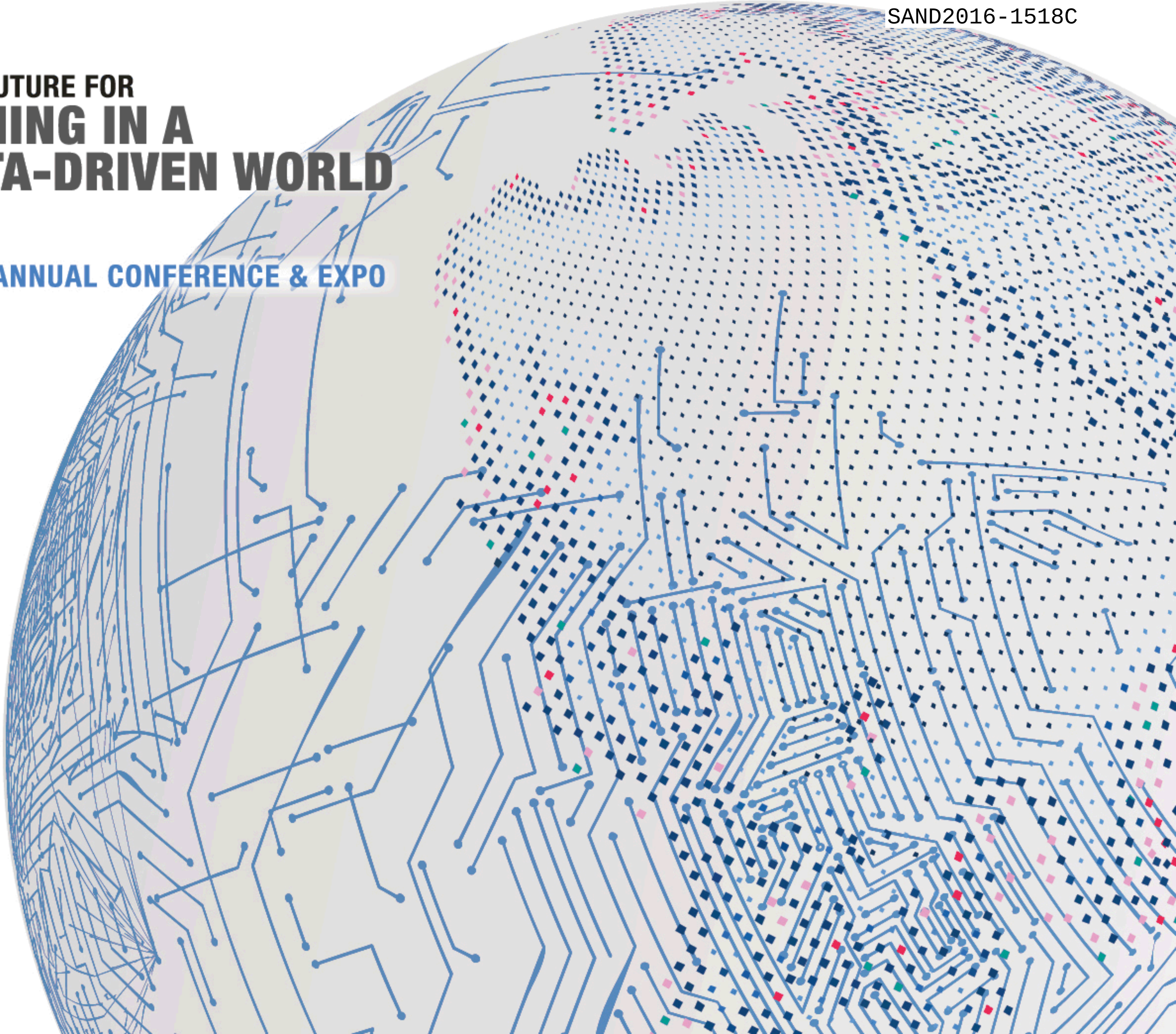
SAND2016-1518C

THE FUTURE FOR MINING IN A DATA-DRIVEN WORLD

SME 2016 ANNUAL CONFERENCE & EXPO



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A 3D numerical analysis on the propagation of 3.2 kHz TTE signals along the rail in underground mines

C Weiss[1,2], S Schafrik[3] and E Jong[3]

[1]Geophysics Department, Sandia National Laboratories

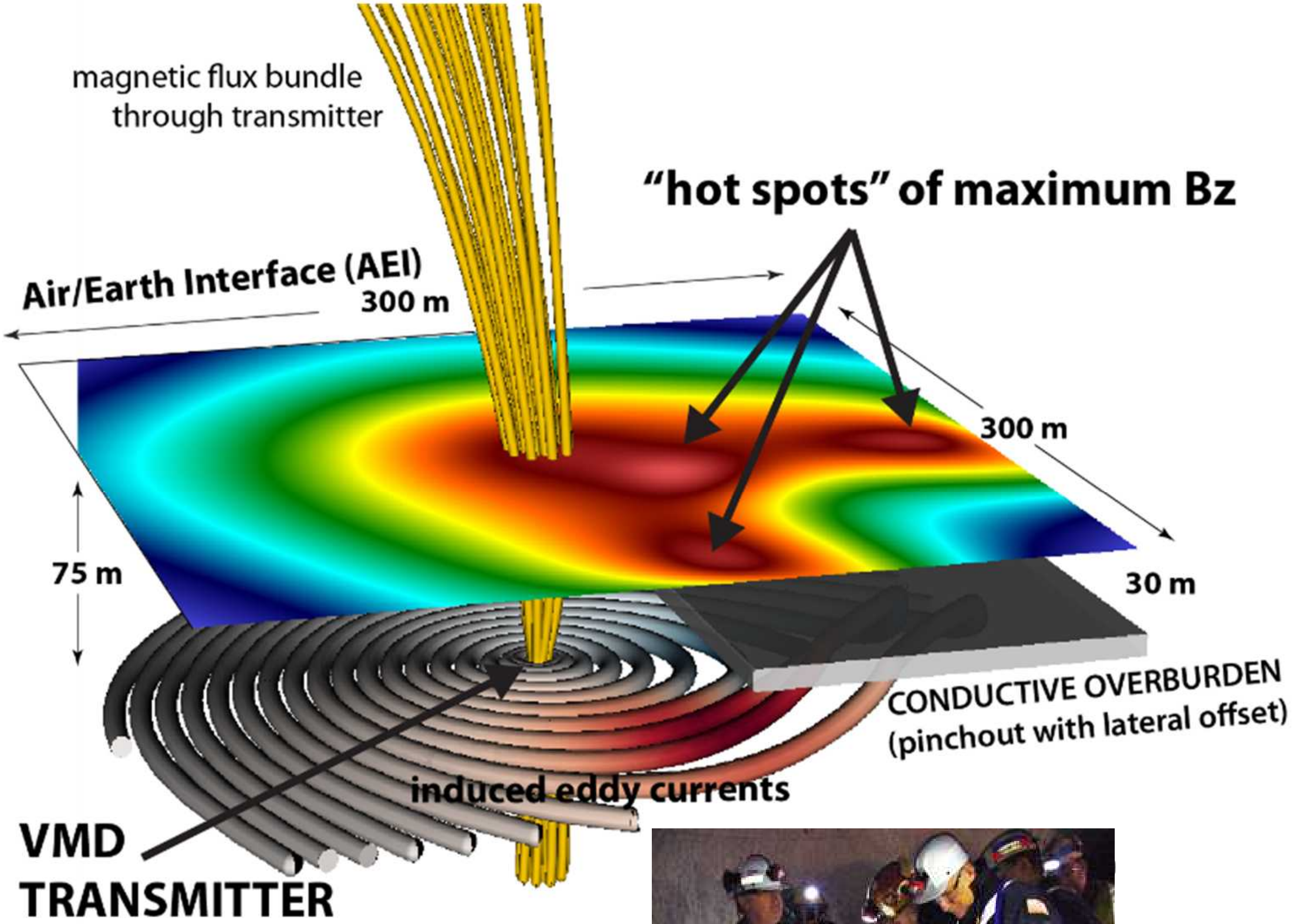
[2]Dept of Earth and Planetary Sciences, University of New Mexico

[3]Mining and Materials Engineering, Virginia Tech

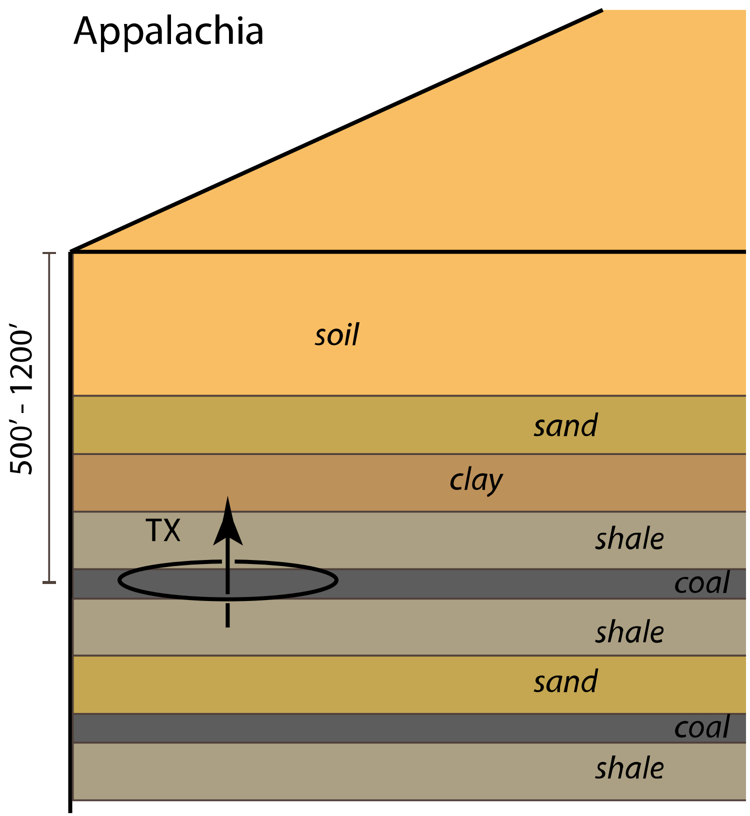
Introduction

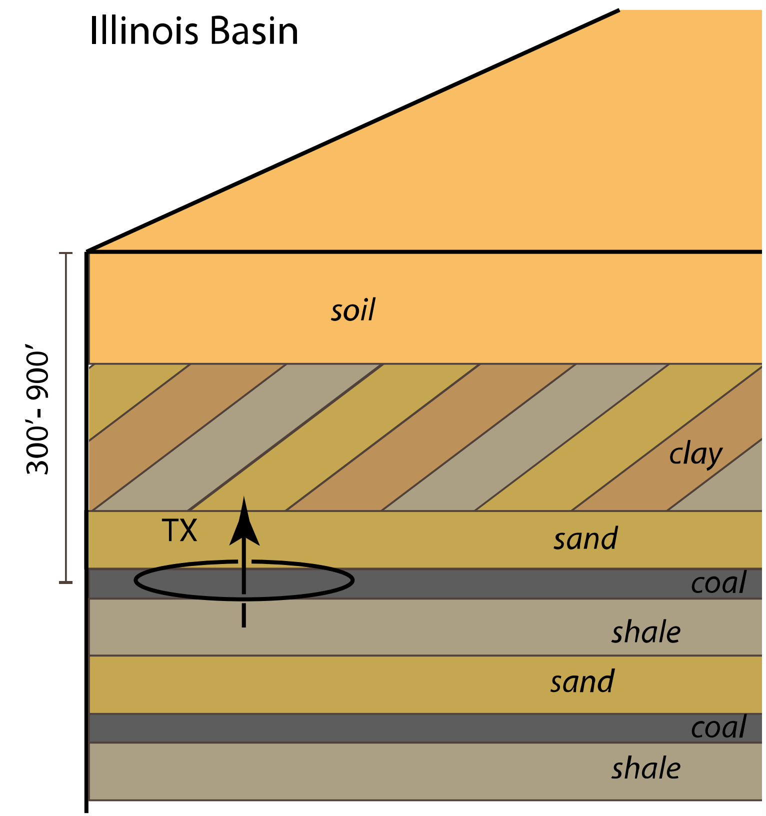
- **BIG PICTURE research question:** *What is the effect of topography, geologic structure and cultural artifacts on TTE signal propagation and reception?*
- **Approach:** *Deconstruct the question into specific causative factors under idealized conditions.*
- **Method:** three dimensional numerical simulations of Maxwell's equations for heterogeneous geology

Example Calculation: signal distortion from subsurface heterogeneity



TTE scenarios of interest: layered geology, no faults



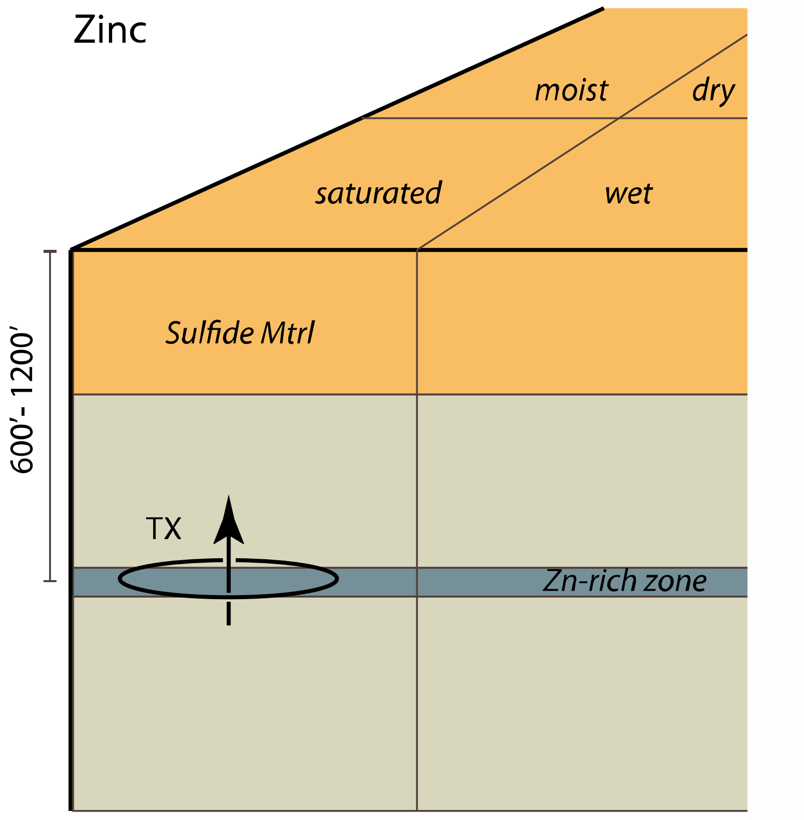


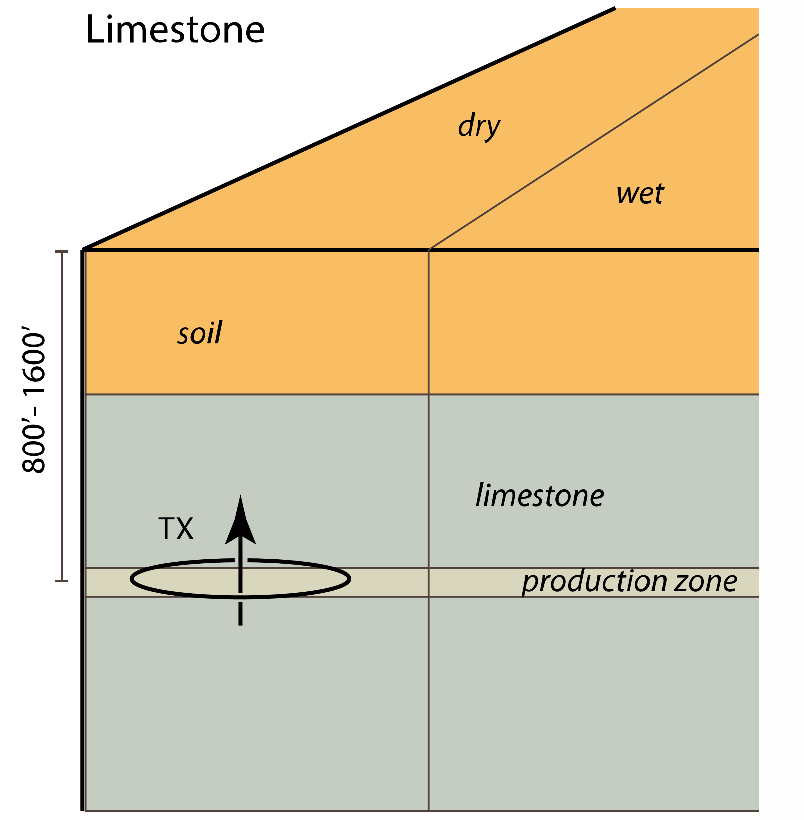
TTE signal affected by variations in rock electrical conductivity

coal, sand: resistive → clay: conductive

layering also likely to introduce anisotropy effects

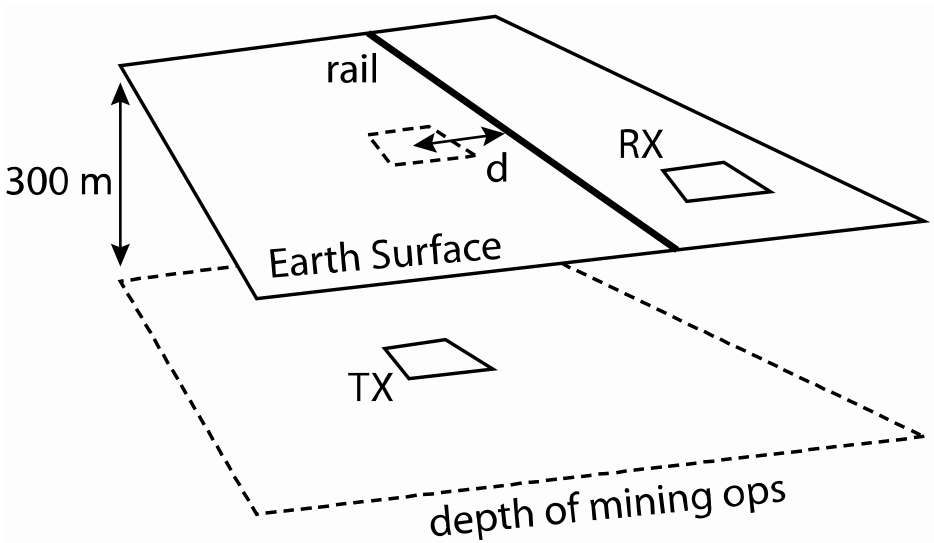
TTE scenarios of interest: massive geology, faulting





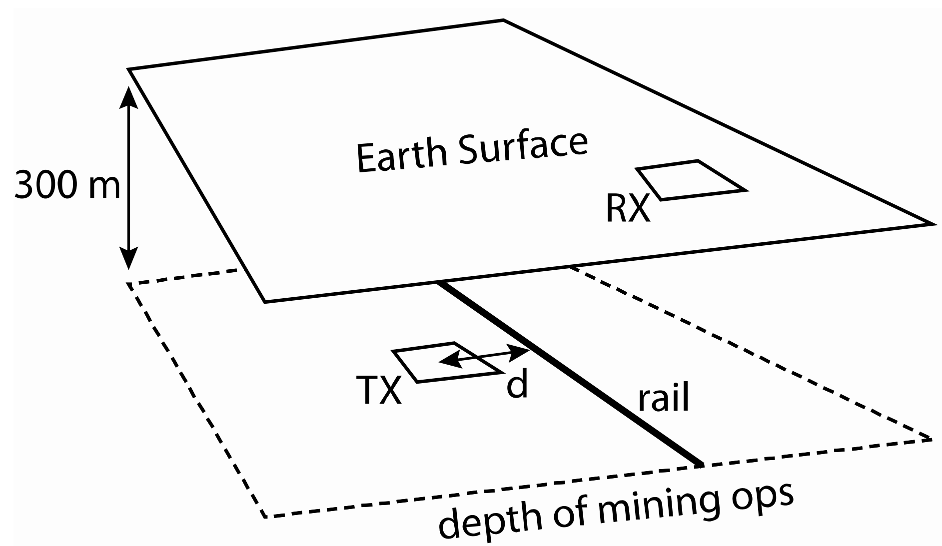
Presence of water also affects conductivity, controlled by free electrolytes. Hydrologic response of fault planes is highly variable: in some cases they act as fluid conduits whereas elsewhere they are strong barriers controlled by gouge zone thickness, pulverization and mineralization

Keeping in simple: neglect geology for now and focus on rail effect



CASE 1:
fixed transmitter (TX) location
variable receiver (RX) location
rail on Earth surface

CASE 2:
fixed transmitter (TX) location
variable receiver (RX) location
rail at depth of mine ops



Analyze the rail effect using 3D numerical modeling

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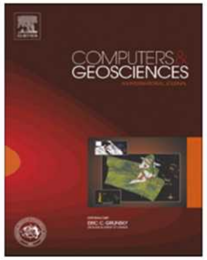


Project APhiD: A Lorenz-gauged $\mathbf{A}$-Φ decomposition for parallelized computation of ultra-broadband electromagnetic induction in a fully heterogeneous Earth

Chester J. Weiss *

Department of Geosciences, Virginia Tech, Blacksburg, VA 24061, United States

Efficient and accurate development of such simulations is a long-standing research problem in the geosciences, influenced heavily by the electrical engineering community and "compatibility" calculations for rotors, heaters, shielding, etc.

Specific challenges for the geosciences are the need for broadband response and "multi-scale" modeling, where both large and small conductivity features are significant.

Complex Geology is mapped onto a Cartesian Grid

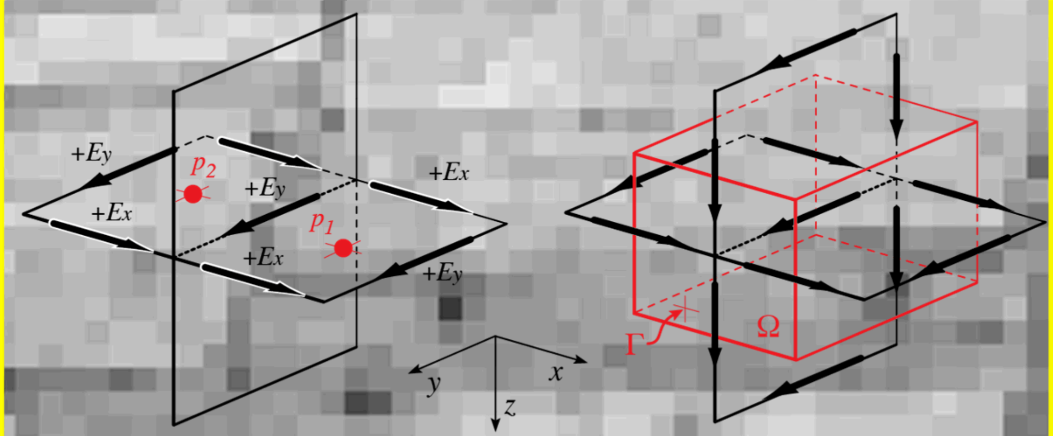
Tijeras Anticline, Yeso Fm, Tijeras NM, © C J Weiss 2014

Complex Geology is mapped onto a Cartesian Grid

Tijeras Anticline, Yeso Fm, Tijeras NM, © C J Weiss 2014

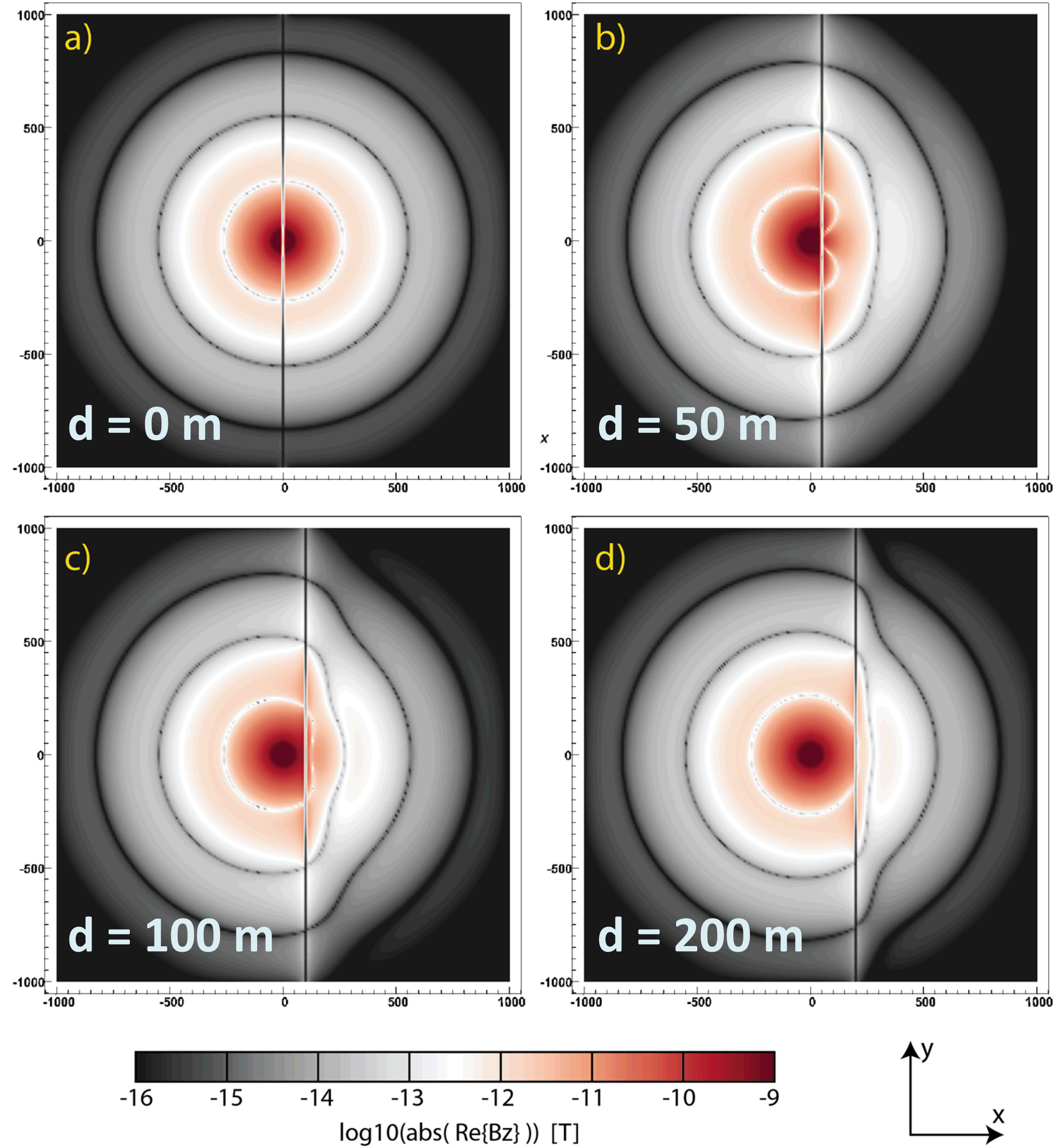
Complex Geology is mapped onto a Cartesian Grid

Generalized Maxwell's equations are solved on cell edges and face centers by finite differences



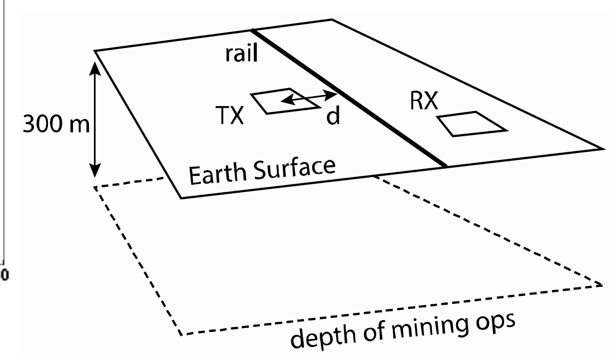
Tijeras Anticline, Yeso Fm, Tijeras NM, © C J Weiss 2014

Vertical magnetic field on Earth's surface: surface rail

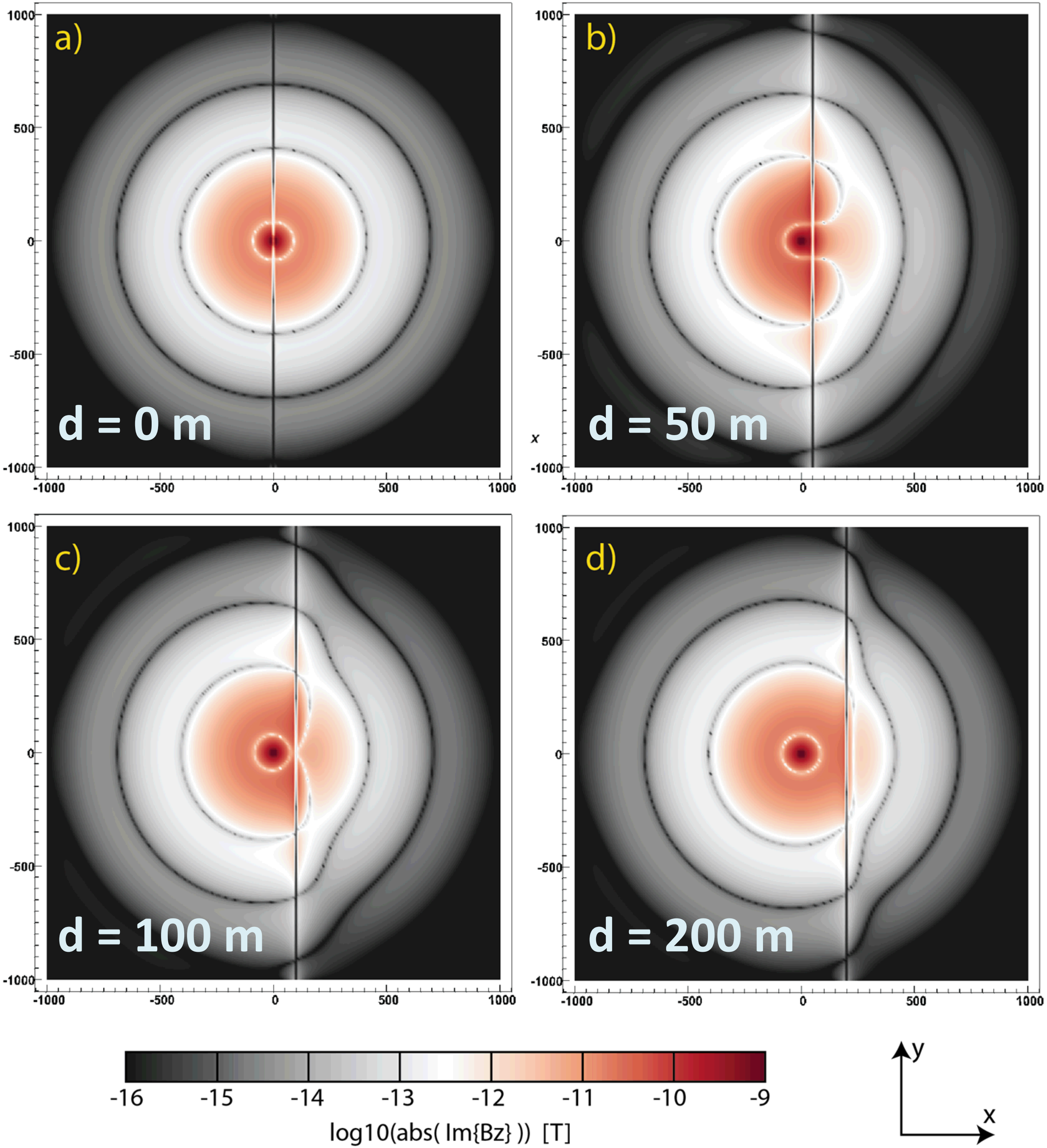


in-phase Bz
202x202x139 nodes
f=3.2 kHz
0.01 S/m Earth
1e4 S/m rail

BENCHMARK
surface transmitter (TX)
variable receiver (RX)
rail on Earth surface

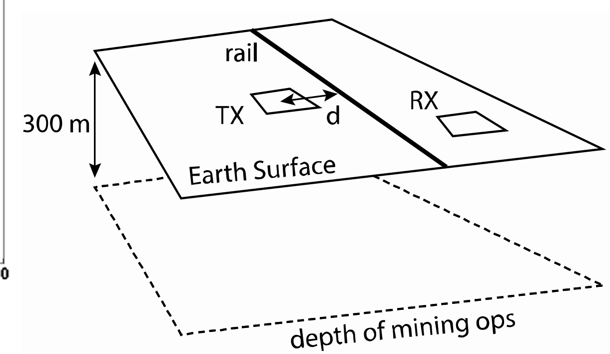


Vertical magnetic field on Earth's surface: surface rail

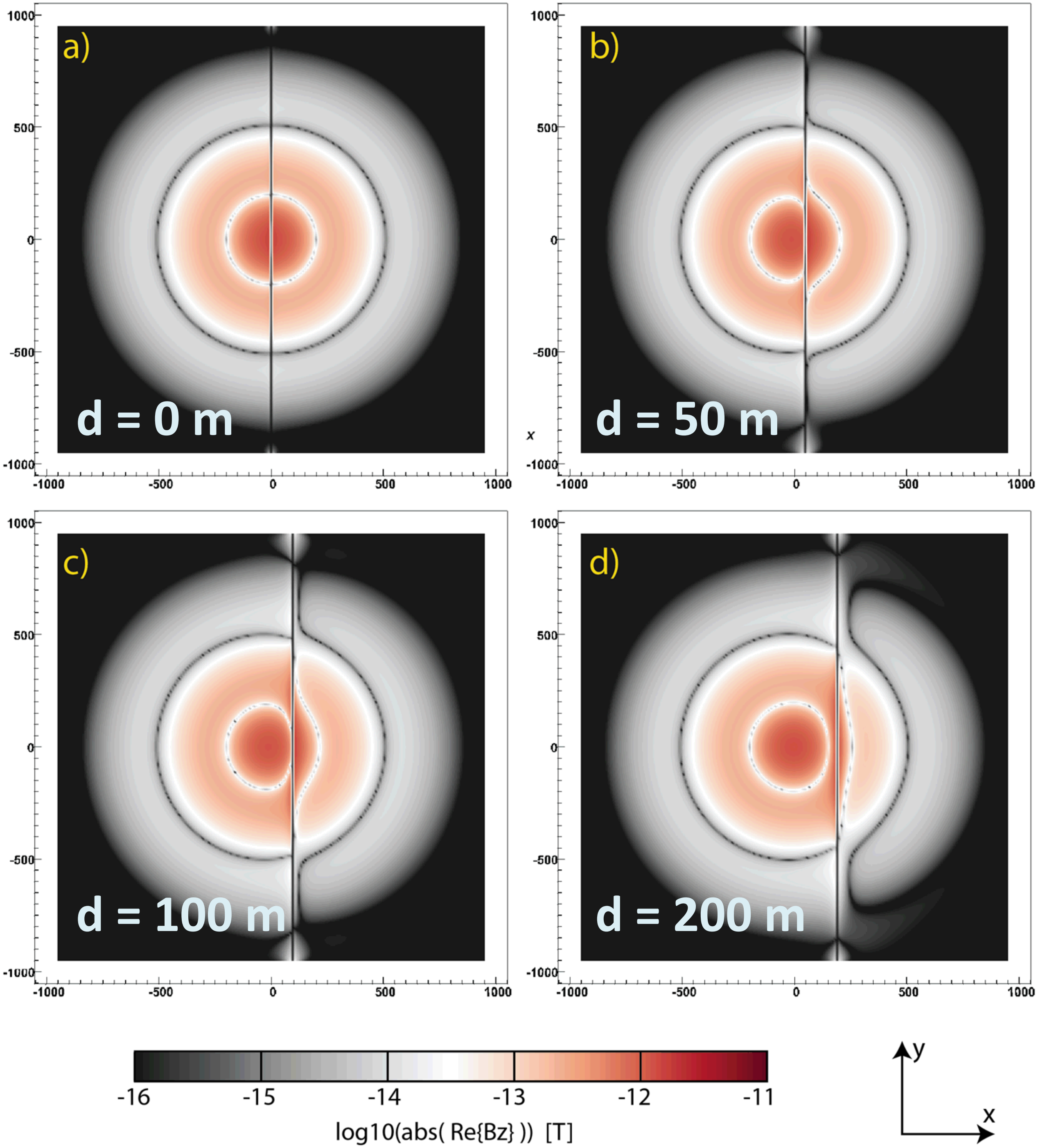


quad-phase Bz
202x202x139 nodes
f=3.2 kHz
0.01 S/m Earth
1e4 S/m rail

BENCHMARK
surface transmitter (TX)
variable receiver (RX)
rail on Earth surface



Vertical magnetic field on Earth's surface: surface rail



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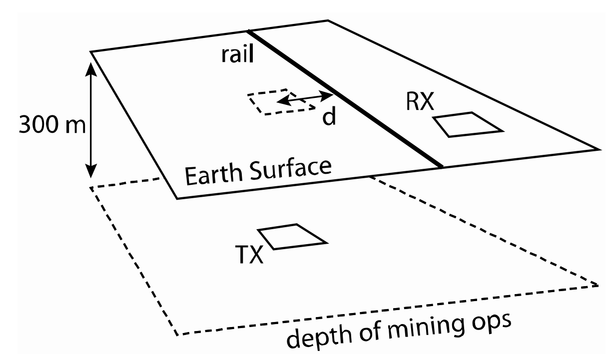
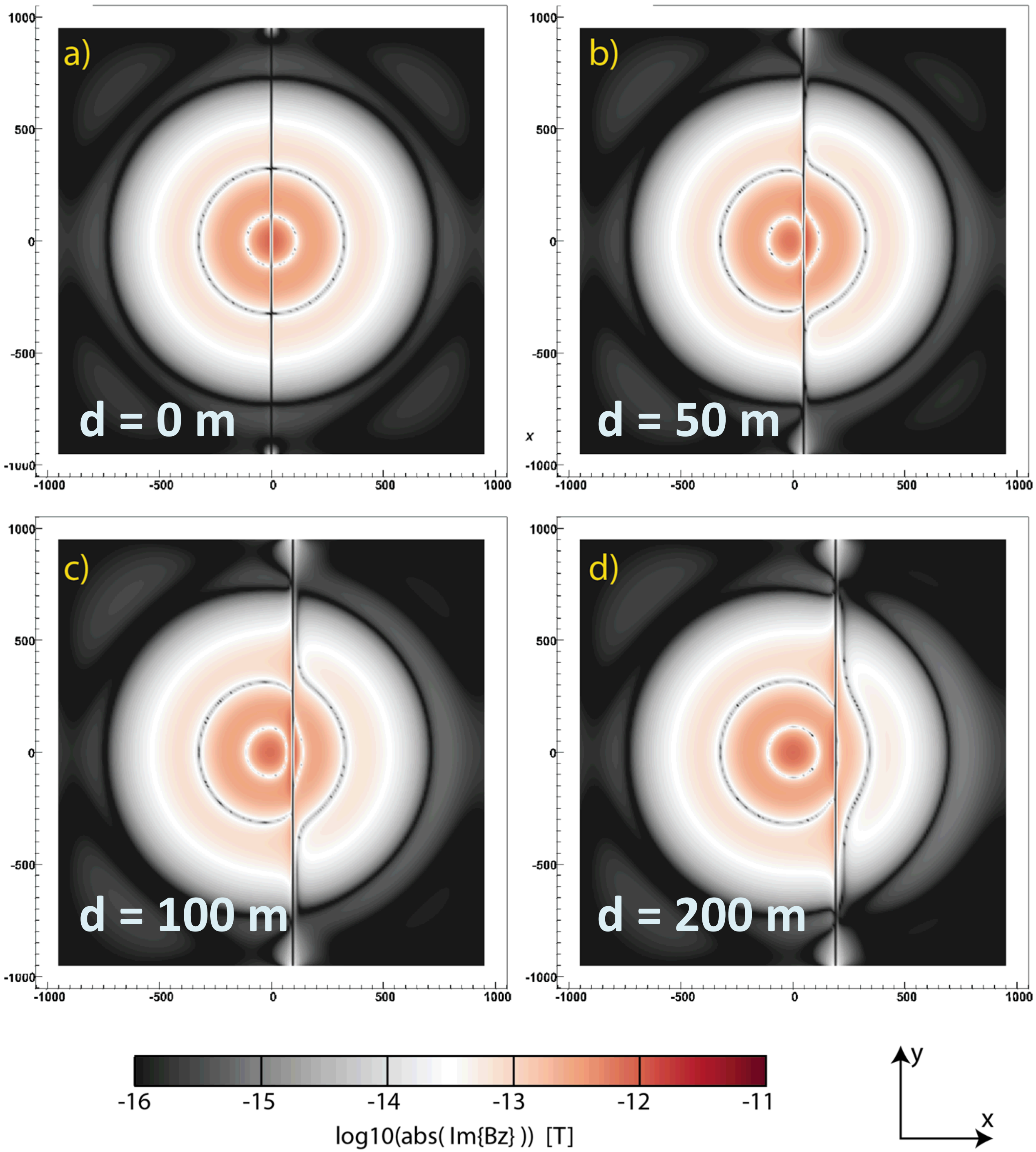
CASE 1:
fixed transmitter (TX)
variable receiver (RX)
rail on Earth surface



Vertical magnetic field on Earth's surface: surface rail



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0.01 S/m Earth
1e4 S/m rail

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variable receiver (RX)
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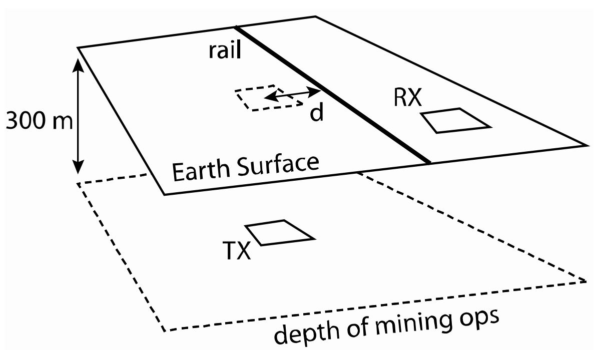
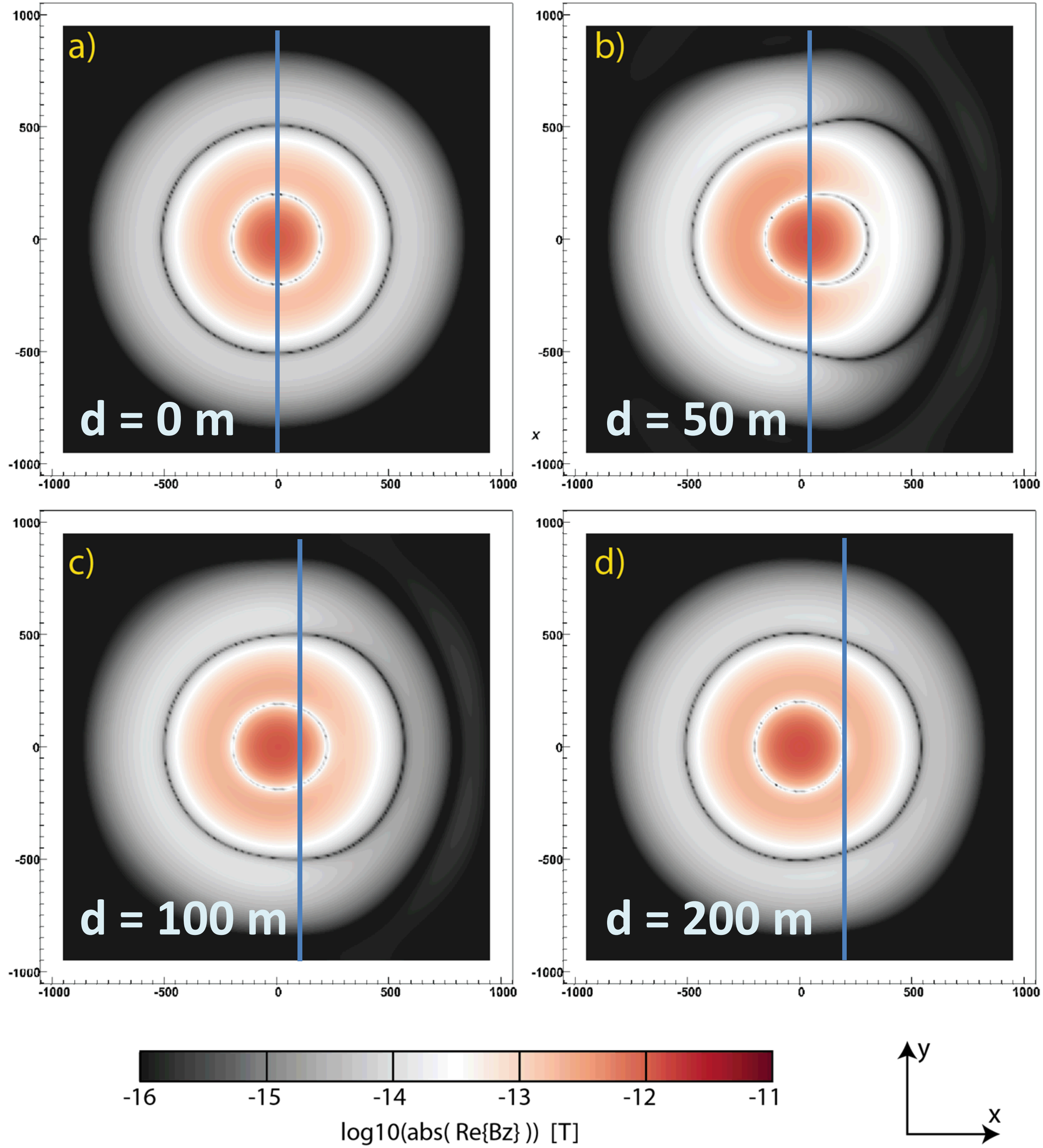
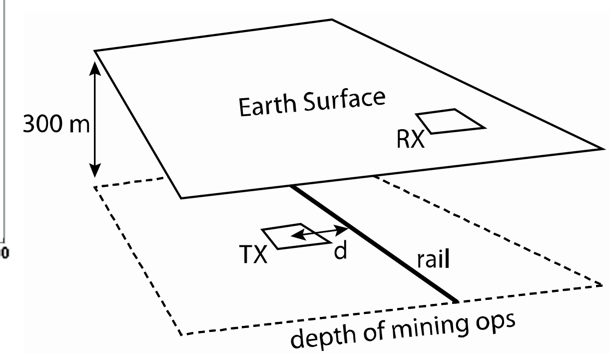


Vertical magnetic field on Earth's surface: buried rail

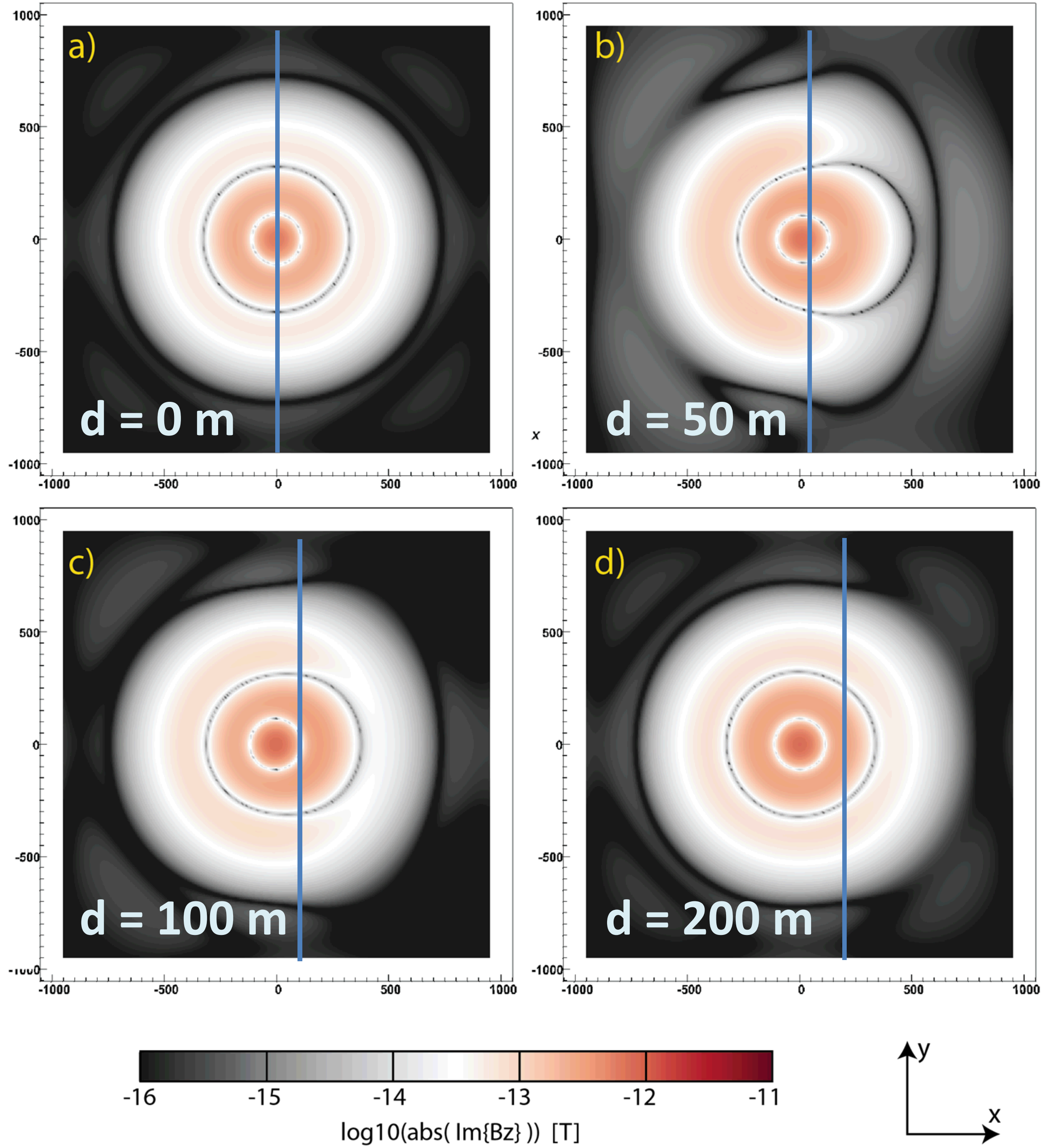


in-phase Bz
202x202x139 nodes
f=3.2 kHz
0.01 S/m Earth
1e4 S/m rail

CASE 2:
fixed transmitter (TX)
variable receiver (RX)
rail at depth of mine ops



Vertical magnetic field on Earth's surface: buried rail



quad-phase Bz
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f=3.2 kHz
0.01 S/m Earth
1e4 S/m rail

CASE 2:
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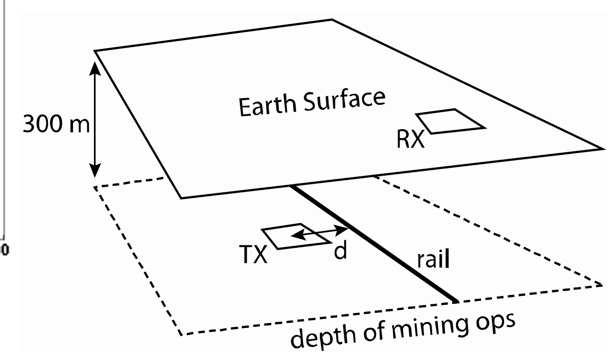
variable receiver (RX)
rail at depth of mine ops



Conclusions

- 3D electromagnetic simulations of the TTE response for Earth/rail system are feasible with explicit discretization of the high-conductivity rail
- Rails lying directly over/on the TX antenna have no effect on TTE response (expected by symmetry, demonstrated by calculation)
- Surface rails efficiently couple to the TTE antenna, leading to longer propagation distances along the rail, but diminished amplitude on the "far" side.
- Fully buried rails, in contrast, show only a mild surface response with no significant effect on enhanced signal propagation efficiency.

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