζ_2
in the new non-orthogonal system of coordinates!!!!

Modeled Tool (that KIGAM has been using)

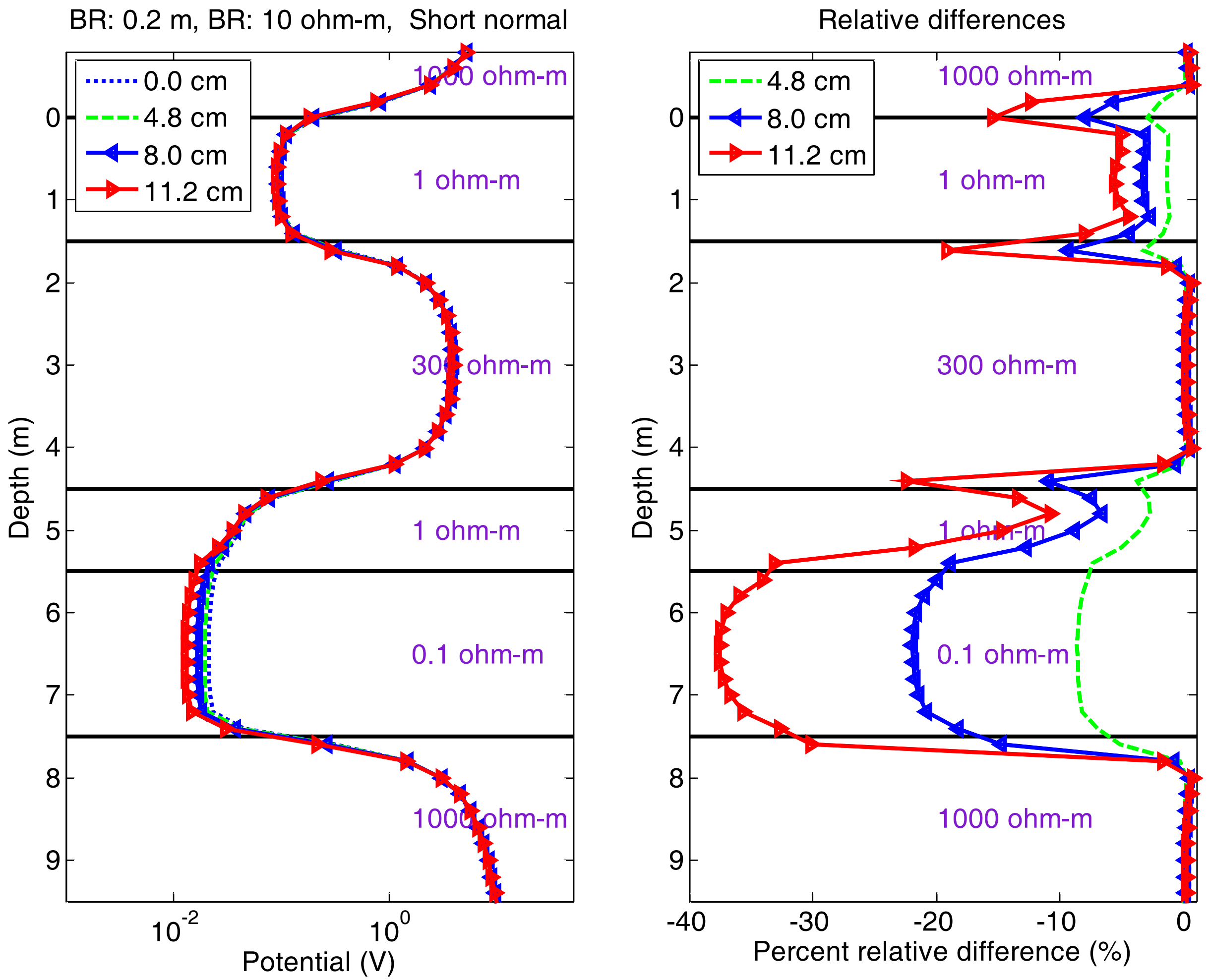


The vertical dimensions and locations of each electrode:
We followed the vertical tool configuration of a commercial tool

Short normal

BH Radius: 0.2 m

BH Resistivity: 10 ohm-m

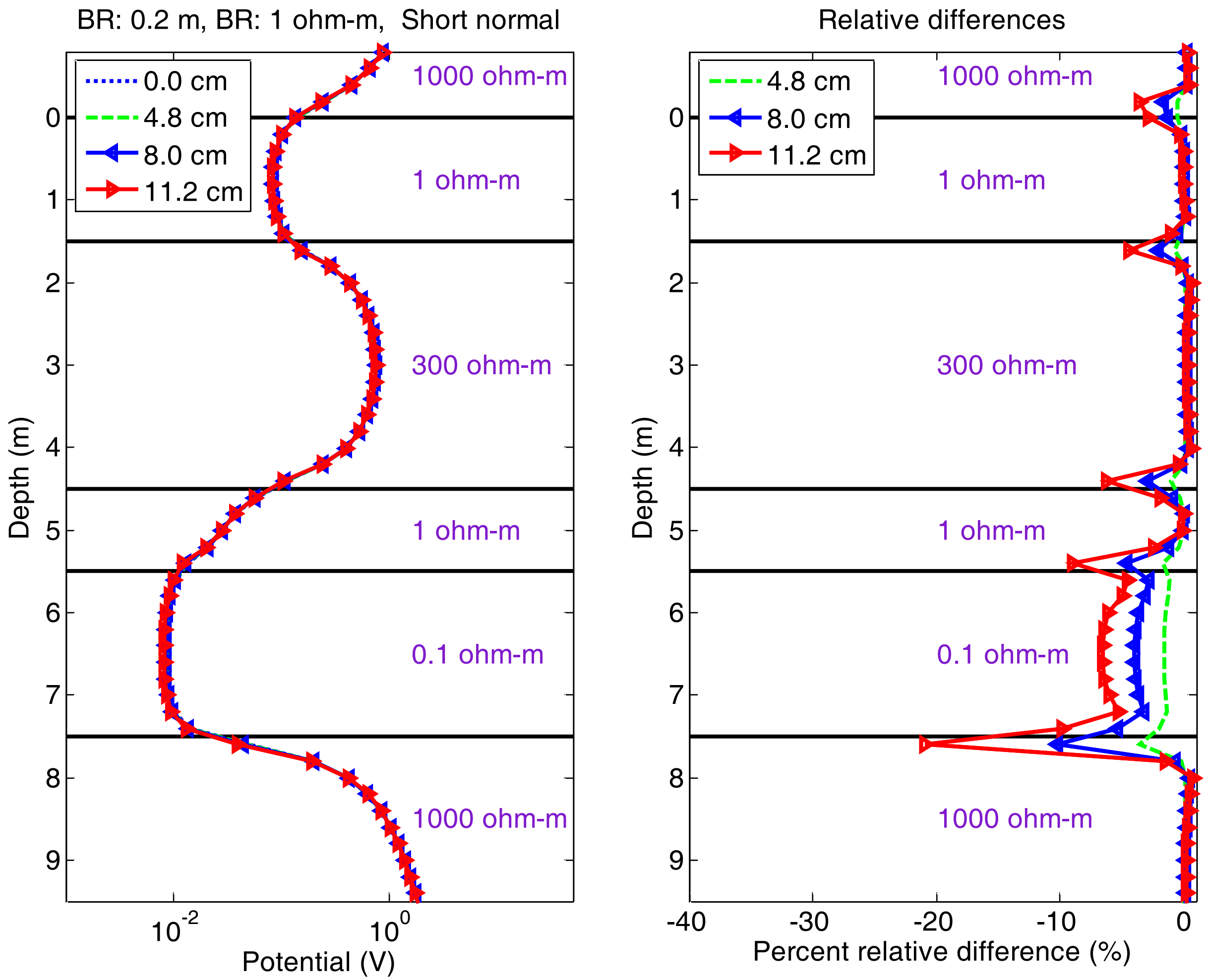


Largest eccentricity effects on the most conductive layers

Short normal

BH Radius: 0.2 m

BH Resistivity: 1 ohm-m

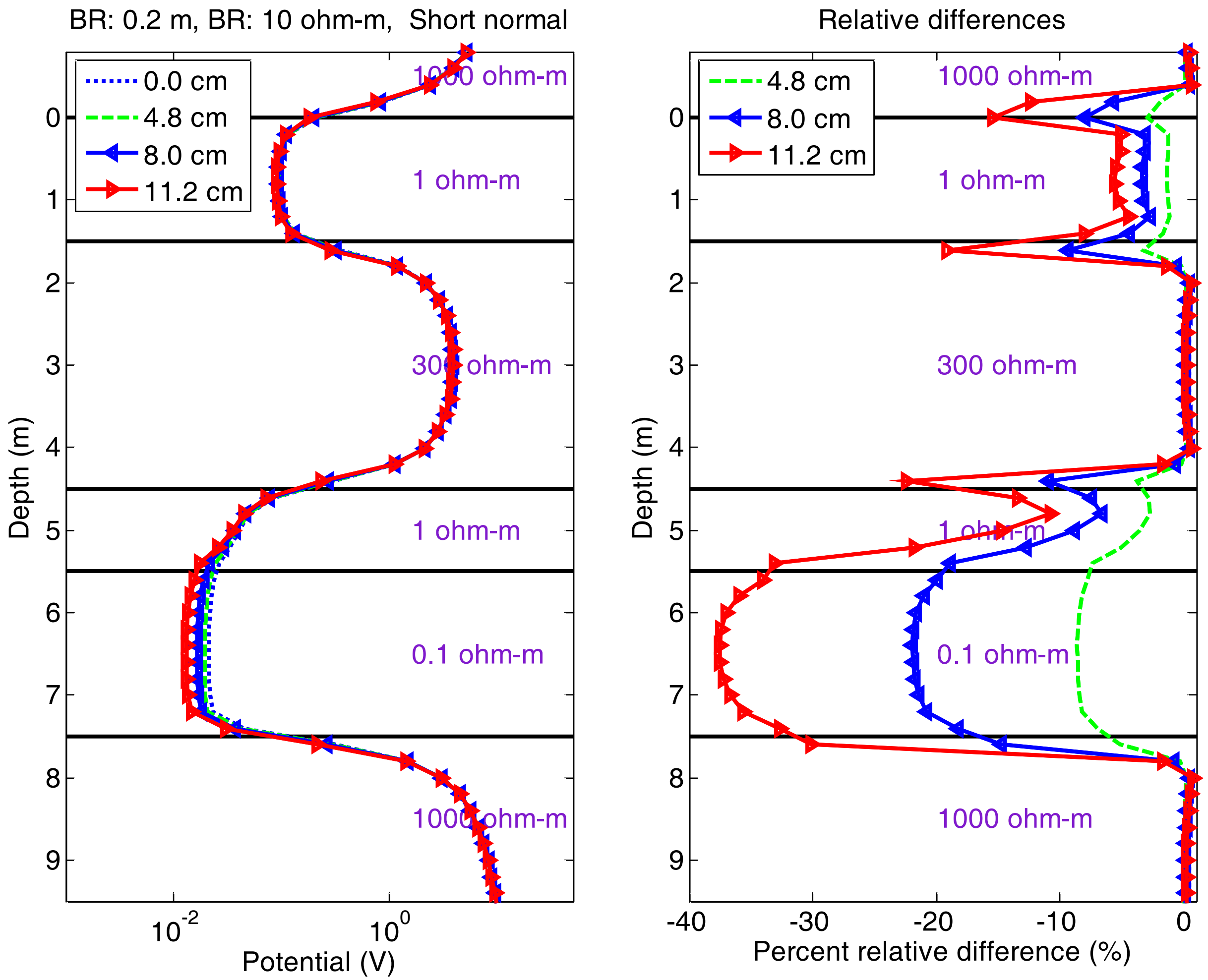


Smaller eccentricity effects with decreasing BH resistivity

Short normal

BH Radius: 0.2 m

BH Resistivity: 10 ohm-m

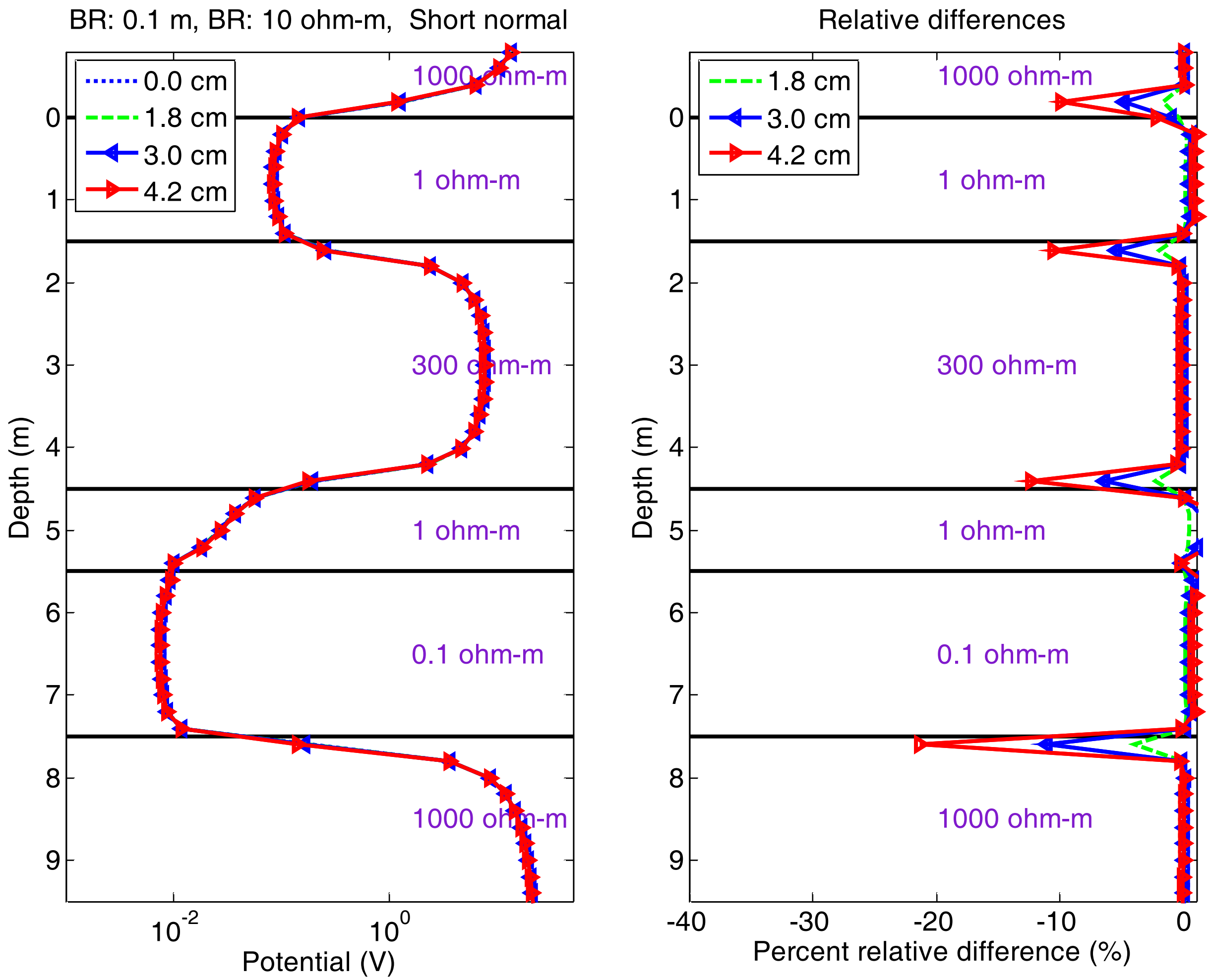


Largest eccentricity effects on the most conductive layers

Short normal

BH Radius: 0.1 m

BH Resistivity: 10 ohm-m

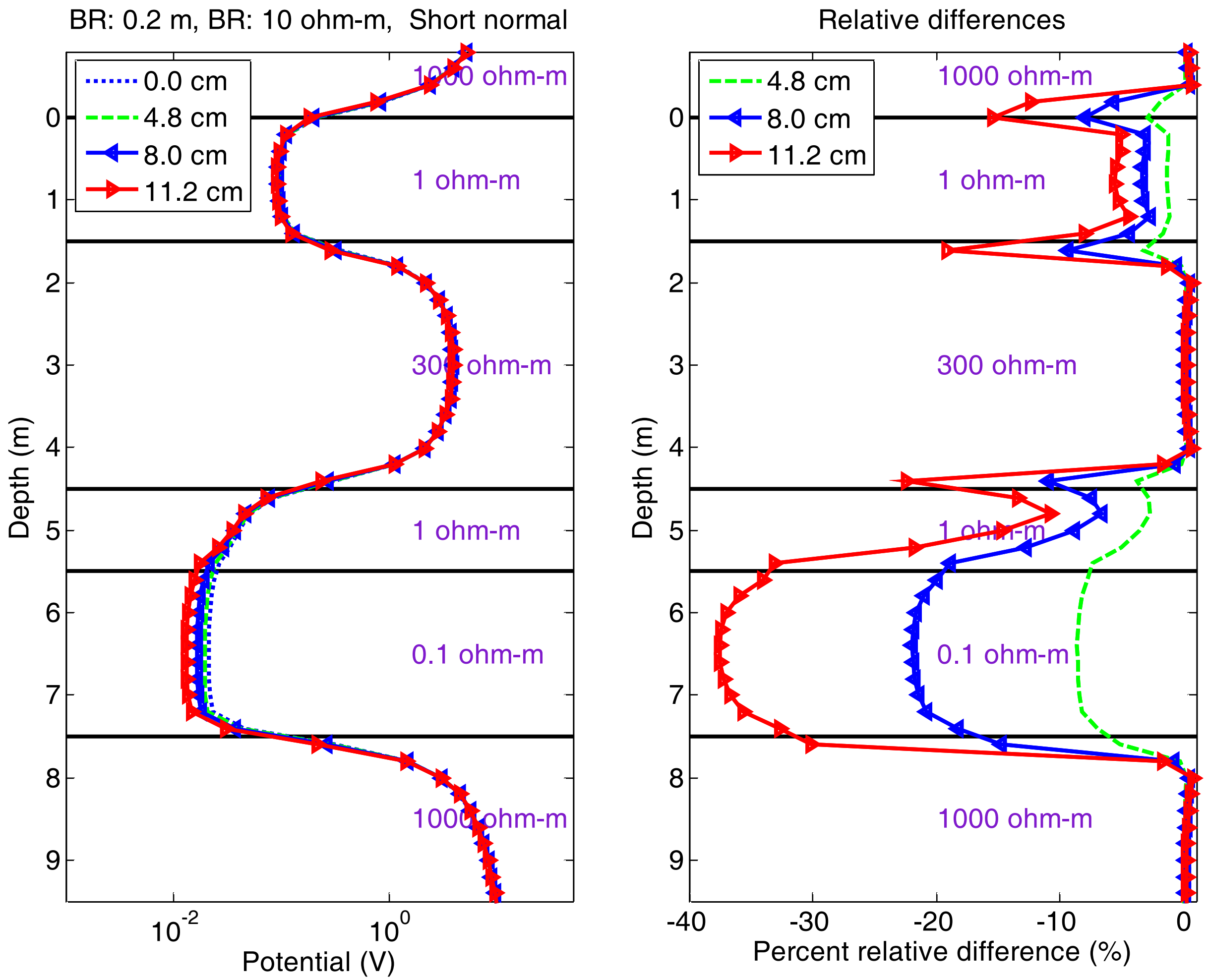


Smaller eccentricity effects with decreasing BH radius

Short normal

BH Radius: 0.2 m

BH Resistivity: 10 ohm-m

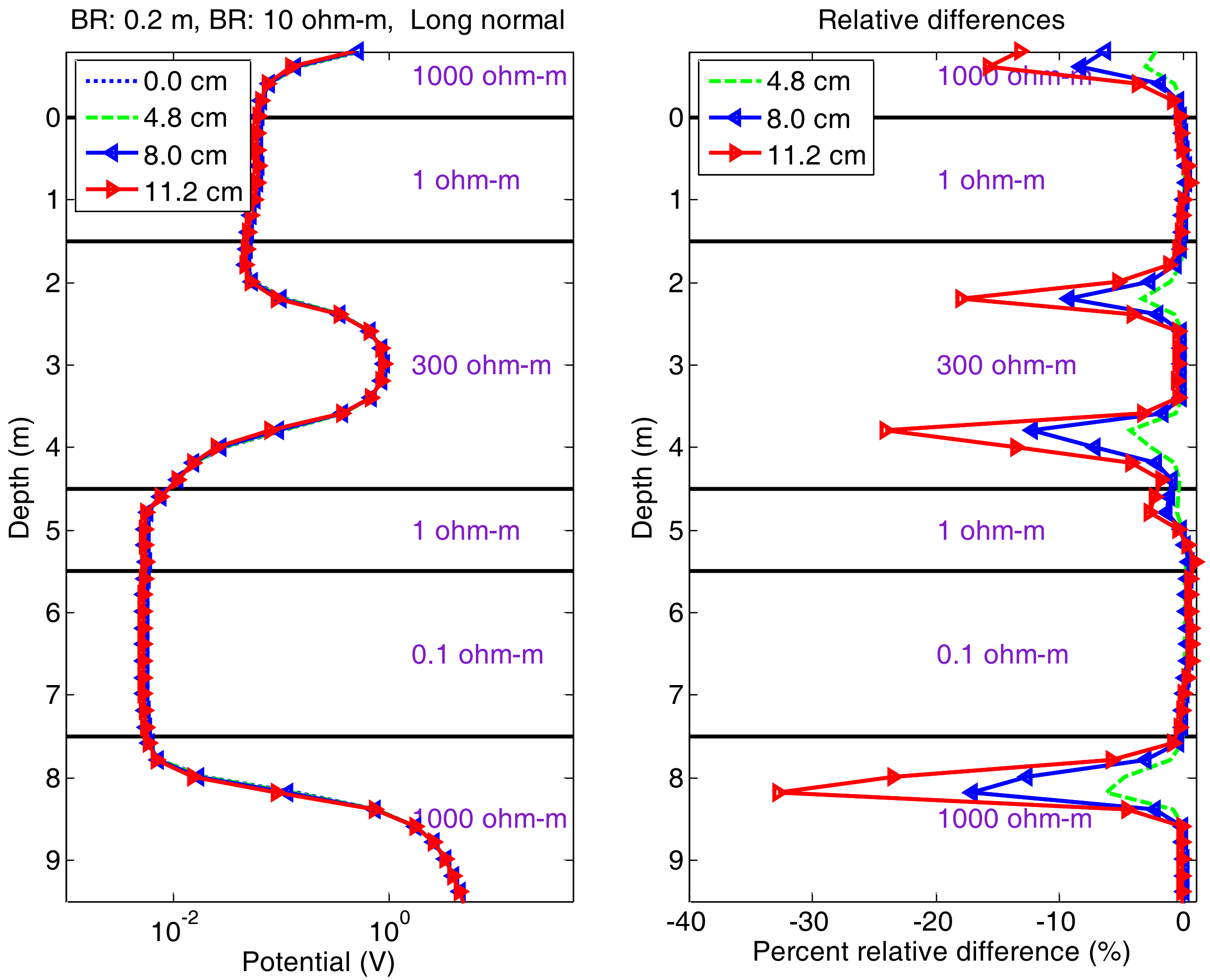


Largest eccentricity effects on the most conductive layers

Long normal

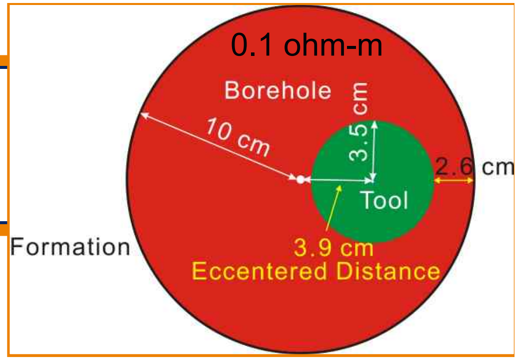
BH Radius: 0.2 m

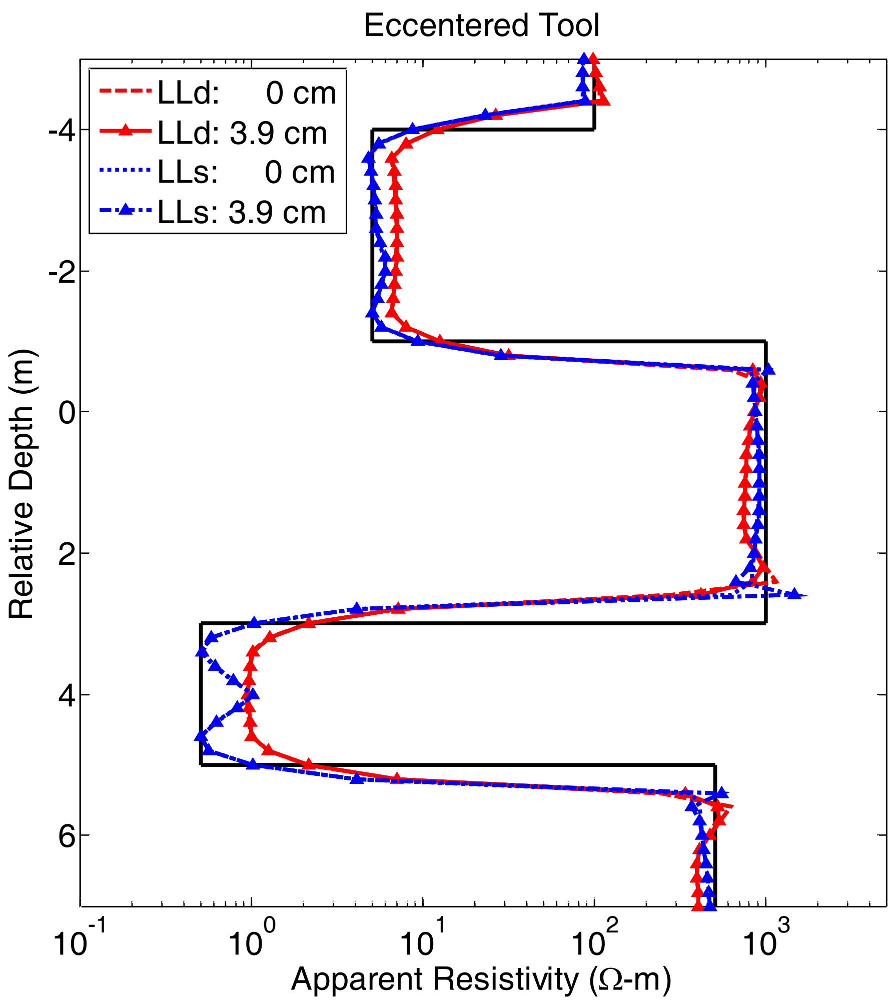
BH Resistivity: 10 ohm-m

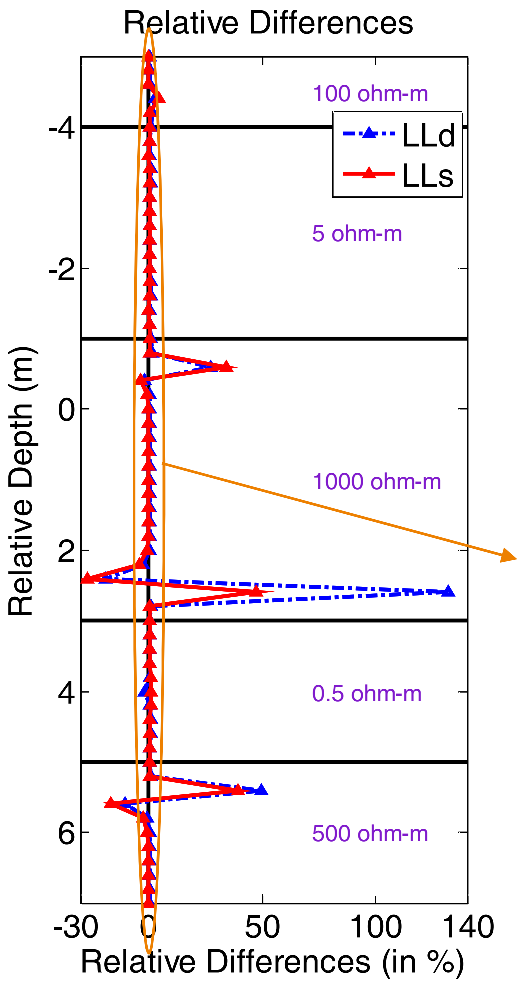


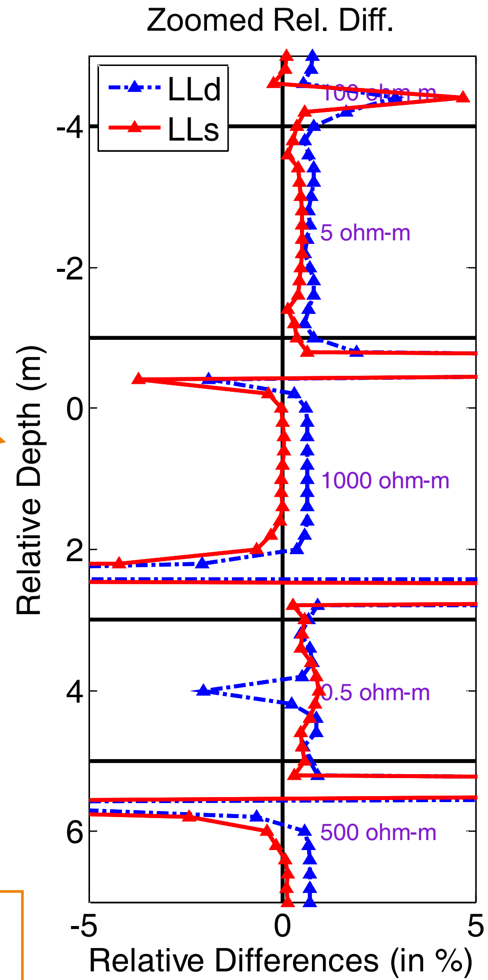
Smaller eccentricity effects on long normal logging measurements

Eccentered Tool Effects (DC DLL)









Eccentered-tool effects are larger
around layer boundaries in resistive layers

Conclusions

- **We have successfully simulated 3D short and long normal logging measurements by combining the use of a Fourier series expansion in a new system of coordinates with a 2D higher-order self-adaptive hp finite element method.**
- **Larger eccentricity effects at a more resistive borehole with a larger radius**
- **Larger eccentricity effects on short normal logging measurements than those on long normal logging measurements**

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