Anisotropy
From basics to 3D modeling

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Angewandte Geophysik
Applied Geophysics

Thanks to collaborators of my MT working group

Michael Häuserer (Rwenzori, Uganda)

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Sharare Zhian (Zagros, Iran)

César Castro (Tepic-Zacoalco, Mexico)

Content for today:

- Motivation – why anisotropy rather than isotropy?
- Numerical simulations in 3D
- The real world

Content for today:

- **Motivation – why anisotropy rather than isotropy?**
- Numerical simulations in 3D
- The real world

Starting with a numerical simulation

3D inversion (ModEM)

of simulated data

(full impedance tensor and tipper)

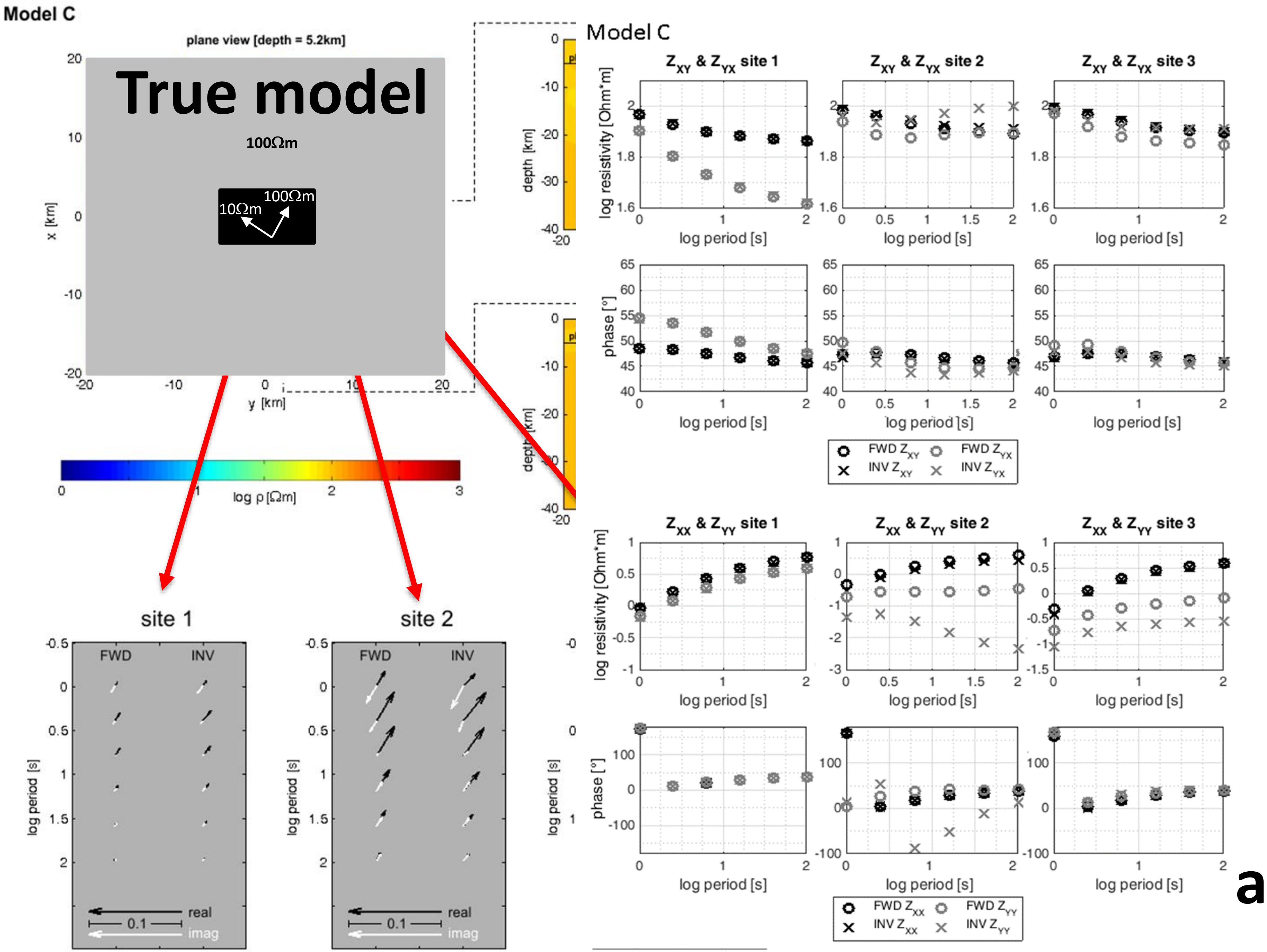
for 6 periods

between 1 – 100 s

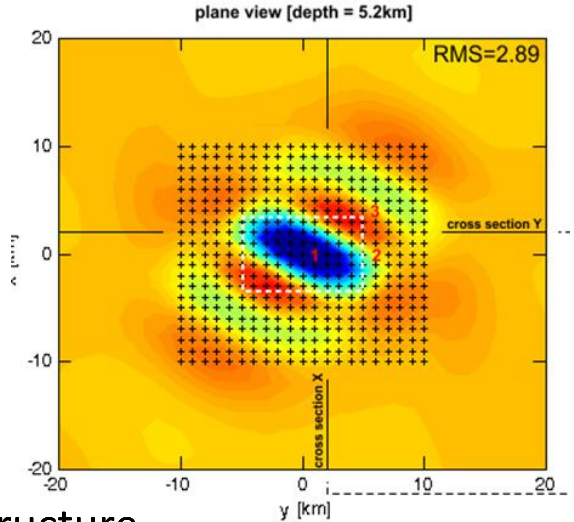
at 441 sites

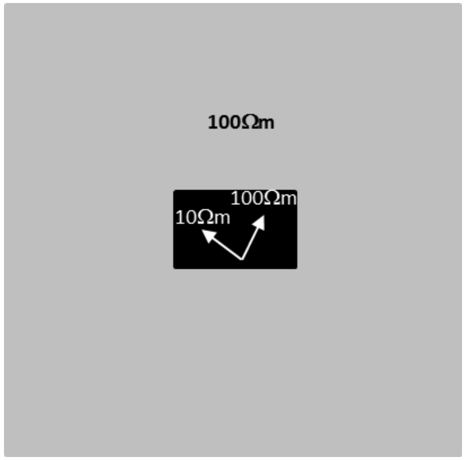
equally distributed in 20 km x 20 km

(Löwer&Junge, PAGEOPH 2017 (online))



Model C
plane view [depth = 5.2km]
True model
100Ωm
10Ωm
100Ωm
x [km]
y [km]
log ρ [Ωm]
depth [km]
Model C
Z_XY & Z_YX site 1
Z_XY & Z_YX site 2
Z_XY & Z_YX site 3
log resistivity [Ohm*m]
phase [°]
log period [s]
FWD Z_XY
INV Z_XY
FWD Z_YX
INV Z_YX
Z_XX & Z_YY site 1
Z_XX & Z_YY site 2
Z_XX & Z_YY site 3
FWD Z_XX
INV Z_XX
FWD Z_YY
INV Z_YY
site 1
site 2
FWD
INV
real
imag
0.1
a





Complex structure
High resistivity contrast

Isotropy or Anisotropy?

Simple structure
Moderate resistivity contrast

According to

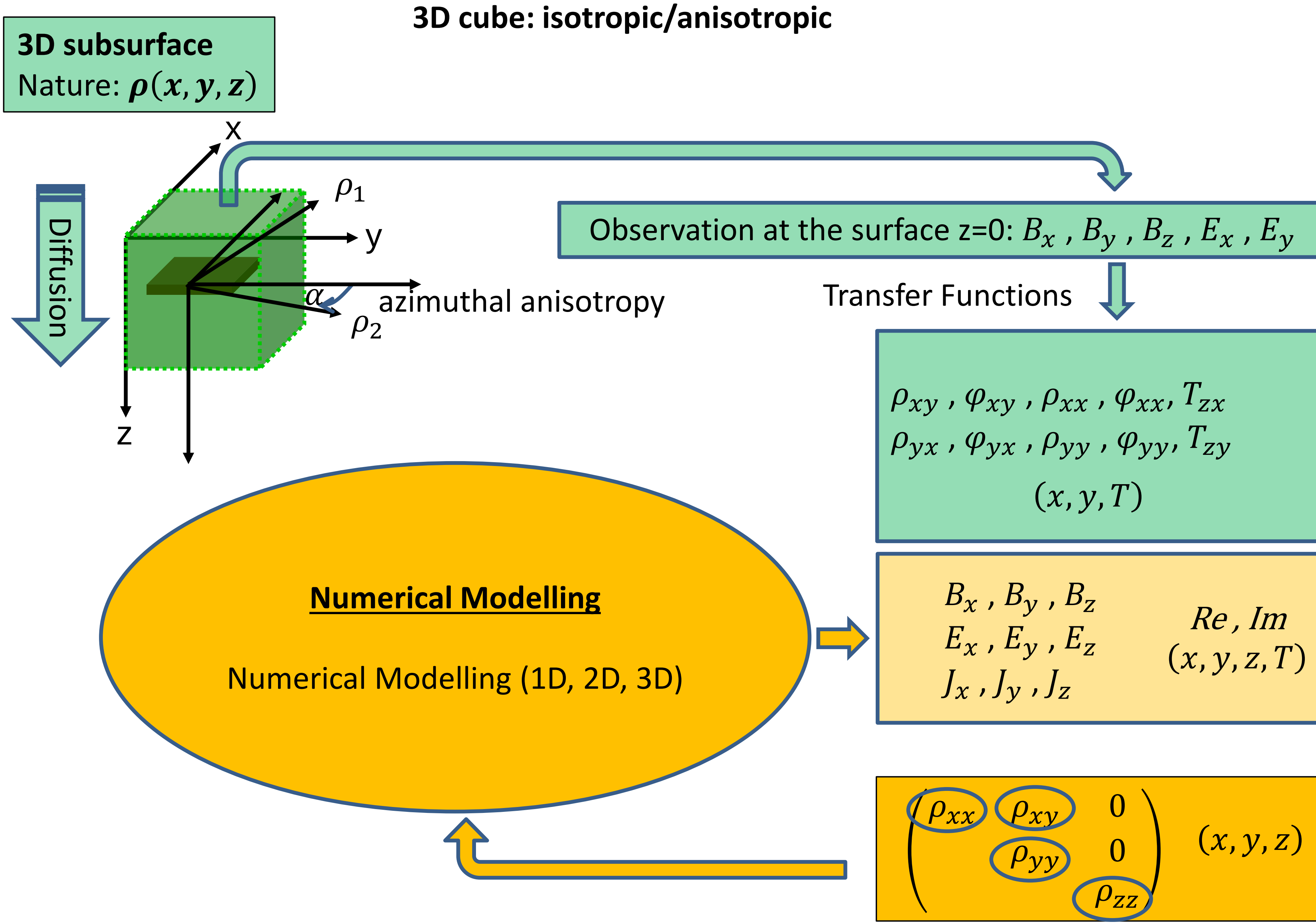
Occam‘s Principle,

what model

do you prefer?

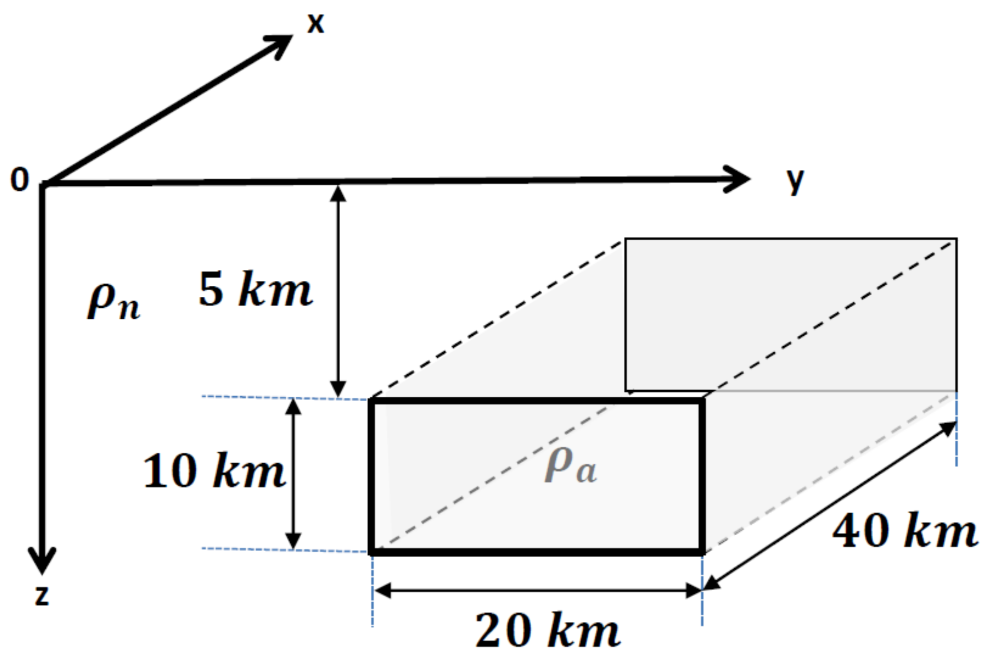
Content for today:

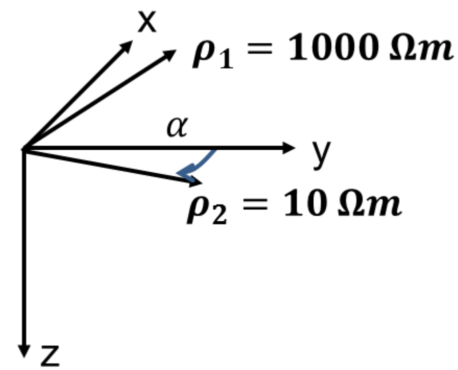
- Motivation – why anisotropy rather than isotropy?
- **Numerical simulations in 3D**
- The real world



3D cube: isotropic/anisotropic
3D subsurface
Nature: $\boldsymbol{\rho(x, y, z)}$
Diffusion
x
y
z
ρ_1
ρ_2
α
azimuthal anisotropy
Observation at the surface z=0: B_x , B_y , B_z , E_x , E_y
Transfer Functions
ρ_{xy} , φ_{xy} , ρ_{xx} , φ_{xx}, T_{zx}
ρ_{yx} , φ_{yx} , ρ_{yy} , φ_{yy}, T_{zy}
(x, y, T)
Numerical Modelling
Numerical Modelling (1D, 2D, 3D)
B_x , B_y , B_z
E_x , E_y , E_z
J_x , J_y , J_z
Re , Im
(x, y, z, T)
$\begin{pmatrix} \rho_{xx} & \rho_{xy} & 0 \\ & \rho_{yy} & 0 \\ & & \rho_{zz} \end{pmatrix}$ (x, y, z)

3D Model Study





ρ_a anisotropic: $\rho_1 = 1000\ \Omega m$

$\rho_2 = 10\ \Omega m$

$\rho_n = 100\ \Omega m$

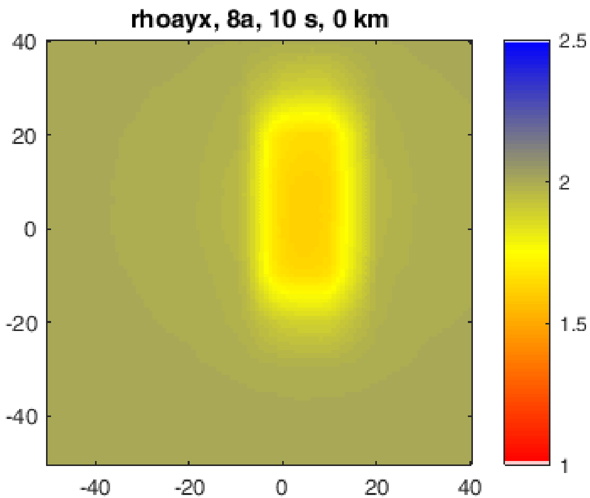
Conductor isotropic

$\rho_a = 10\ \Omega m$

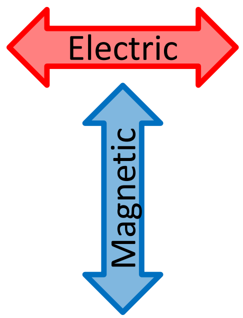
Apparent resistivity

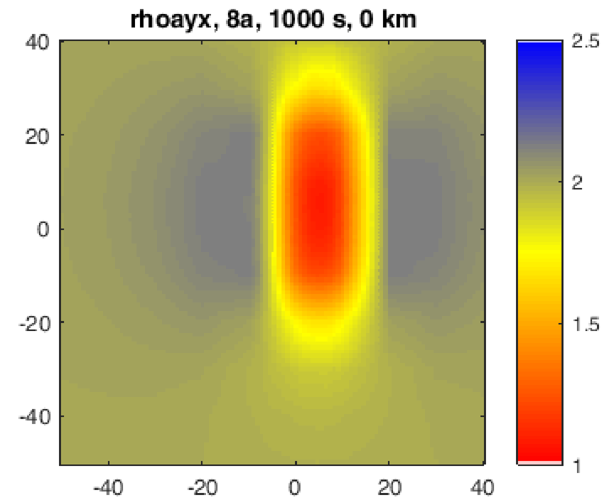
10 sec

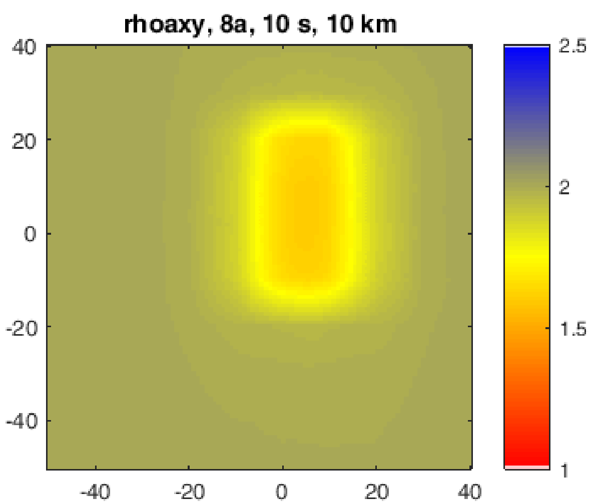
1000 sec



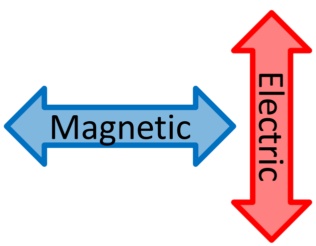
Source field polarization

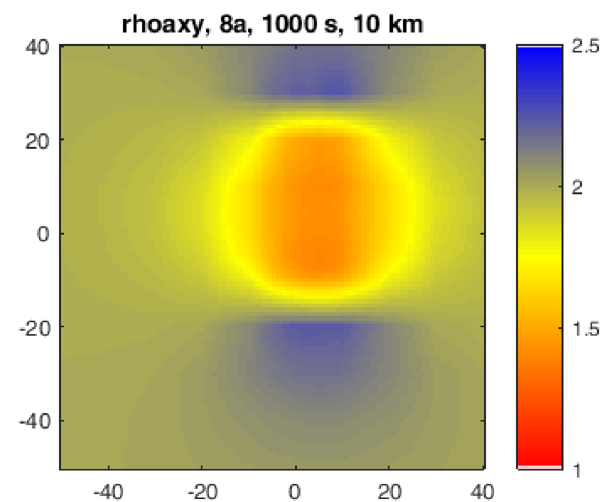






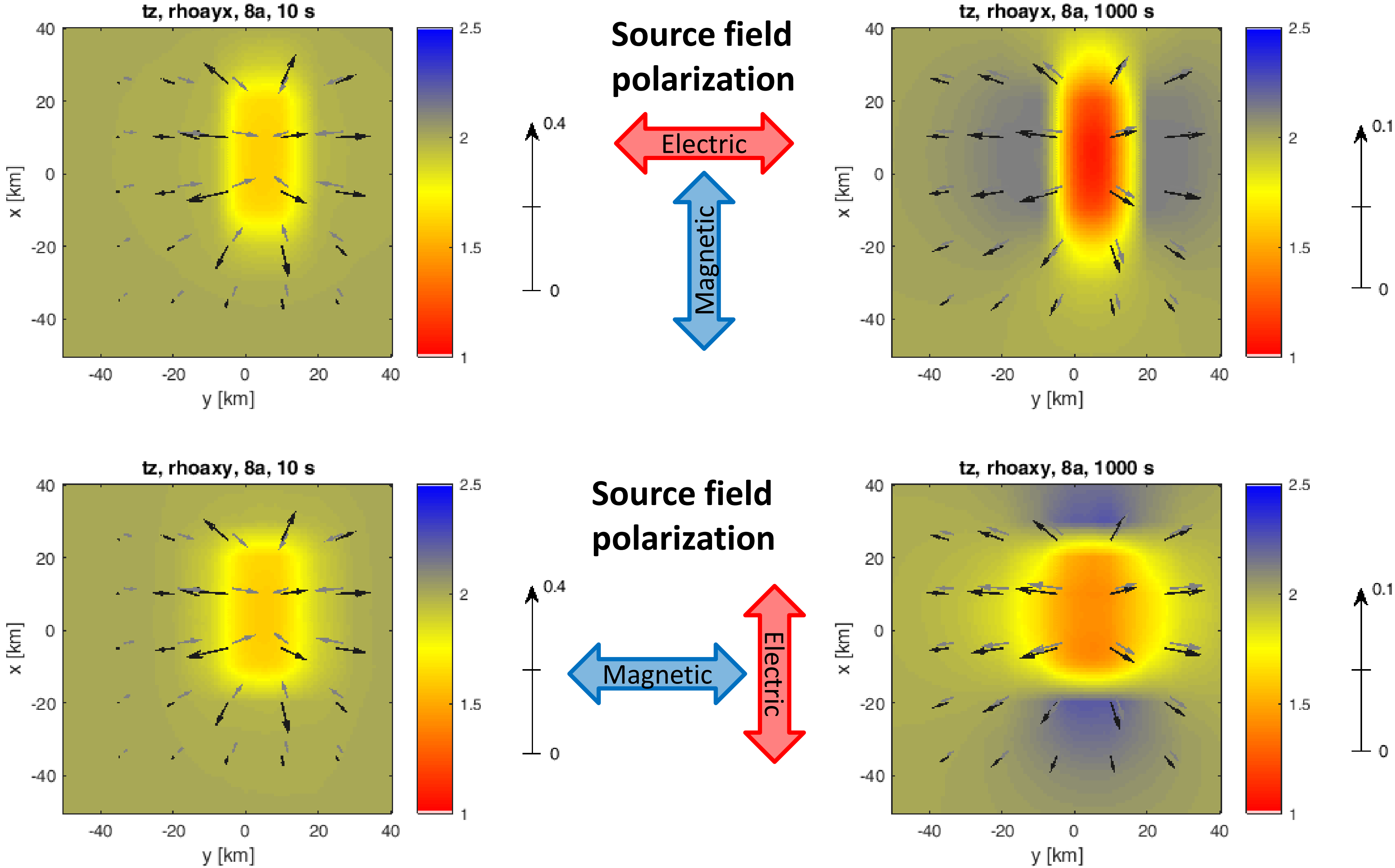
Source field polarization





Conductor isotropic $\rho_a = 10\ \Omega m$ **Apparent resistivity**

10 sec **1000 sec**



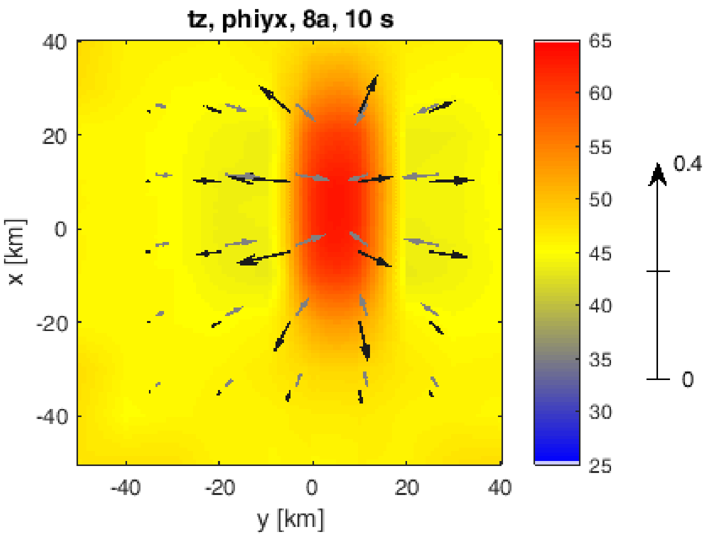
Conductor isotropic

$\rho_a = 10\ \Omega m$

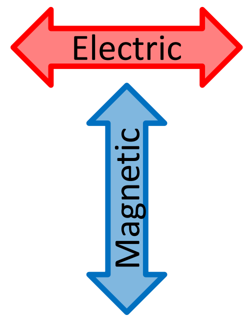
Phase

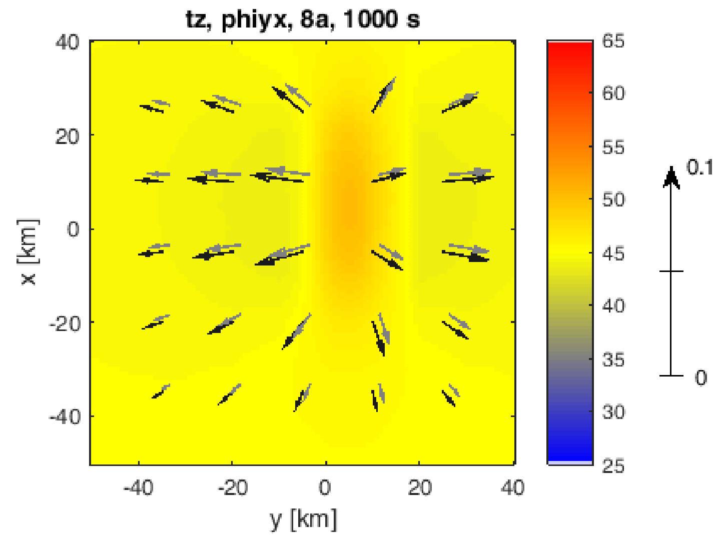
10 sec

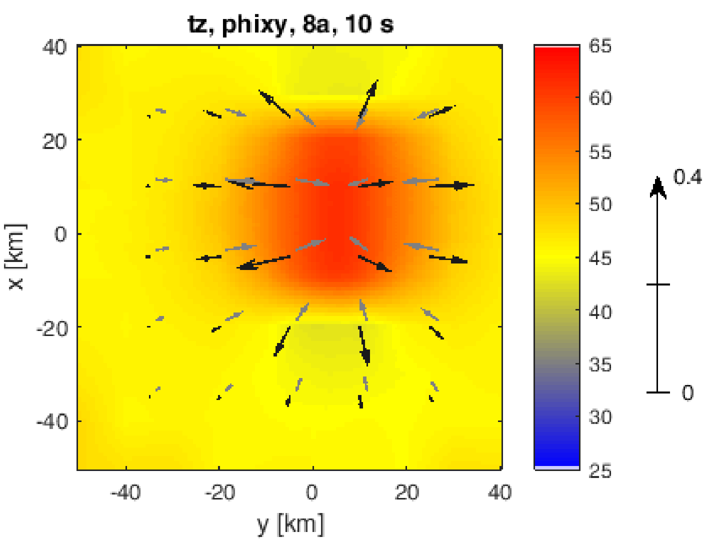
1000 sec



Source field polarization







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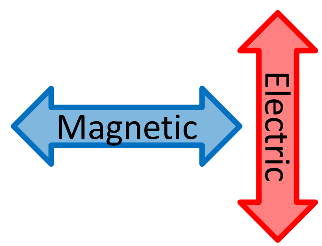
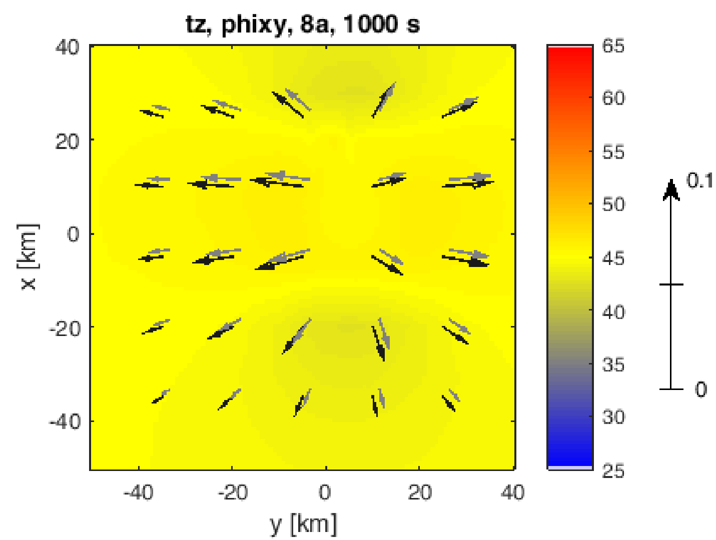




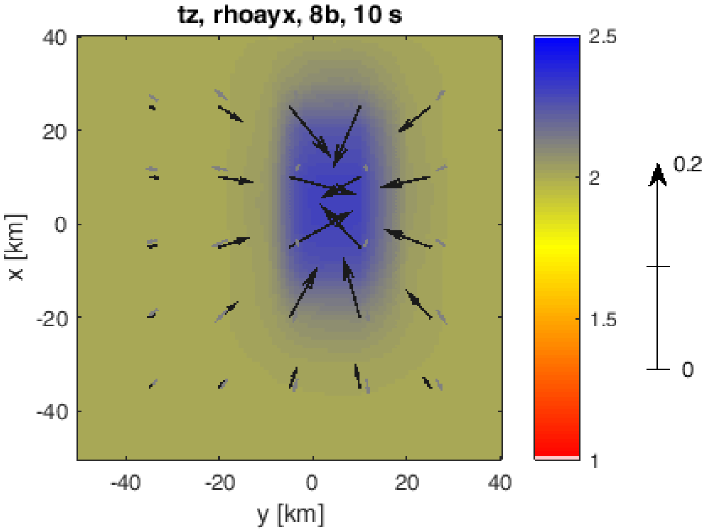
Resistor isotropic

$\rho_a = 1000\ \Omega m$

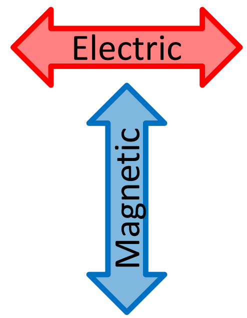
Apparent resistivity

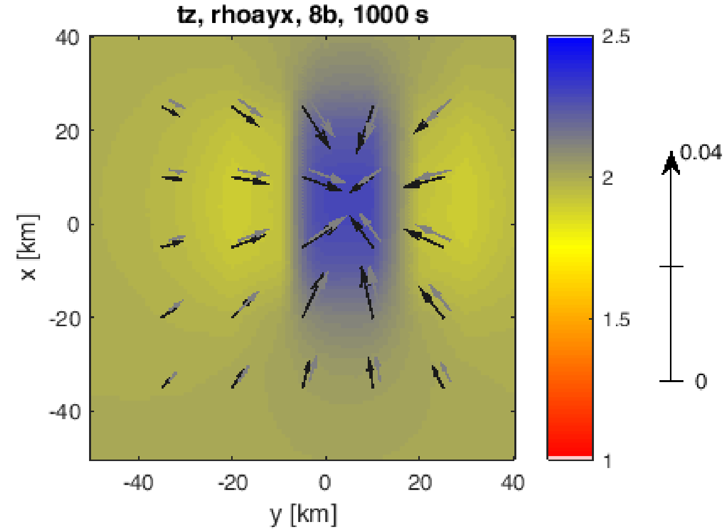
10 sec

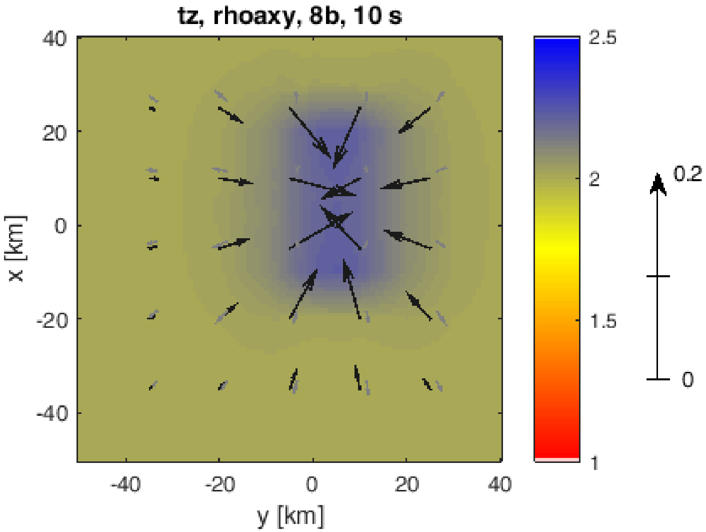
1000 sec



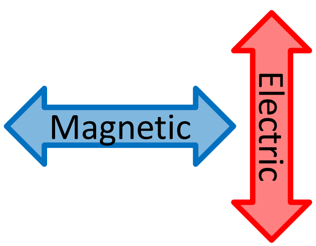
Source field polarization

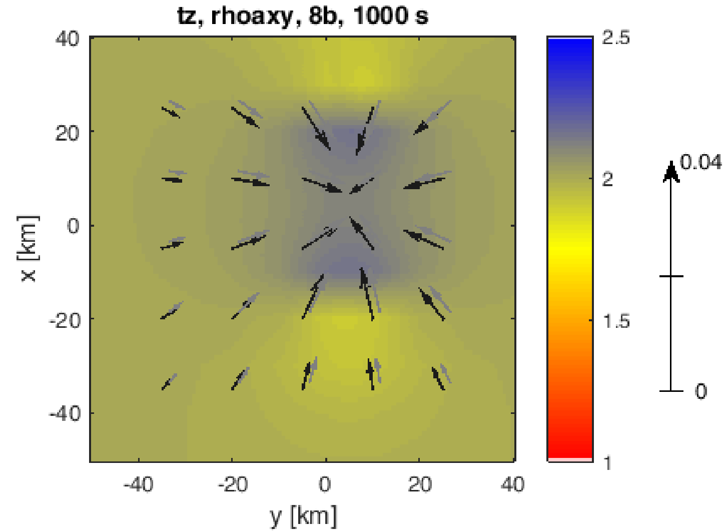






Source field polarization





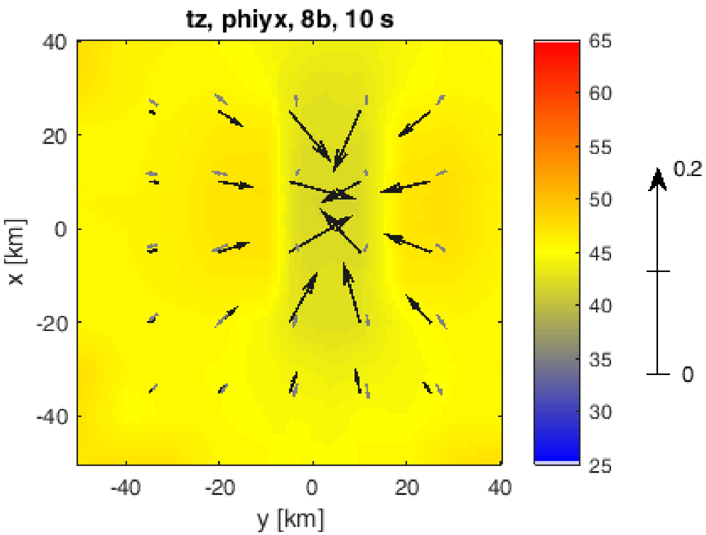
Resistor isotropic

$\rho_a = 1000\ \Omega m$

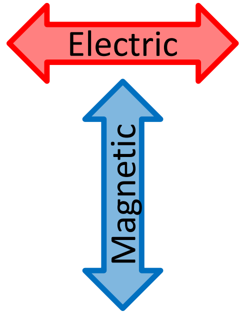
Phase

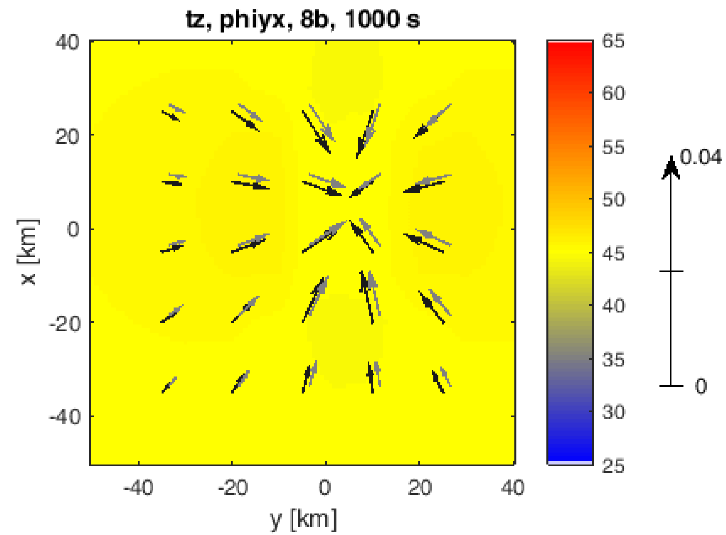
10 sec

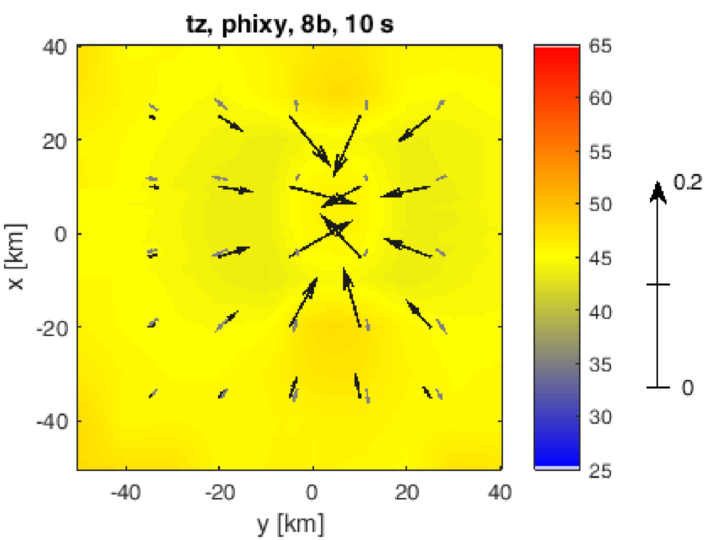
1000 sec



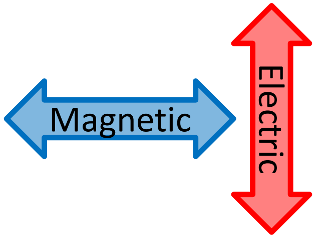
Source field polarization

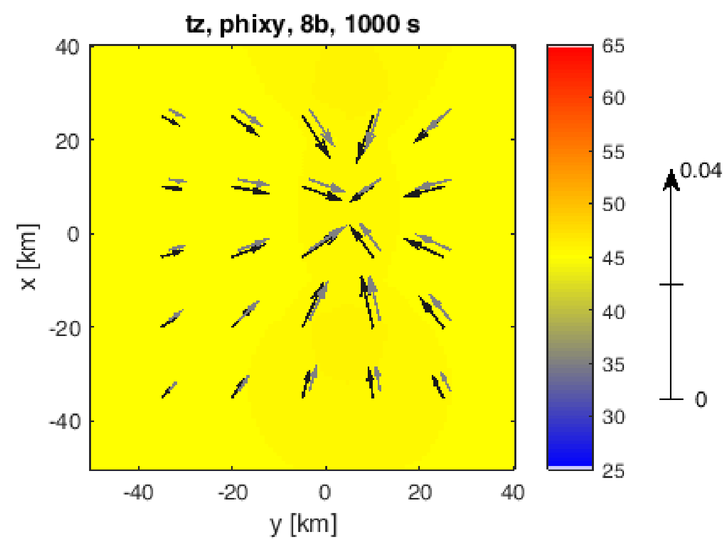






Source field polarization





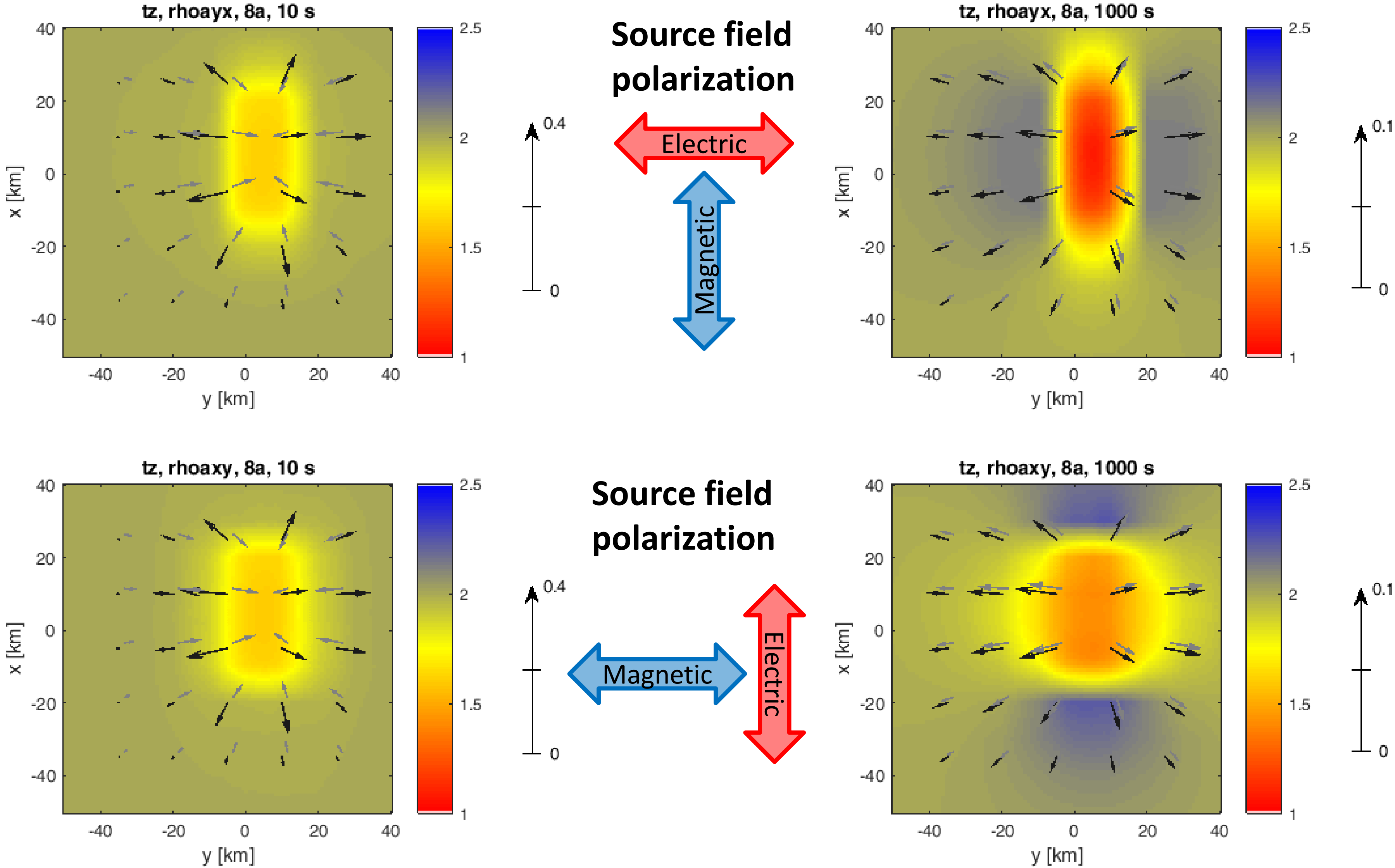
Conductor isotropic

$\rho_a = 10\ \Omega m$

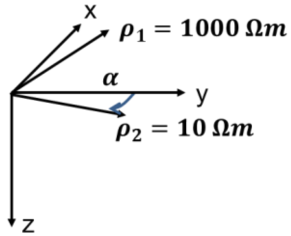
Apparent resistivity

10 sec

1000 sec



Anisotropic Anomaly

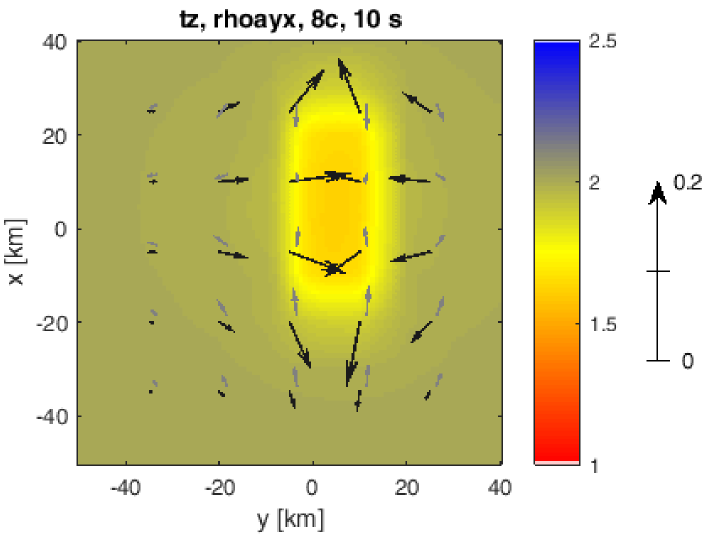


$\alpha = 0°$

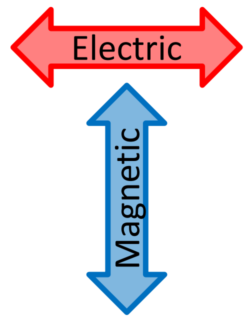
Apparent resistivity

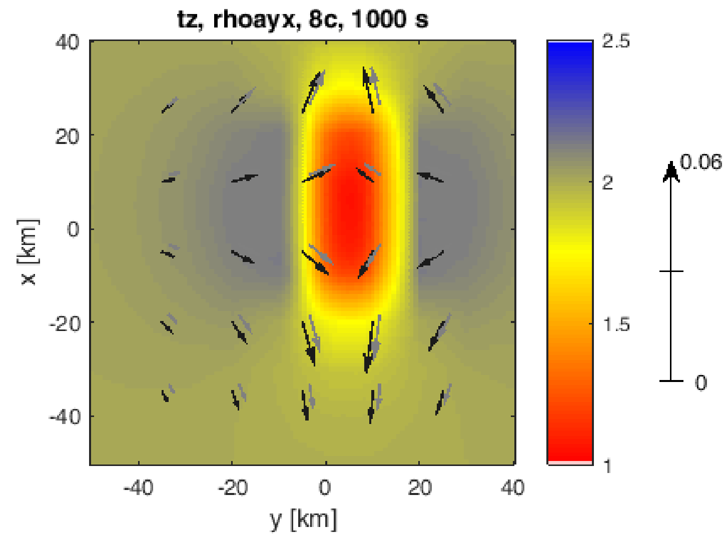
10 sec

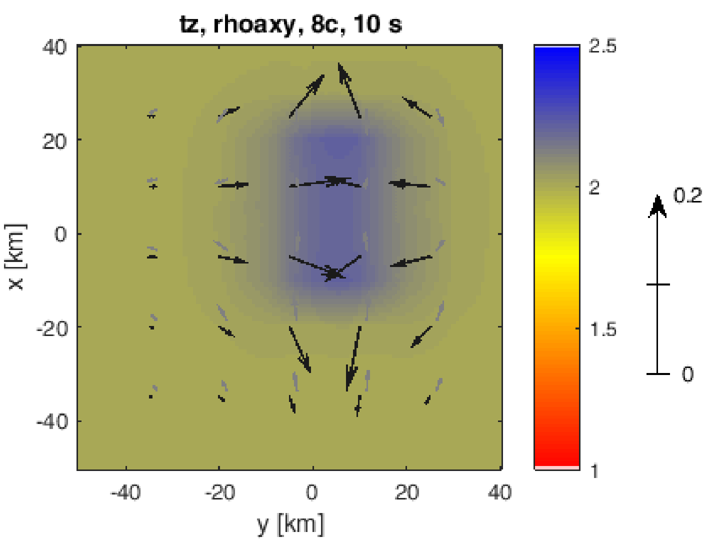
1000 sec



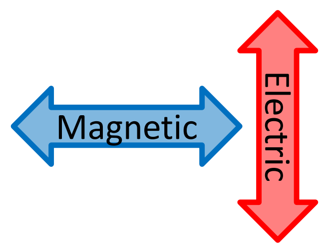
Source field polarization

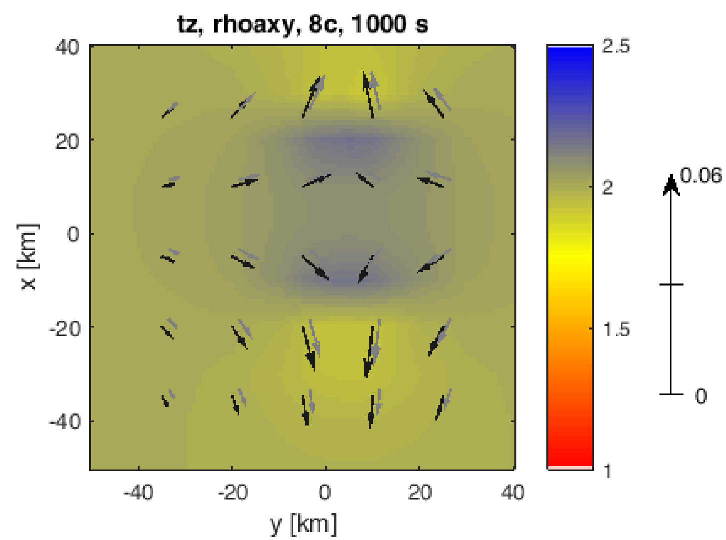




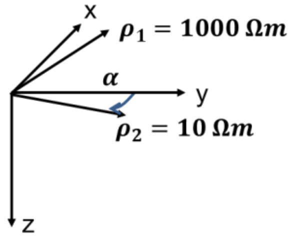


Source field polarization





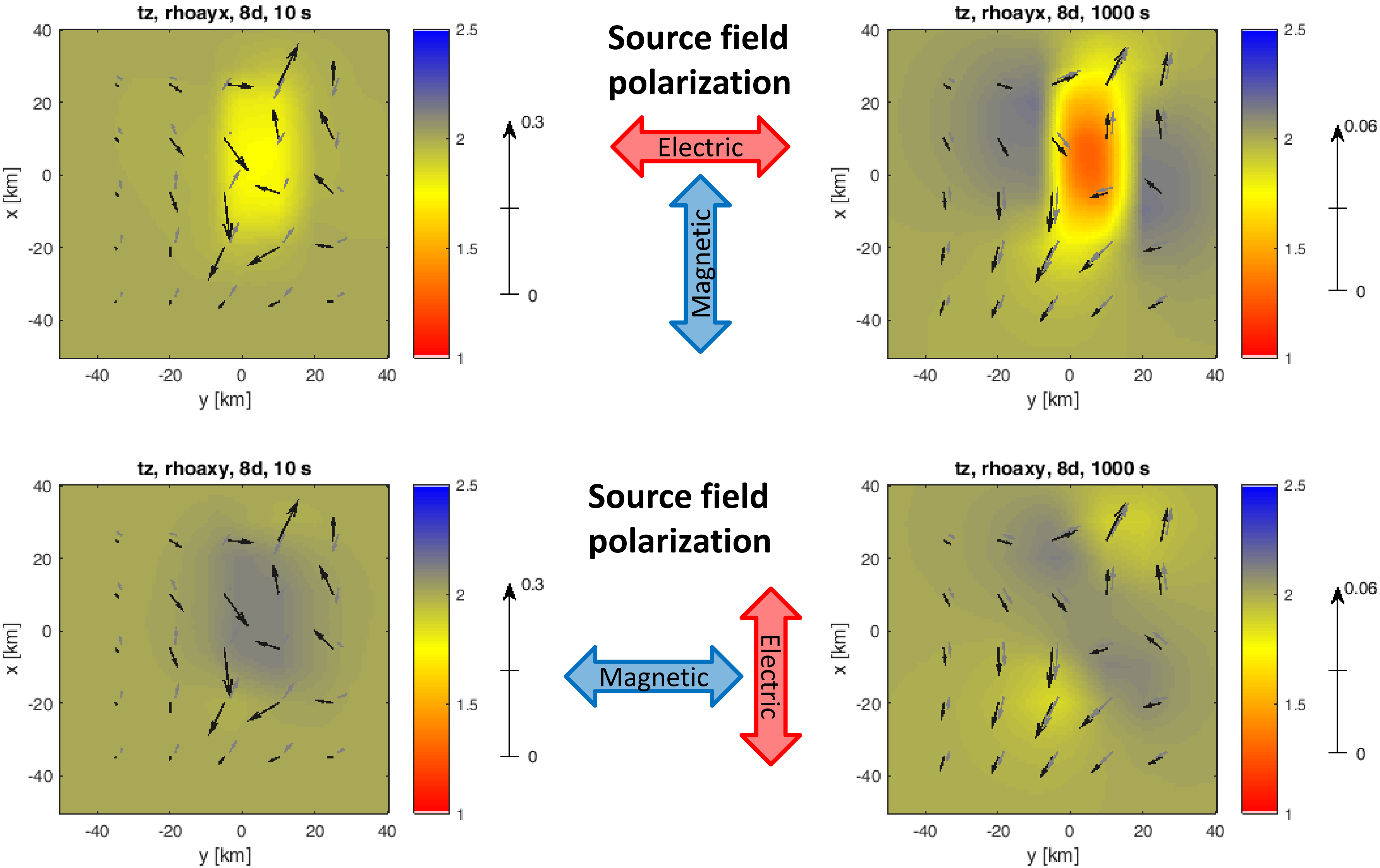
Anisotropic Anomaly



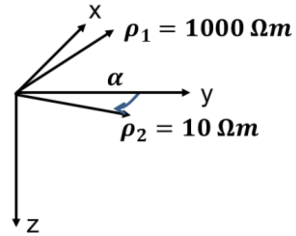
$\alpha = 30°$ **Apparent resistivity**

10 sec

1000 sec



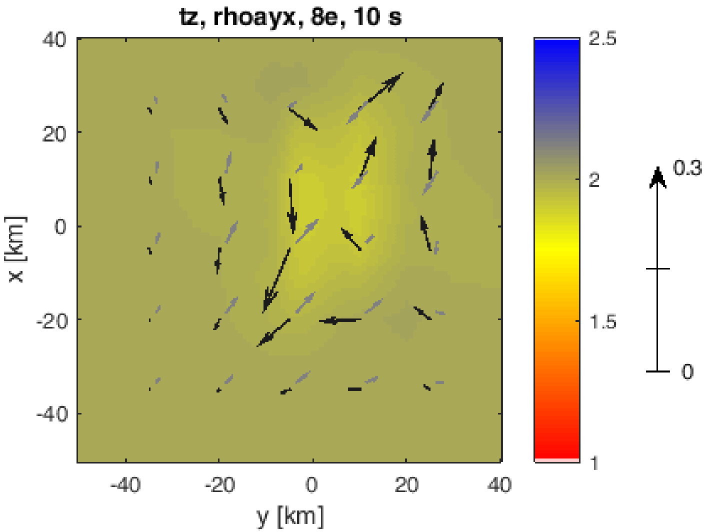
Anisotropic Anomaly



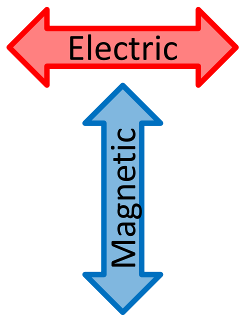
$\alpha = 45°$ **Apparent resistivity**

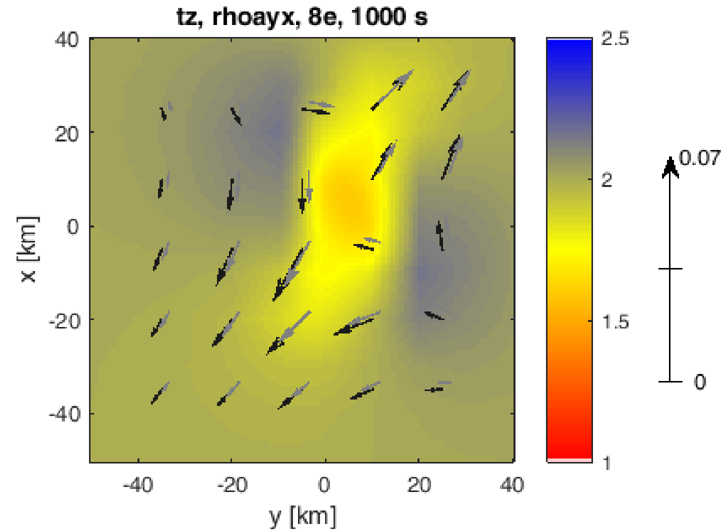
10 sec

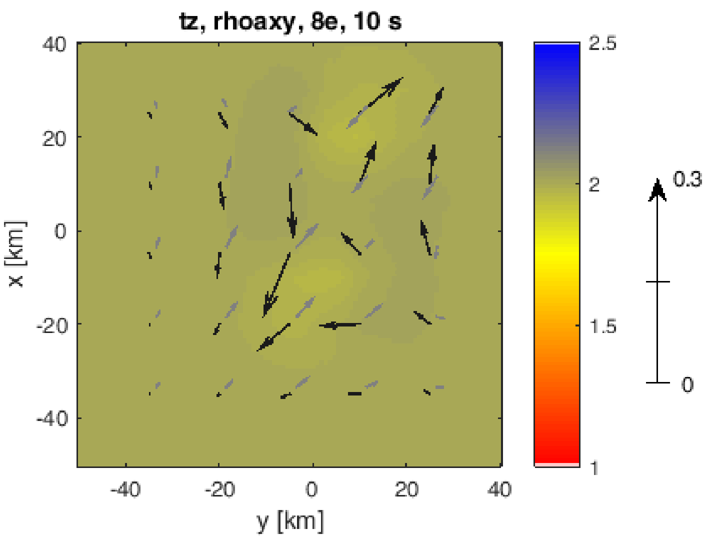
1000 sec



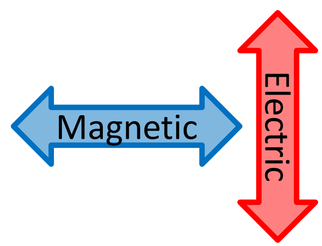
Source field polarization

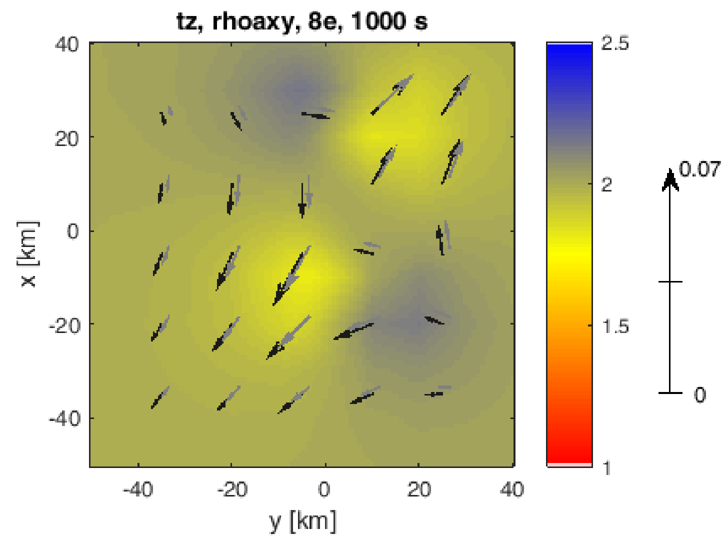






Source field polarization





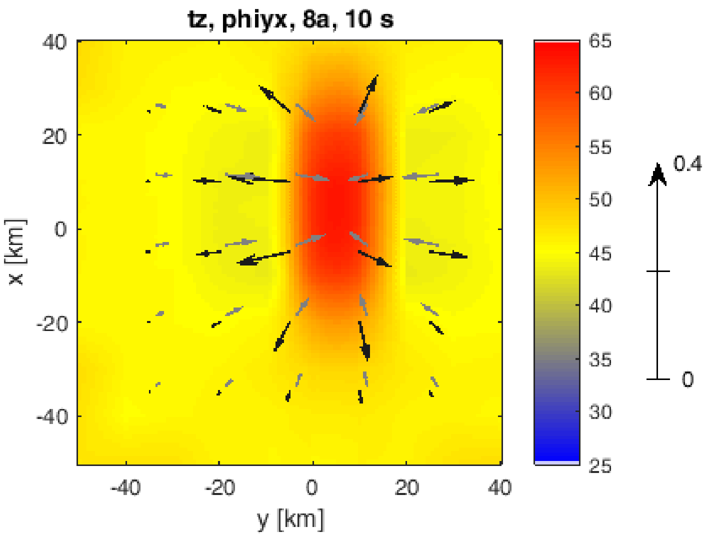
Conductor isotropic

$\rho_a = 10\ \Omega m$

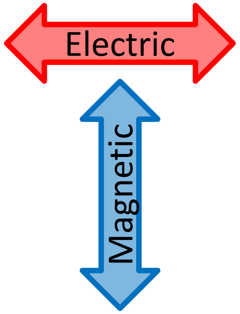
Phase

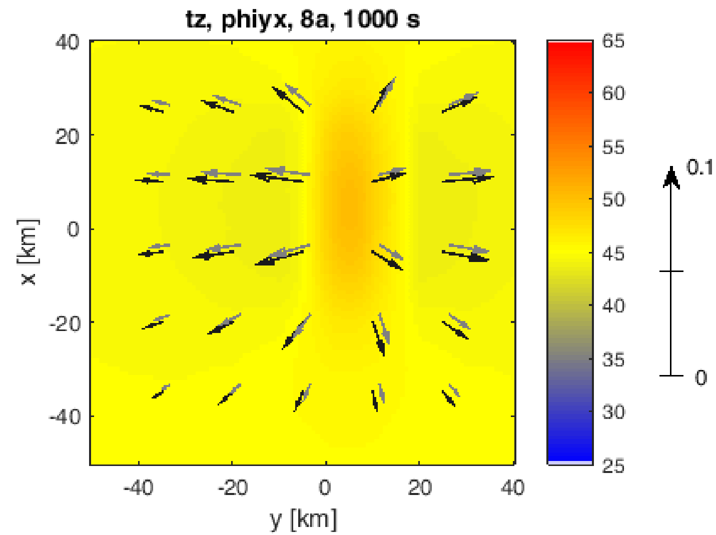
10 sec

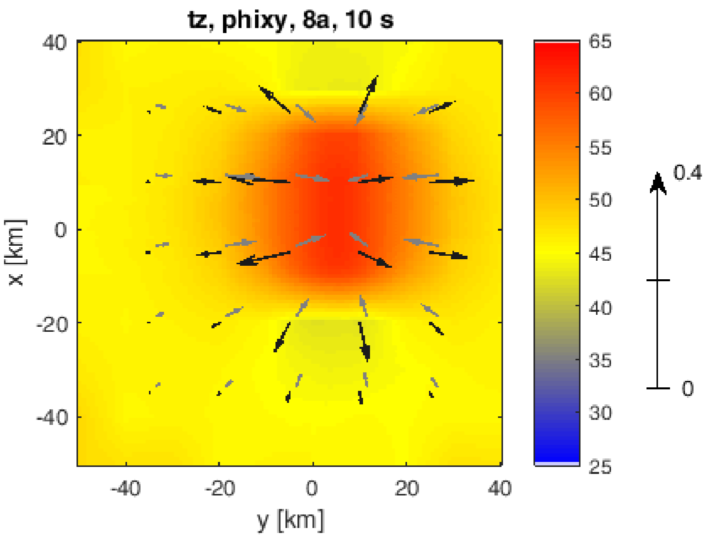
1000 sec



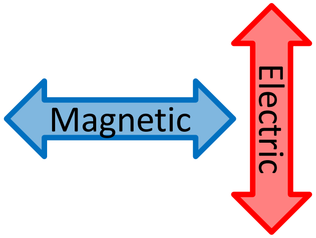
Source field polarization

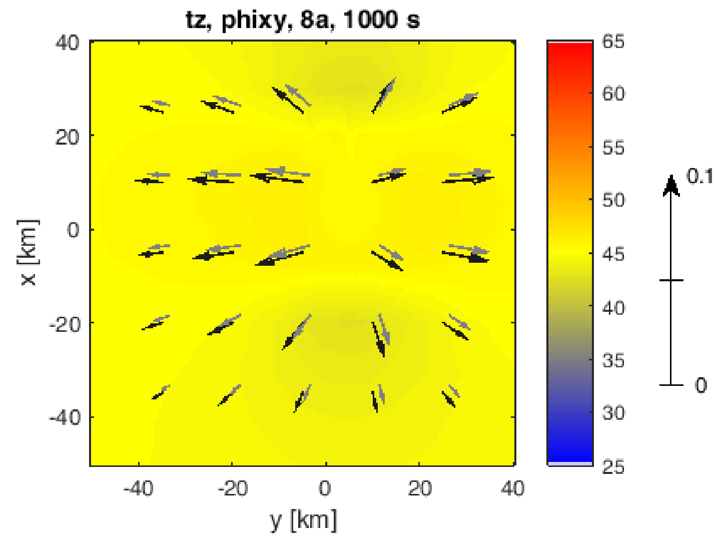




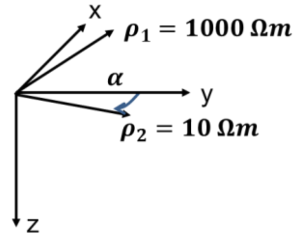


Source field polarization





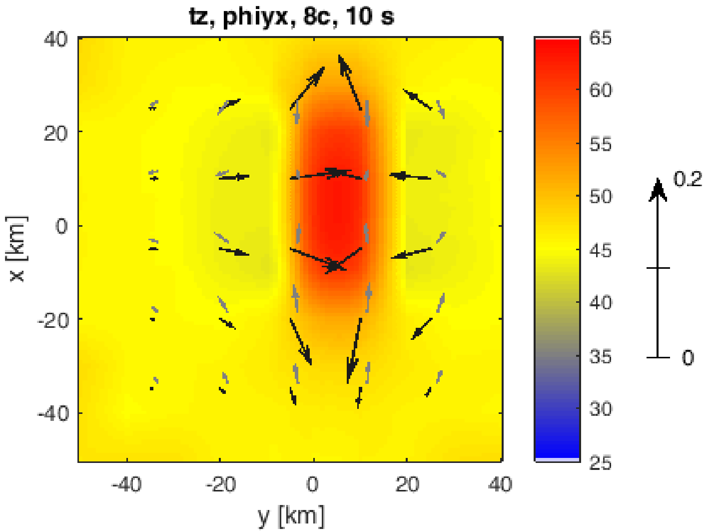
Anisotropic Anomaly



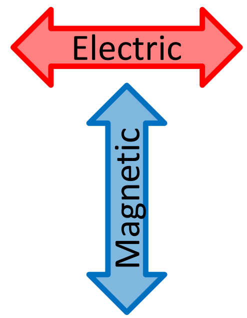
$\alpha = 0°$ **Phase**

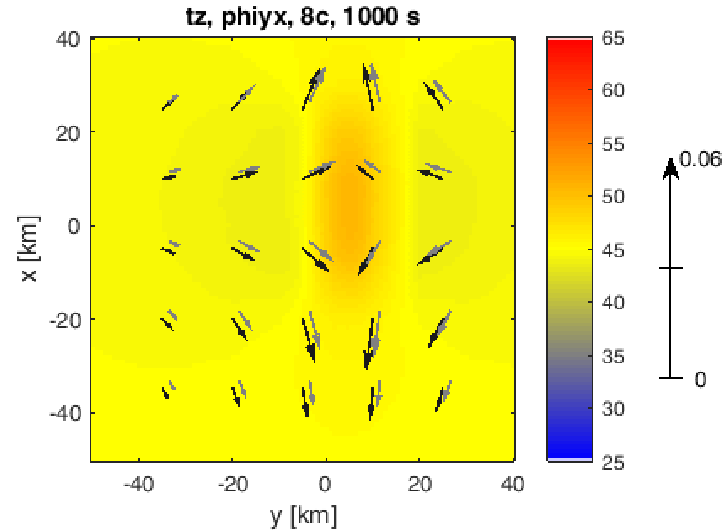
10 sec

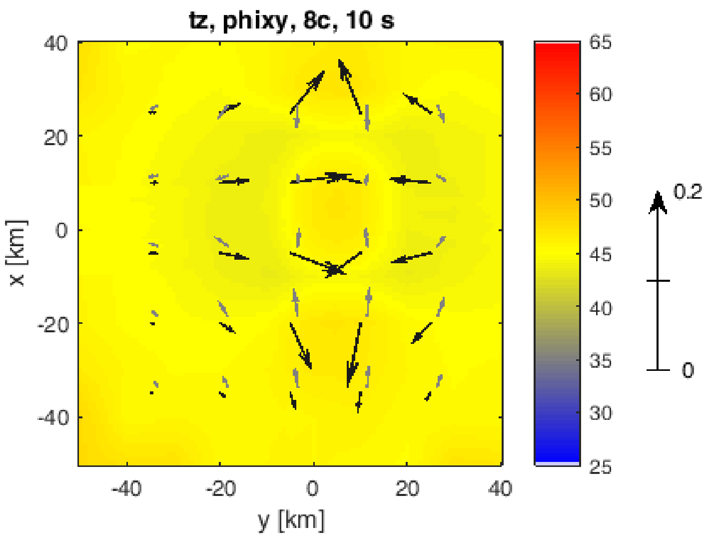
1000 sec



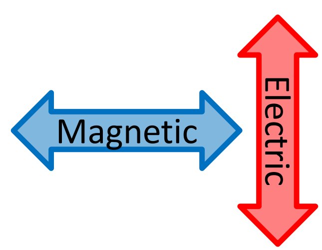
Source field polarization

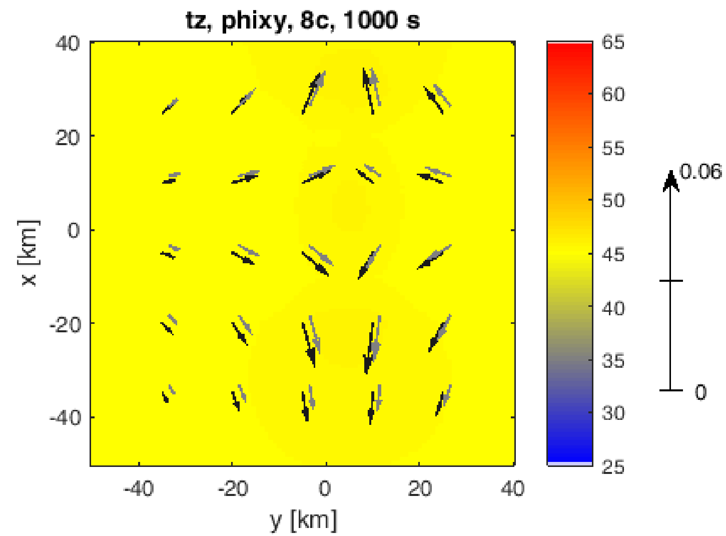






Source field polarization





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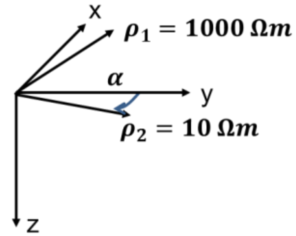
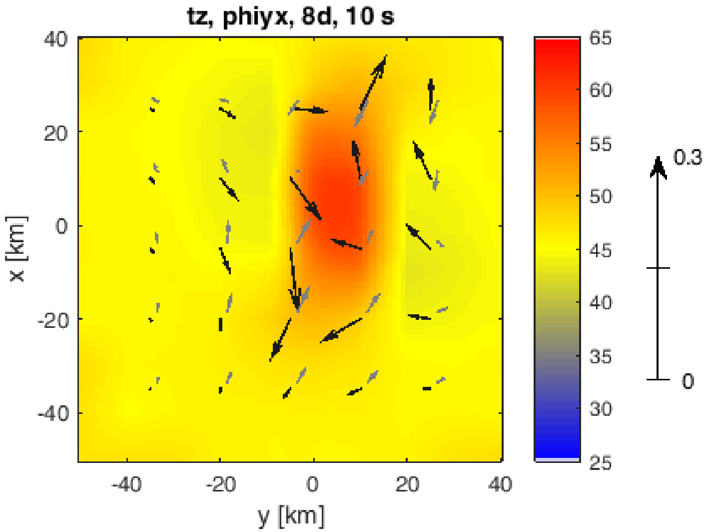


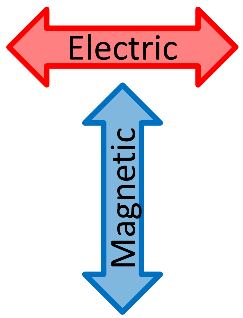
$\alpha = 30°$ **Phase**

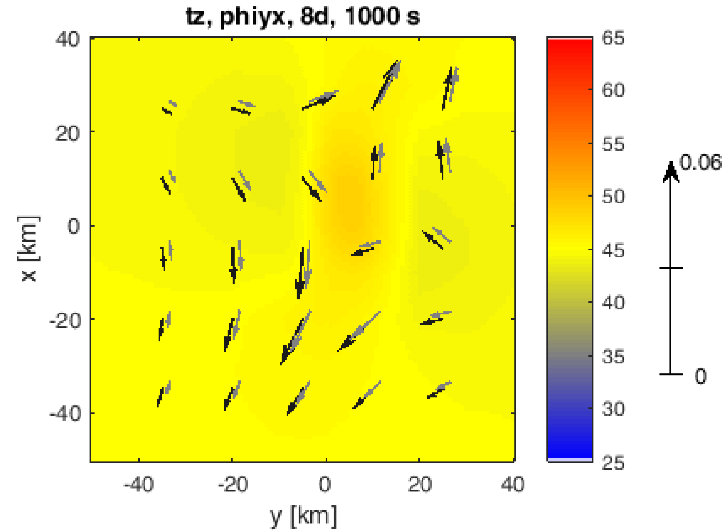
10 sec

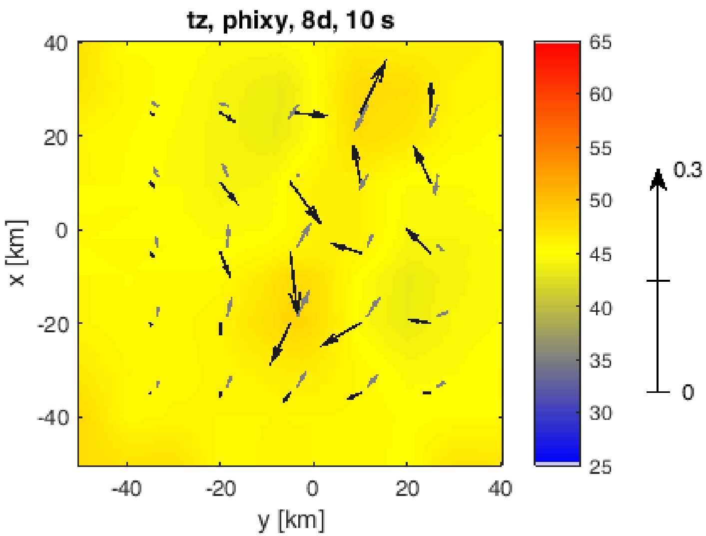
1000 sec



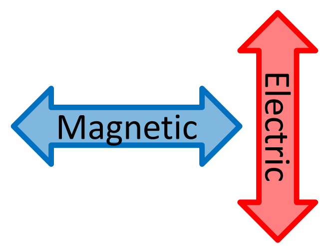
Source field polarization

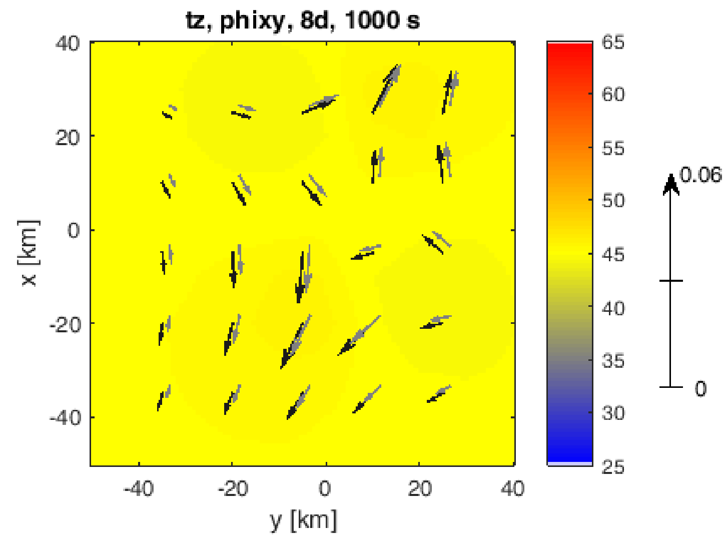


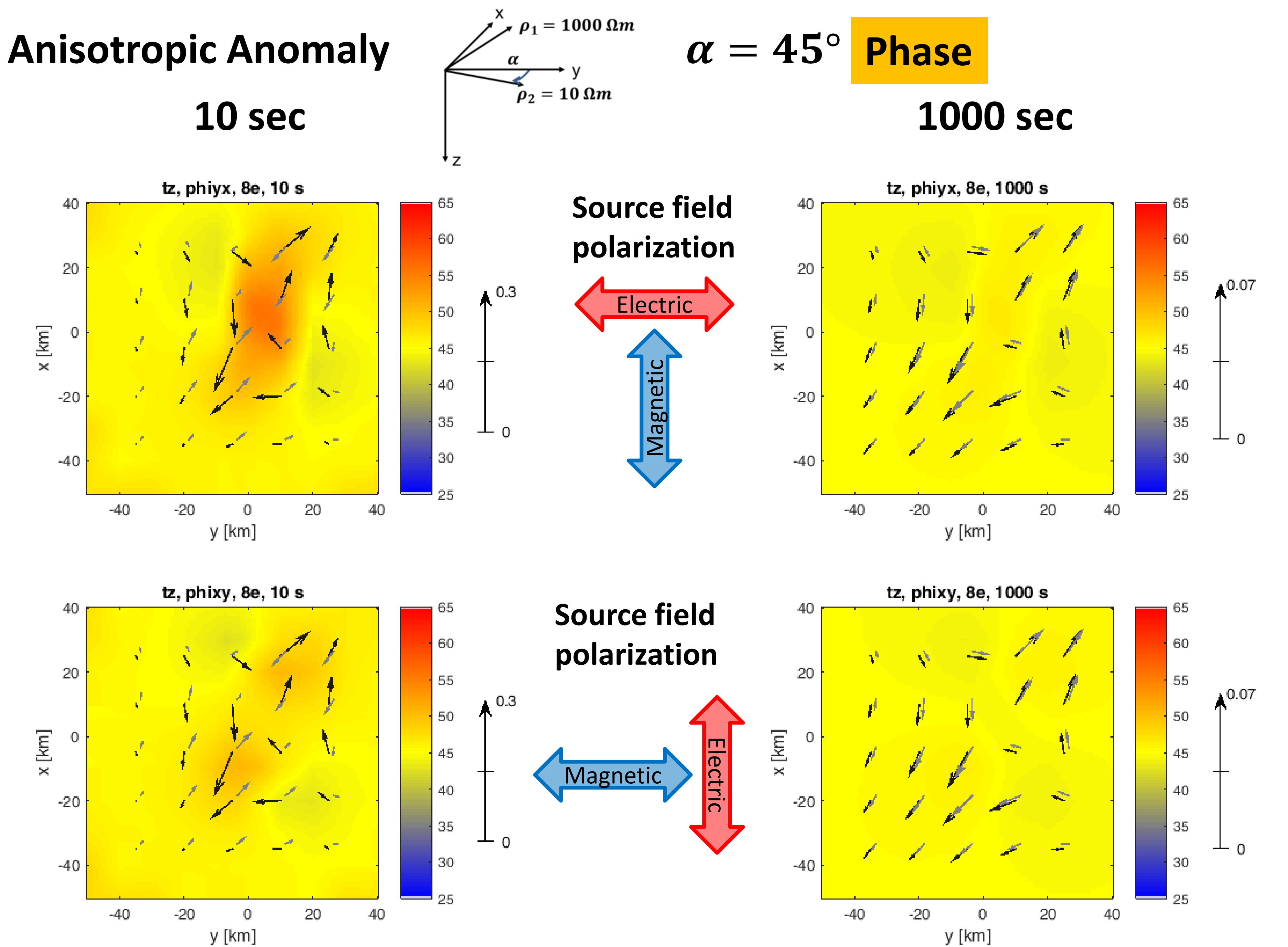




Source field polarization







Anisotropic Anomaly
10 sec
1000 sec
x
y
z
α
$\rho_1 = 1000\ \Omega m$
$\rho_2 = 10\ \Omega m$
$\alpha = 45°$
Phase
tz, phiyx, 8e, 10 s
tz, phiyx, 8e, 1000 s
tz, phixy, 8e, 10 s
tz, phixy, 8e, 1000 s
x [km]
y [km]
Source field polarization
Electric
Magnetic
Source field polarization
Magnetic
Electric
0.3
0.07
0

Some MT Definitions

Impedance Tensor $\mu\boldsymbol{Z}$: $\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \begin{pmatrix} B_x \\ B_y \end{pmatrix}$ or $\underline{E} = \boldsymbol{Z}\underline{B}$

Apparent Resistivity ρ_a: $\rho_{a,xy} = {}^{\mu}/_{\omega} \left|Z_{xy}\right|^2$, Phase: $\varphi_{xy} = \tan^{-1}\left({}^{\Im Z_{xy}}/_{\Re Z_{xy}}\right)$

Phase Tensor $\boldsymbol{\Phi}$: $\boldsymbol{\phi} = (\Re\boldsymbol{Z})^{-1}(\Im\boldsymbol{Z})$ (Caldwell et al., 2004)

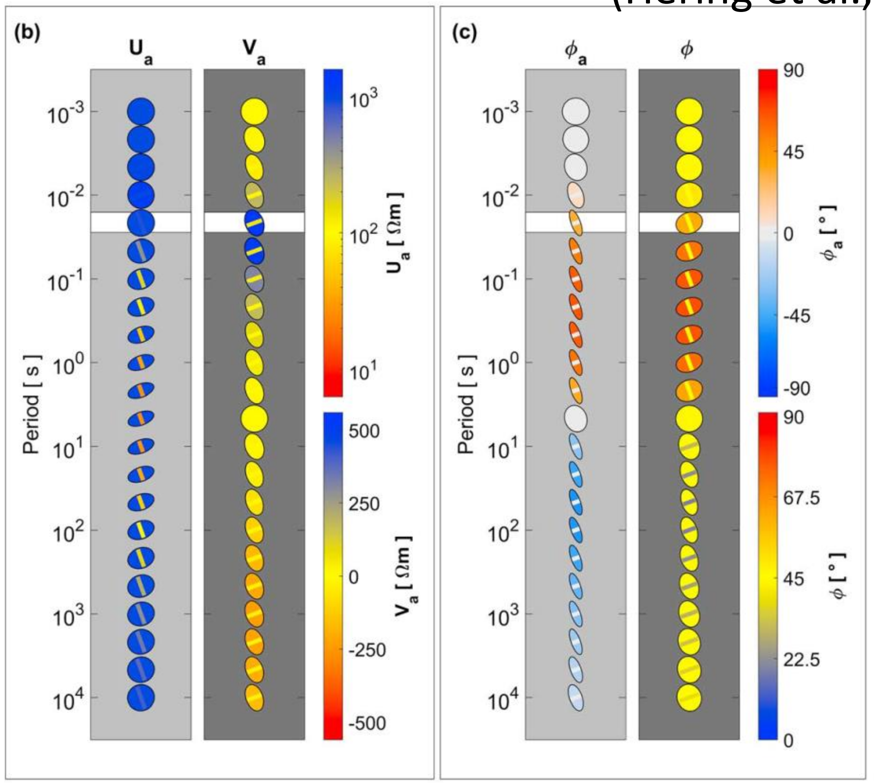
Apparent Resistivity Tensor $\boldsymbol{\rho}$: $\boldsymbol{\rho} = \left({}^{i\mu}/_{\omega}\right) det(\boldsymbol{Z})\boldsymbol{Z}(\boldsymbol{Z}^{-1})^T$ (Brown, JGR 2017)

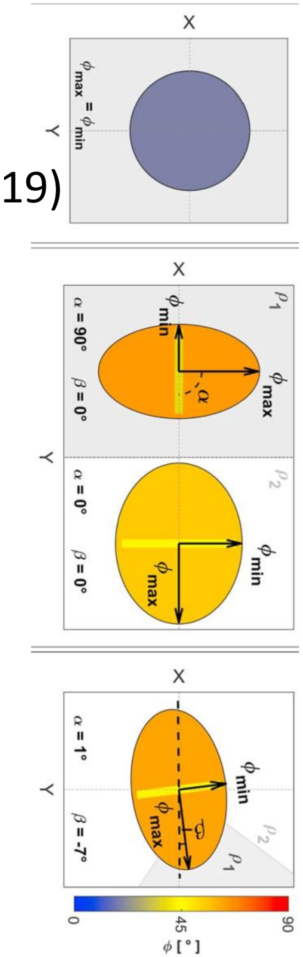
Apparent Current Density $\underline{J}$: $\underline{E} = \boldsymbol{\rho}\underline{J}$ (Brown, JGR 2017)

Some MT Definitions

Graphical Presentation

(Hering et al., JGR 2019)





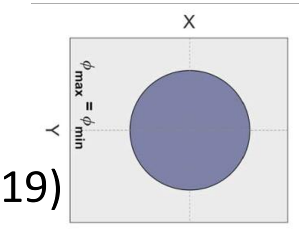
Phase Tensor $\mathbf{\Phi}$: $\boldsymbol{\phi} = (\Re \boldsymbol{Z})^{-1}(\Im \boldsymbol{Z})$(Caldwell et al., 2004)

Apparent Resistivity Tensor $\boldsymbol{\rho}$: $\boldsymbol{\rho} = \left({}^{i\mu}/_{\omega}\right) det(\boldsymbol{Z})\boldsymbol{Z}(\boldsymbol{Z}^{-1})^T$ (Brown, JGR 2017)

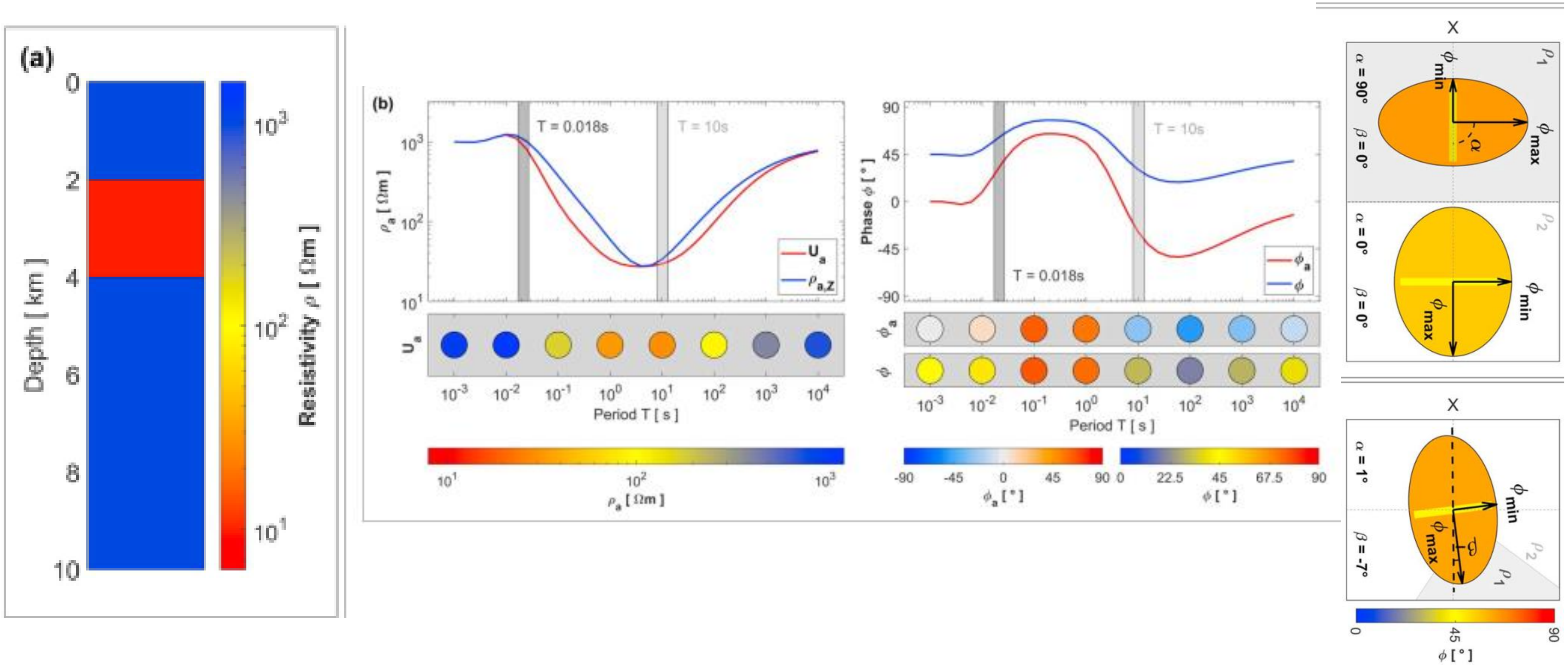
$\boldsymbol{\rho} = \boldsymbol{U}_a + i\boldsymbol{V}_a$ $\boldsymbol{\phi}_a = (\boldsymbol{U}_a)^{-1}(\boldsymbol{V}_a)$

Some MT Definitions

1D isotropic



(Hering et al., JGR 2019)



(Hering et al., 2018)

Phase Tensor $\boldsymbol{\Phi}$: $\boldsymbol{\phi} = (\Re \boldsymbol{Z})^{-1}(\Im \boldsymbol{Z})$(Caldwell et al., 2004)

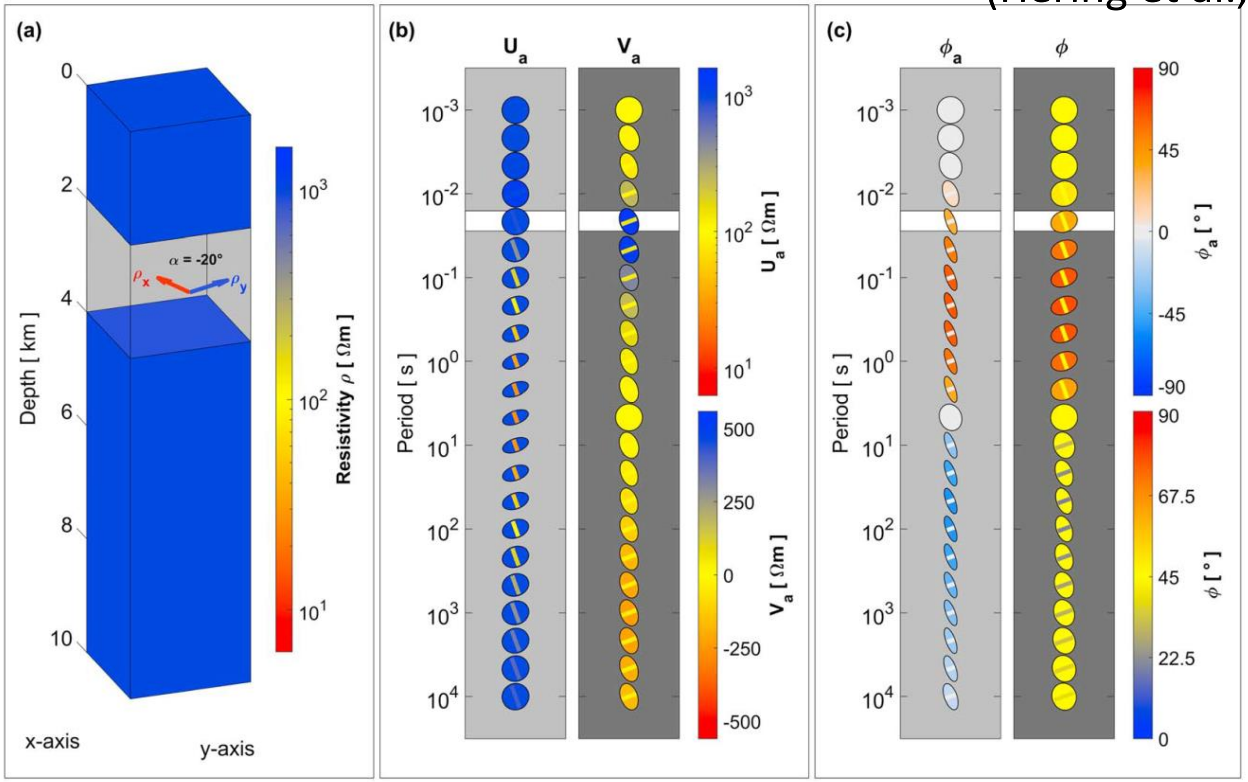
Apparent Resistivity Tensor $\boldsymbol{\rho}$: $\boldsymbol{\rho} = \left({}^{i\mu}/_{\omega}\right) det(\boldsymbol{Z})\boldsymbol{Z}(\boldsymbol{Z}^{-1})^{T}$ (Brown, JGR 2017)

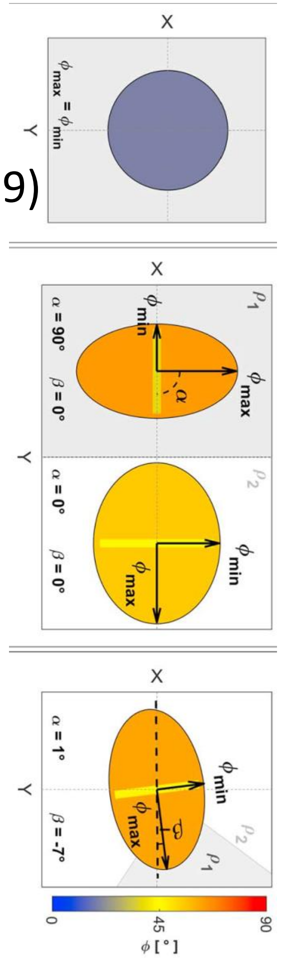
$\boldsymbol{\rho} = \boldsymbol{U}_a + \mathrm{i}\boldsymbol{V}_a$ $\boldsymbol{\phi}_a = (\boldsymbol{U}_a)^{-1}(\boldsymbol{V}_a)$

Some MT Definitions

1D anisotropic

(Hering et al., JGR 2019)





Phase Tensor $\boldsymbol{\Phi}$: $\boldsymbol{\phi} = (\Re \boldsymbol{Z})^{-1}(\Im \boldsymbol{Z})$(Caldwell et al., 2004)

Apparent Resistivity Tensor $\boldsymbol{\rho}$: $\boldsymbol{\rho} = \left({}^{i\mu}/_{\omega}\right) det(\boldsymbol{Z})\boldsymbol{Z}(\boldsymbol{Z}^{-1})^{T}$ (Brown, JGR 2017)

$\boldsymbol{\rho} = \boldsymbol{U}_a + i\boldsymbol{V}_a$ $\boldsymbol{\phi}_a = (\boldsymbol{U}_a)^{-1}(\boldsymbol{V}_a)$

1D isotropic - anisotropic: What happens inside the body?

In general for 1D subsurface:

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \underbrace{\begin{pmatrix} 0 & Z_{xy} \\ Z_{yx} & 0 \end{pmatrix}}\begin{pmatrix} B_x \\ B_y \end{pmatrix}$$

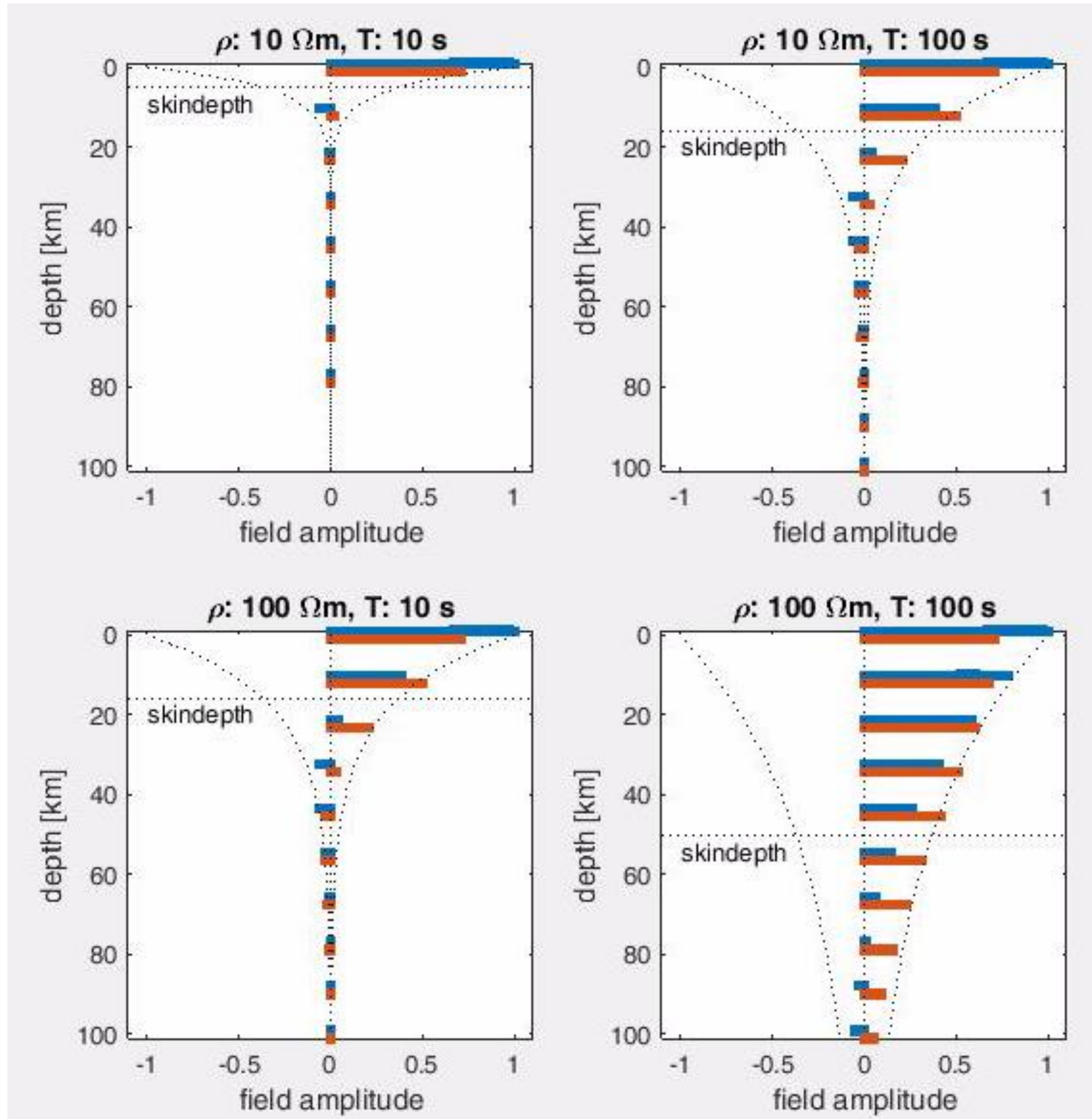
$$\rho_{axy} = \rho_{ayx}$$
$$\varphi_{xy} = \varphi_{yx} + \pi$$

$$B_y(z) = B_{y0} e^{-\sqrt{i\frac{\mu_0}{\rho}\omega}\, z}$$

$$Z_{xy} = \frac{E_x}{B_y}$$

$$E_x = (1+i)\sqrt{\frac{\rho\omega}{2\mu_0}}\, B_y$$

Behaviour of B and E with depth and period

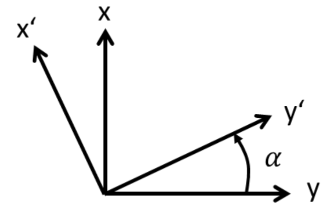


1D isotropic - anisotropic: What happens inside the body?

Azimuthal anisotropic Conductivity

For (x', y', z)

$$\boldsymbol{\sigma}' = \begin{pmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{pmatrix}$$



Generally

$$\boldsymbol{\sigma} = \begin{pmatrix} \sigma_{xx} & \sigma_{xy} & 0 \\ \sigma_{xy} & \sigma_{yy} & 0 \\ 0 & 0 & \sigma_3 \end{pmatrix} = \boldsymbol{R}_\alpha^T \boldsymbol{\sigma}' \boldsymbol{R}_{\boldsymbol{\alpha}}$$

Ohm‘s law

$$J_x = \sigma_{xx} E_x + \sigma_{xy} E_y$$

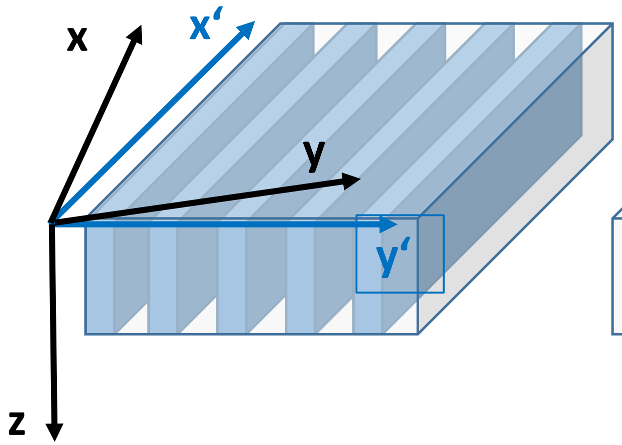
$$J_y = \sigma_{xy} E_x + \sigma_{yy} E_y$$

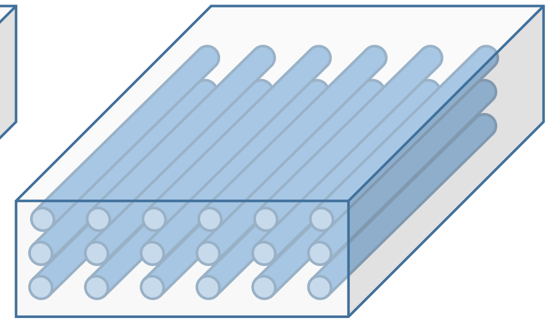
$$\rightarrow \quad \underline{J} \nparallel \underline{E}$$

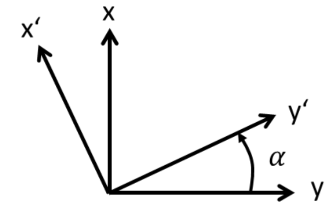
1D isotropic - anisotropic: What happens inside the body?

Azimuthal anisotropic Conductivity

„Dyke“ **„Pipe“**







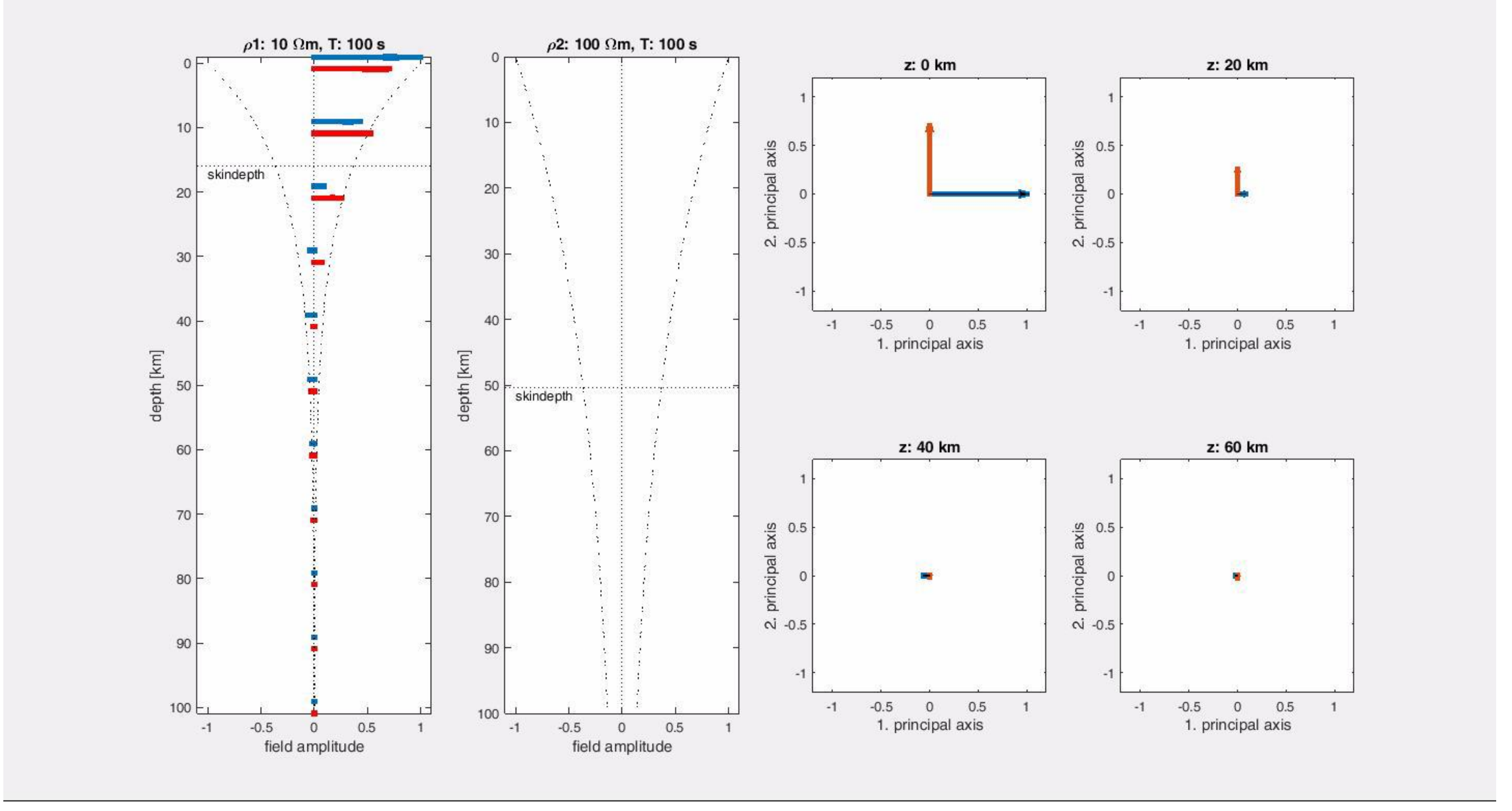
$$\begin{pmatrix} \sigma_{x'x'} & 0 & 0 \\ 0 & \sigma_{y'y'} & 0 \\ 0 & 0 & \sigma_{x'x'} \end{pmatrix} \quad \begin{pmatrix} \sigma_{x'x'} & 0 & 0 \\ 0 & \sigma_{y'y'} & 0 \\ 0 & 0 & \sigma_{y'y'} \end{pmatrix}$$

$\sigma_{x'x'} = \sigma_{zz}$ $$\begin{pmatrix} \sigma_{xx} & \sigma_{xy} & 0 \\ \sigma_{xy} & \sigma_{yy} & 0 \\ 0 & 0 & \sigma_{zz} \end{pmatrix}$$ $\sigma_{y'y'} = \sigma_{zz}$

1D isotropic - anisotropic: What happens inside the body?

Behaviour of B and E with depth and period

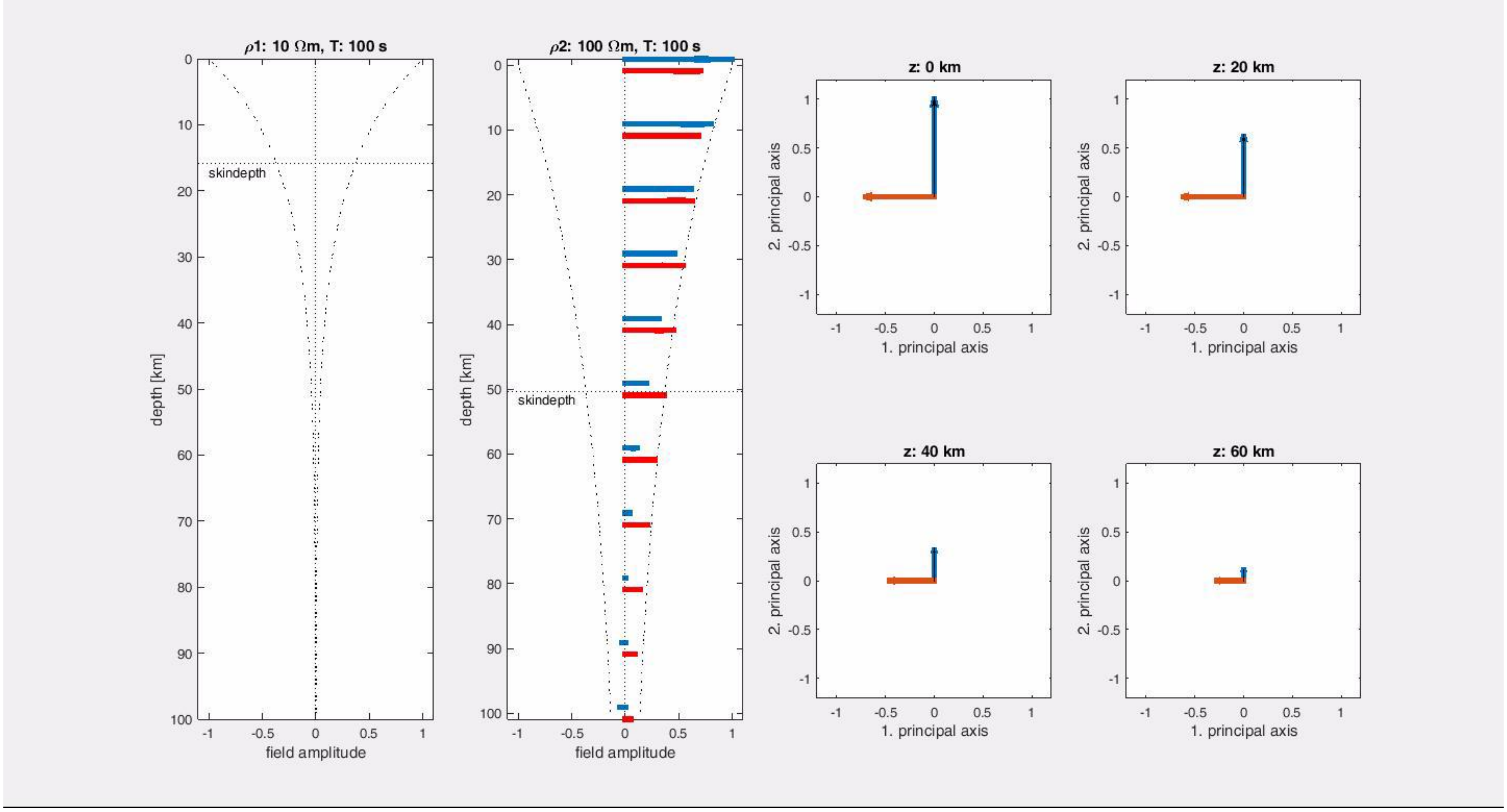
Anisotropic homogeneous halfspace, $\alpha = 0°$



1D isotropic - anisotropic: What happens inside the body?

<u>Behaviour of B and E with depth and period</u>

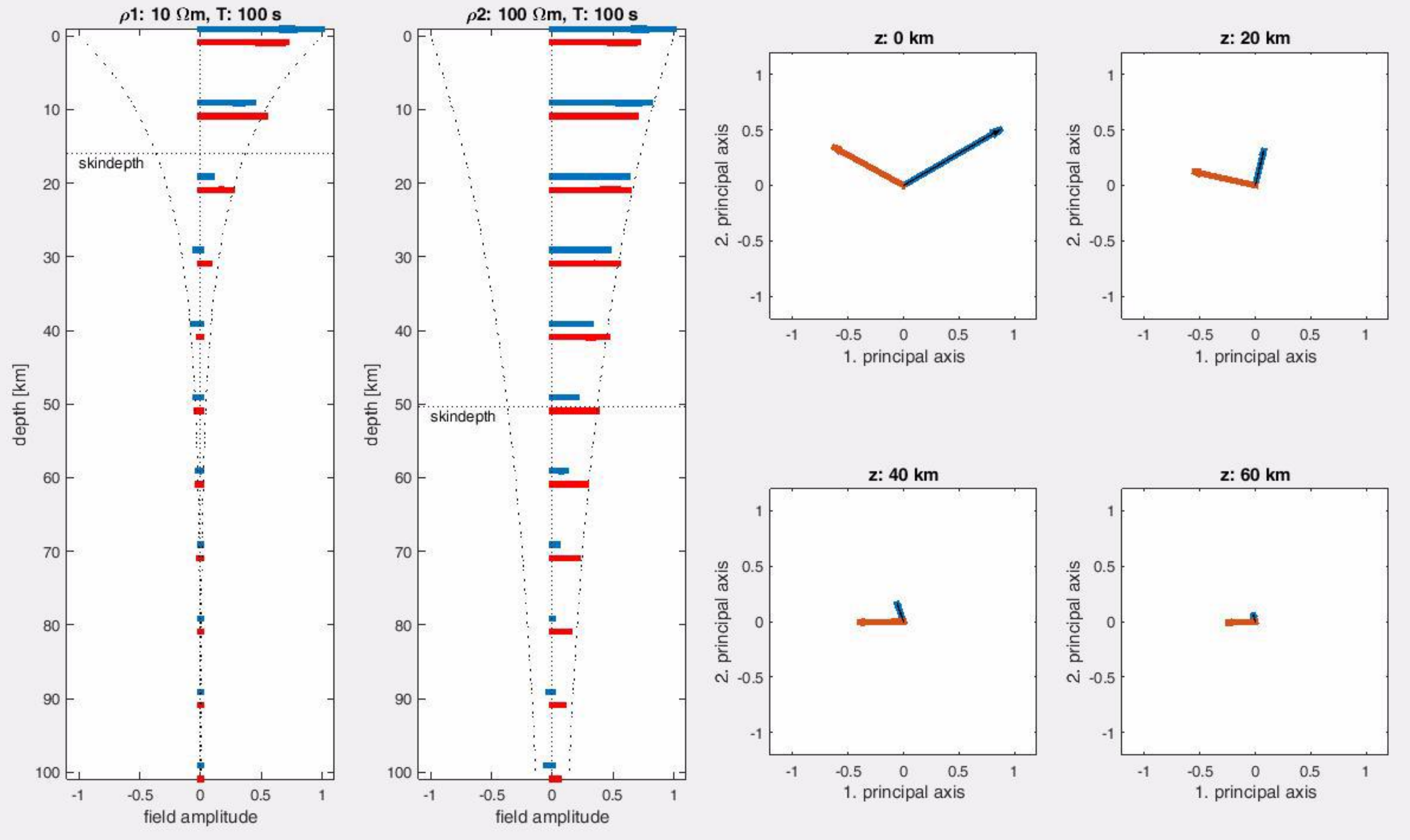
Anisotropic homogeneous halfspace, $\alpha = 90°$



1D isotropic - anisotropic: What happens inside the body?

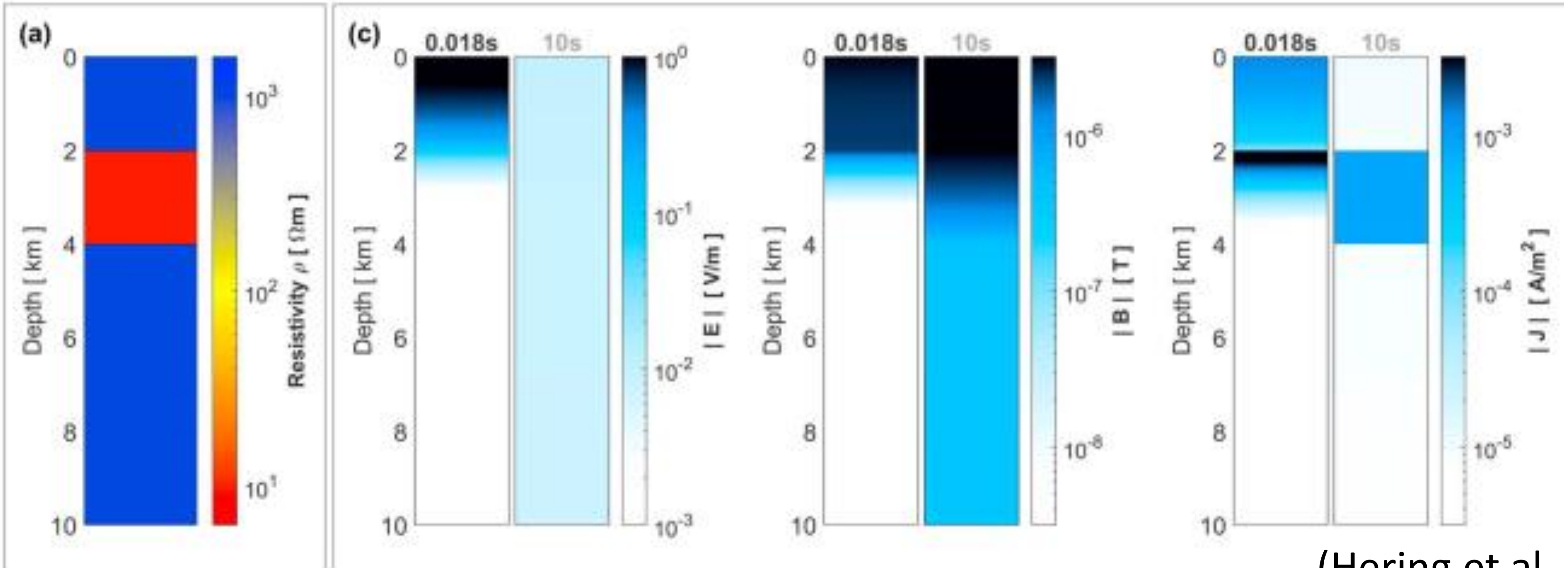
Behaviour of B and E with depth and period

Anisotropic homogeneous halfspace, $\alpha = 30°$



1D isotropic - anisotropic: What happens inside the body?

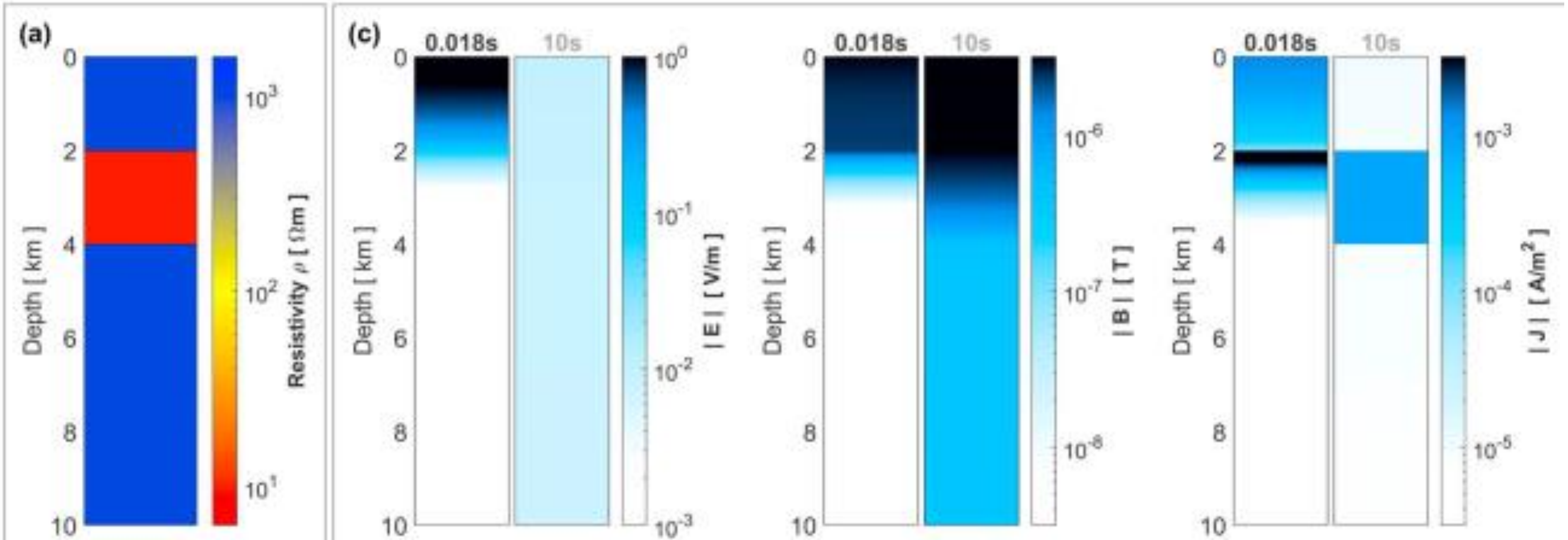
Behaviour of B, E and J with depth and period   Isotropic



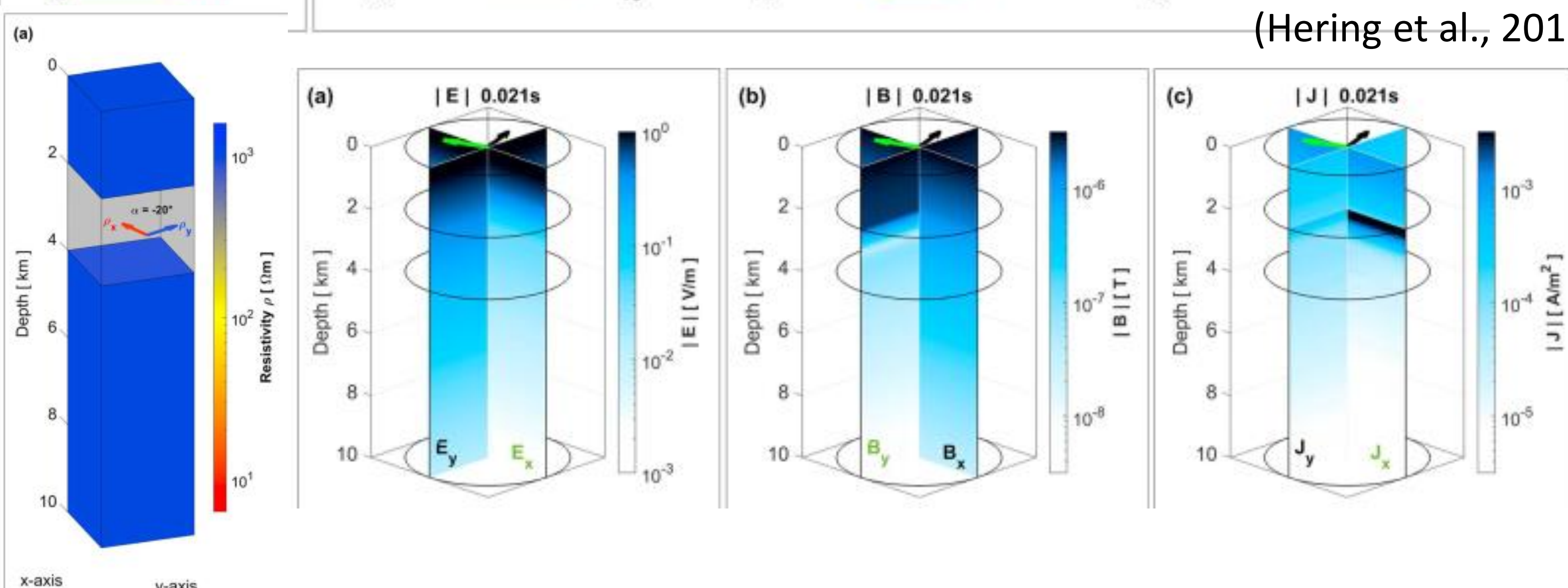
(Hering et al., 2018)

1D isotropic - anisotropic: What happens inside the body?

Behaviour of B, E and J with depth and period   Isotropic, Anisotropic Layer, α = -20°

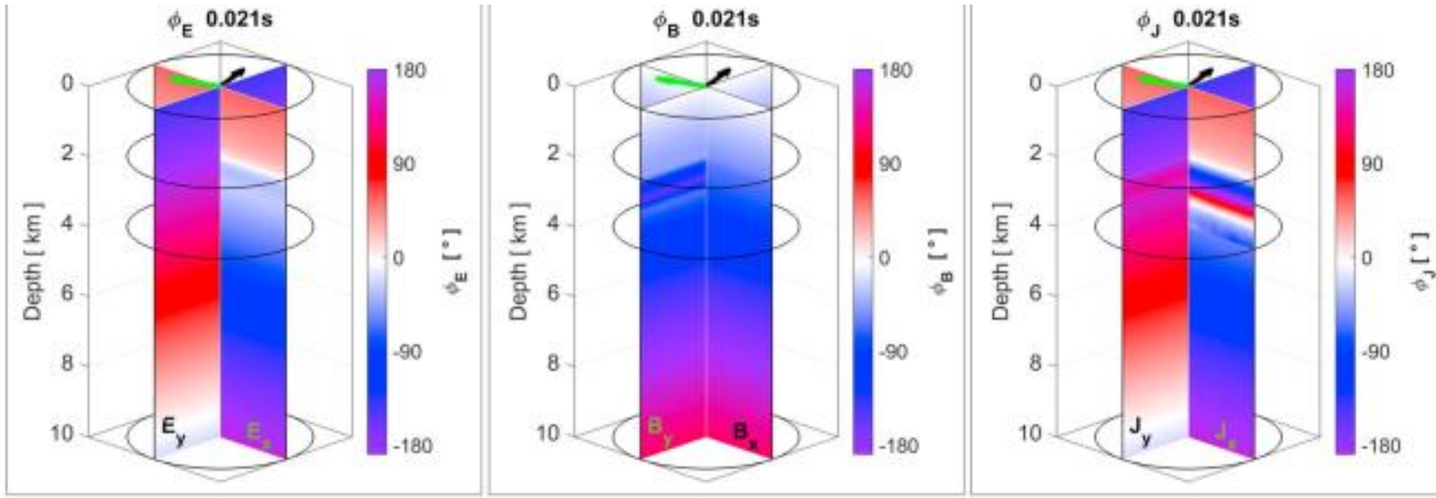


(Hering et al., 2018)

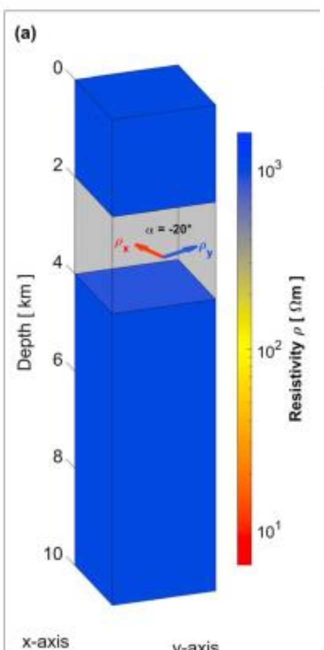


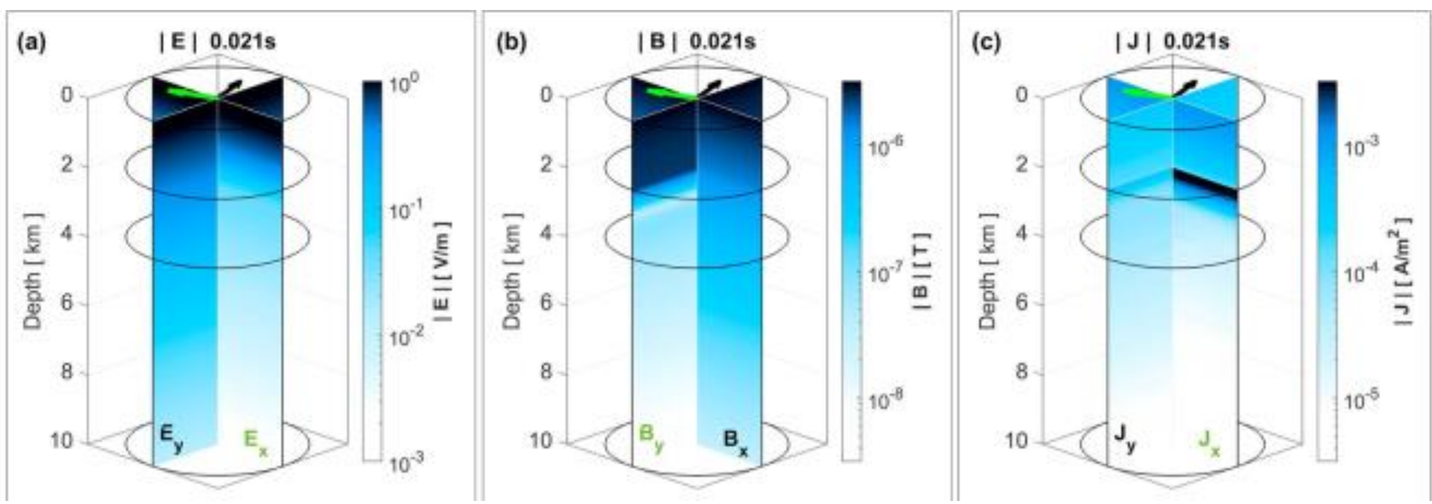
1D isotropic - anisotropic: What happens inside the body?

Behaviour of B, E and J with depth and period   Isotropic, Anisotropic Layer, α = -20°



(Hering et al., 2018)



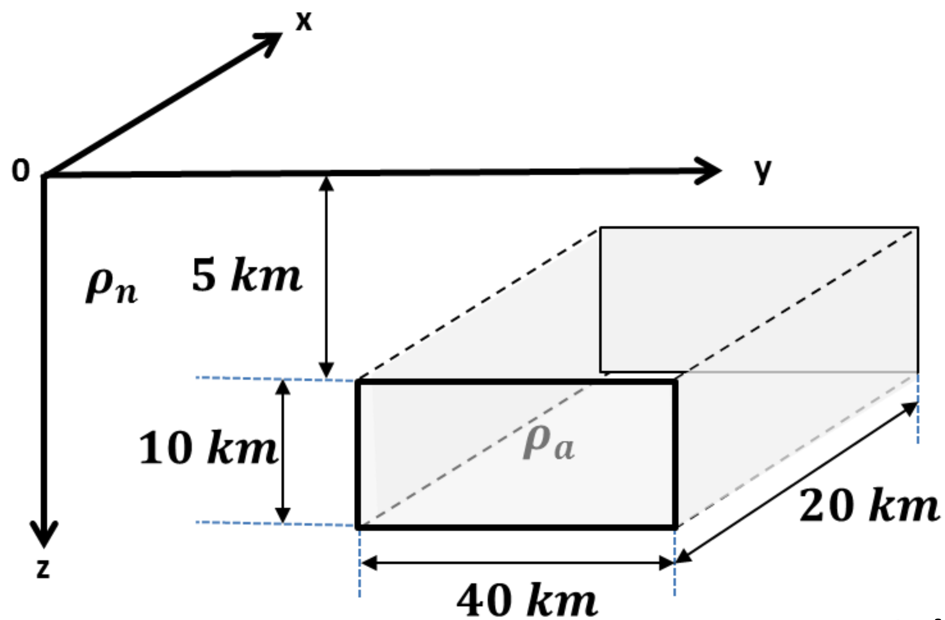


3D isotropic - anisotropic: What happens inside the body?

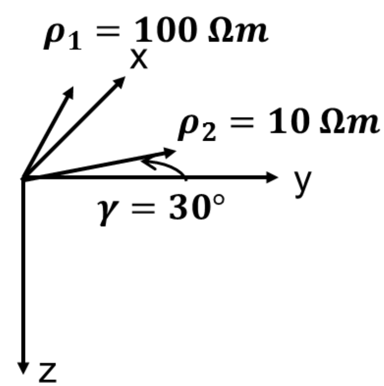
3 Studies:

- Anisotropic Cube within isotropic half space
- Isotropic Cube above anisotropic half space
- Dipping Anisotropy

Anisotropic Cube within isotropic half space



Azimuthal anisotropy!



ρ_a anisotropic: $\rho_1 = 100\ \Omega m$

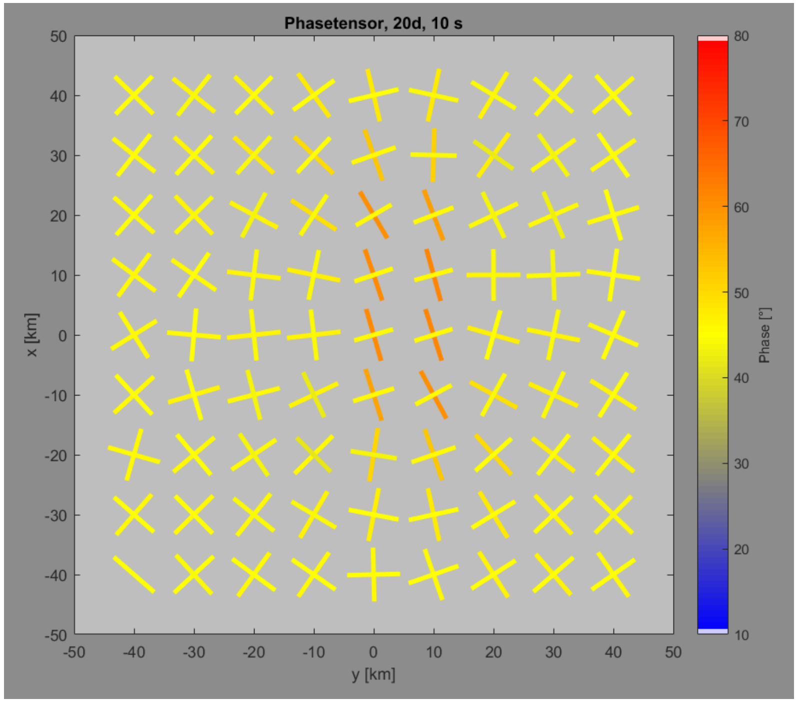
$\rho_2 = 10\ \Omega m$

background: $\rho_n = 100\ \Omega m$

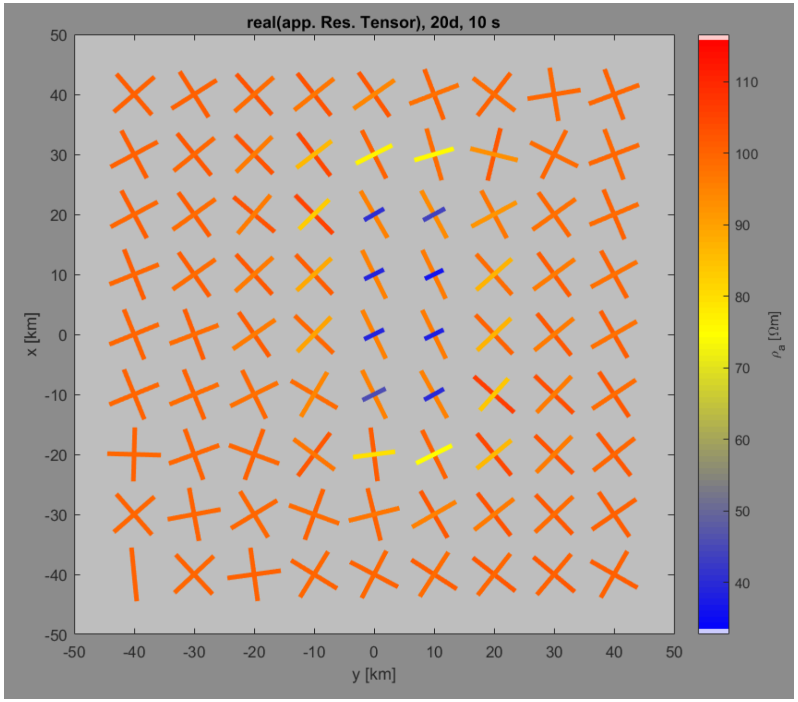
Transfer functions: phase tensor, app.res. tensor

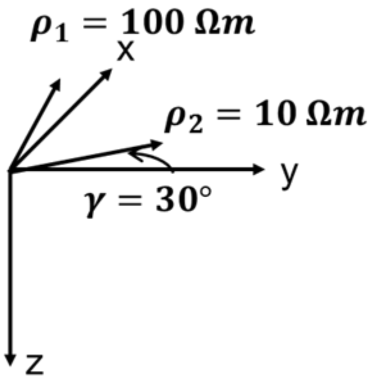
plane view, period 10 sec

$\boldsymbol{\phi}$



$\Re\boldsymbol{\rho}$

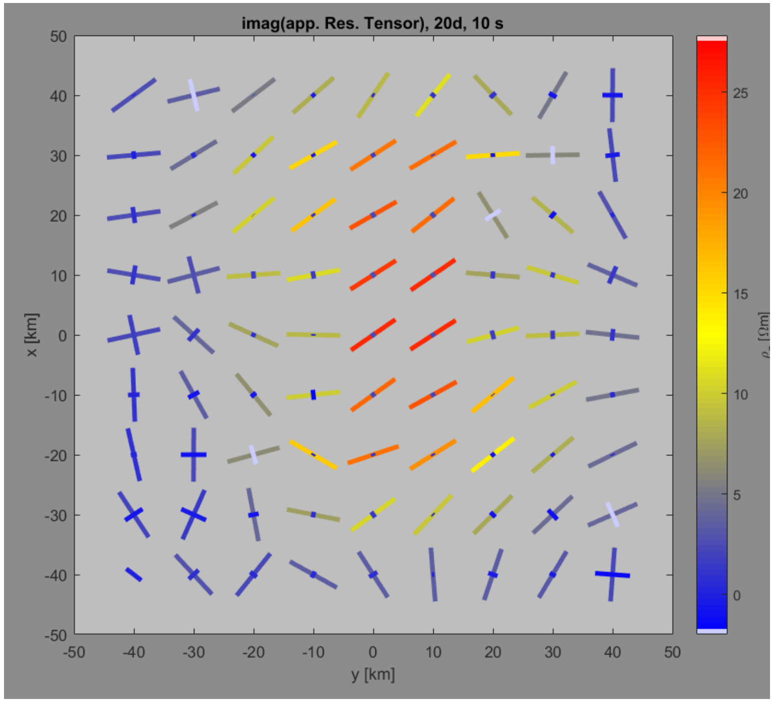




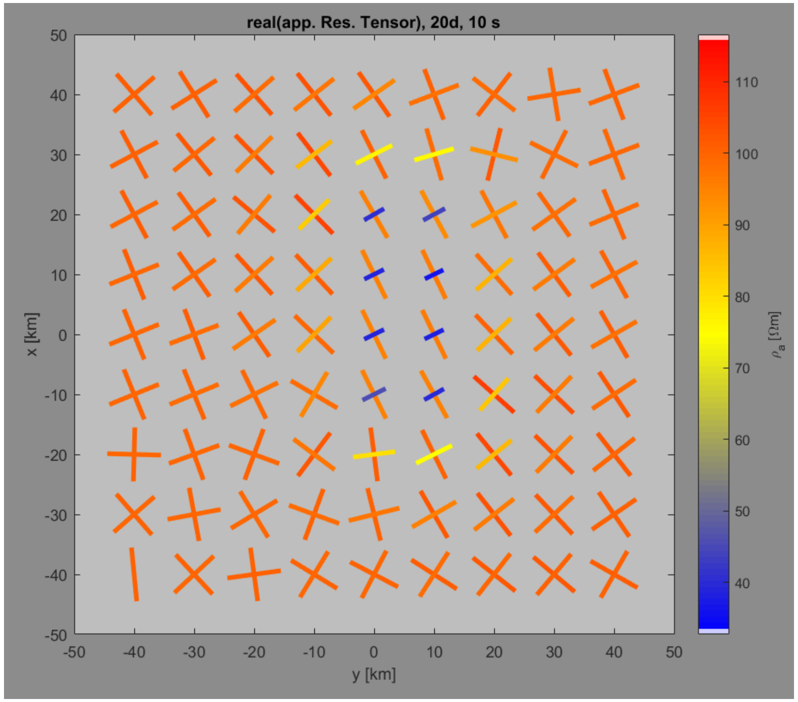
Transfer functions: phase tensor, app.res. tensor

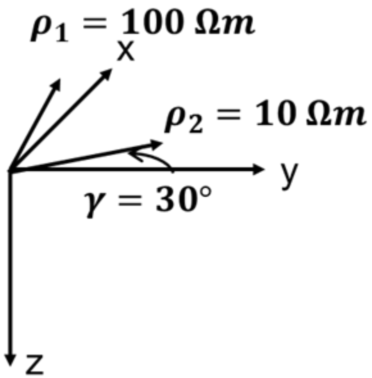
plane view, period 10 sec

$\Im\boldsymbol{\rho}$



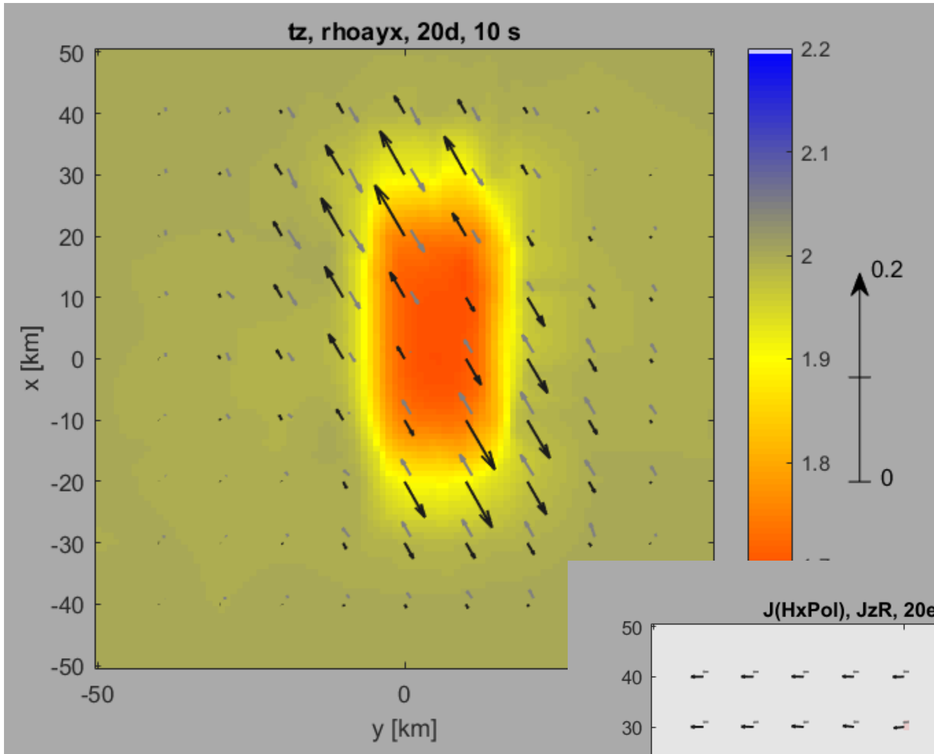
$\Re\boldsymbol{\rho}$

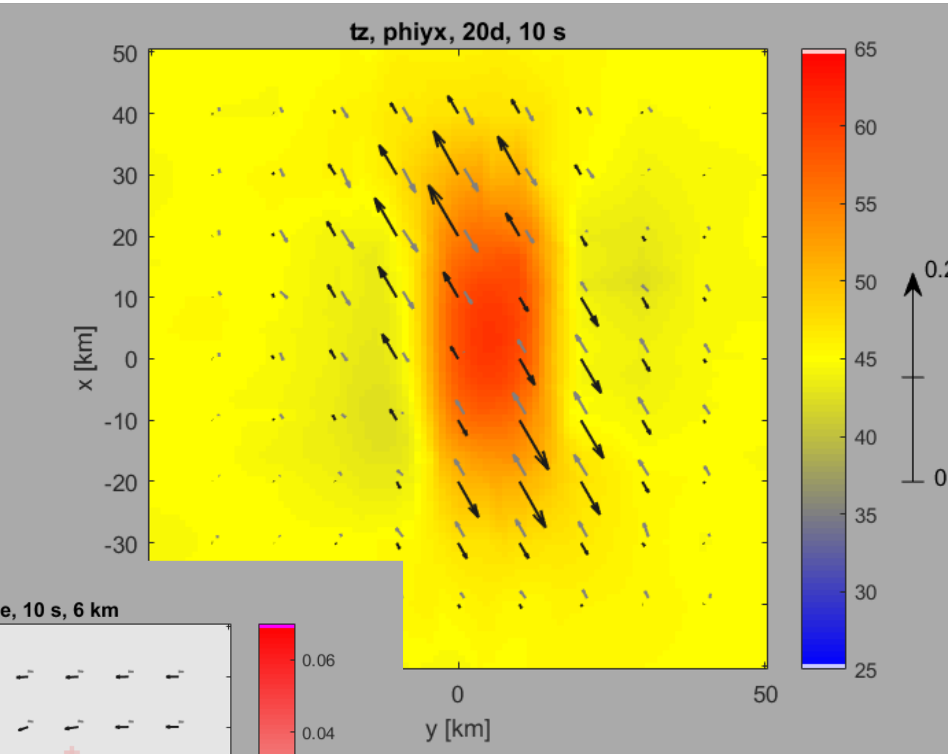


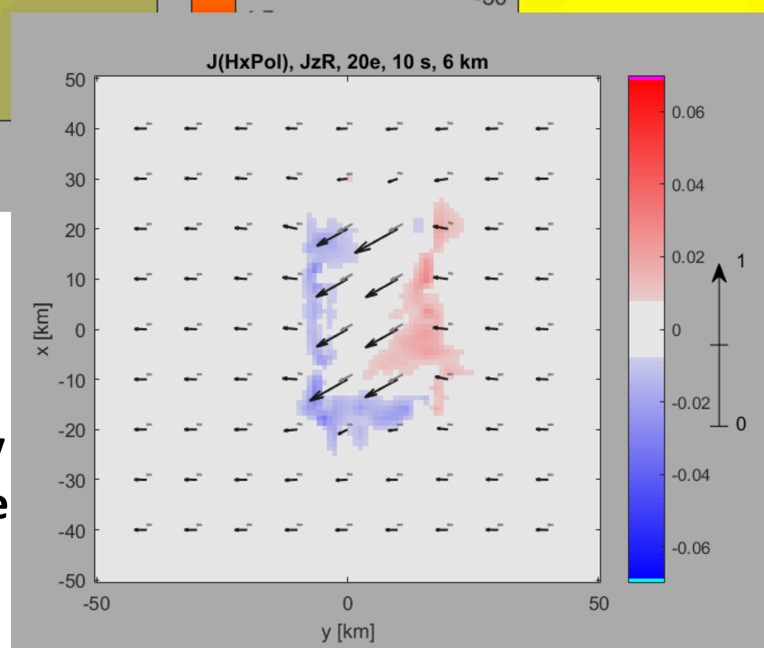


Transfer functions: apparent resistivity, phase and tipper

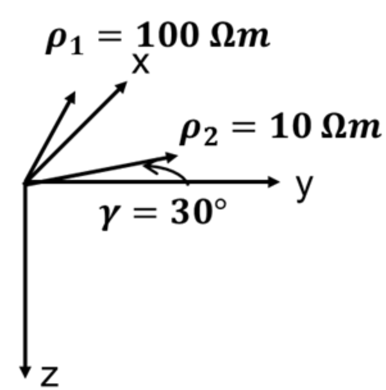
plane view, period 10 sec





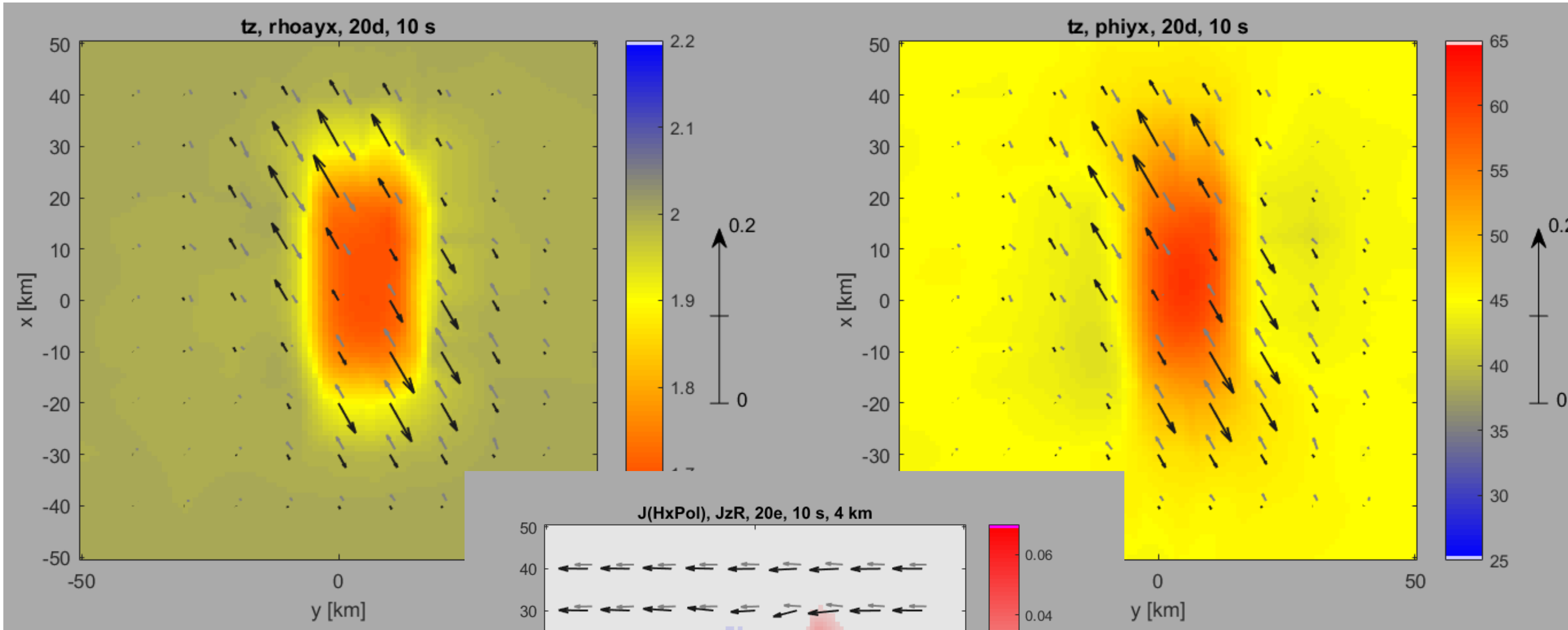


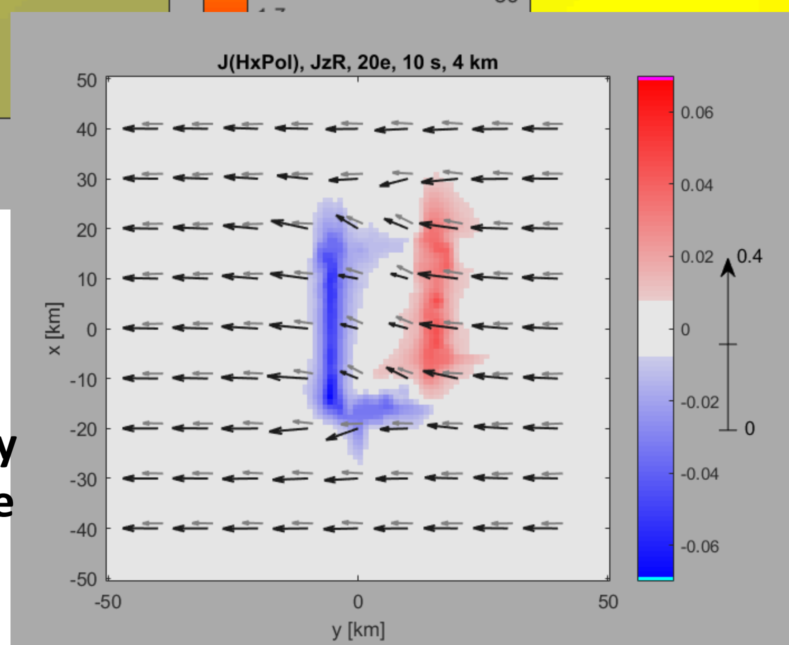
Current density **within** **the cube**



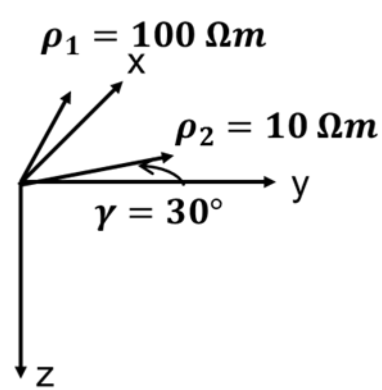
Transfer functions: apparent resistivity, phase and tipper

plane view, period 10 sec

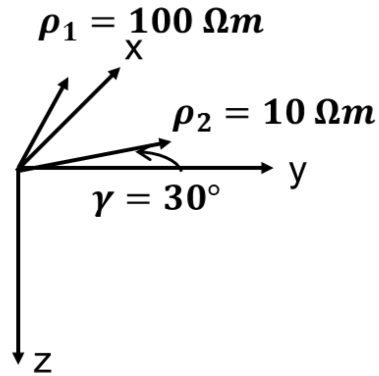




Current density
above the cube



current density Hx polarization
plane view
z = 6 km (inside cube)
arrows: (J_x, J_y)
colors: J_z (red: downward)
period: 10 s



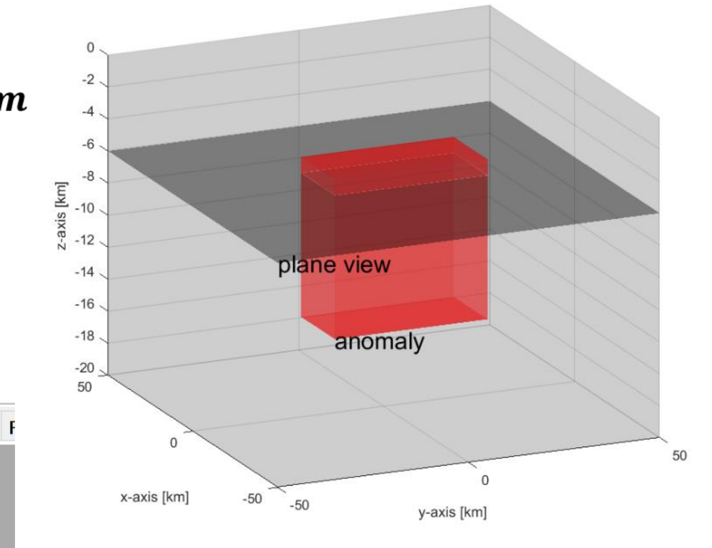
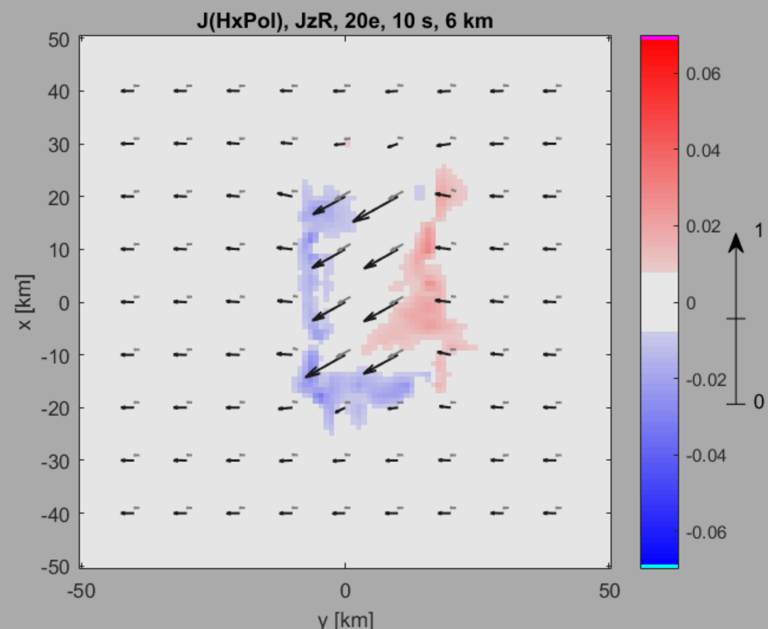
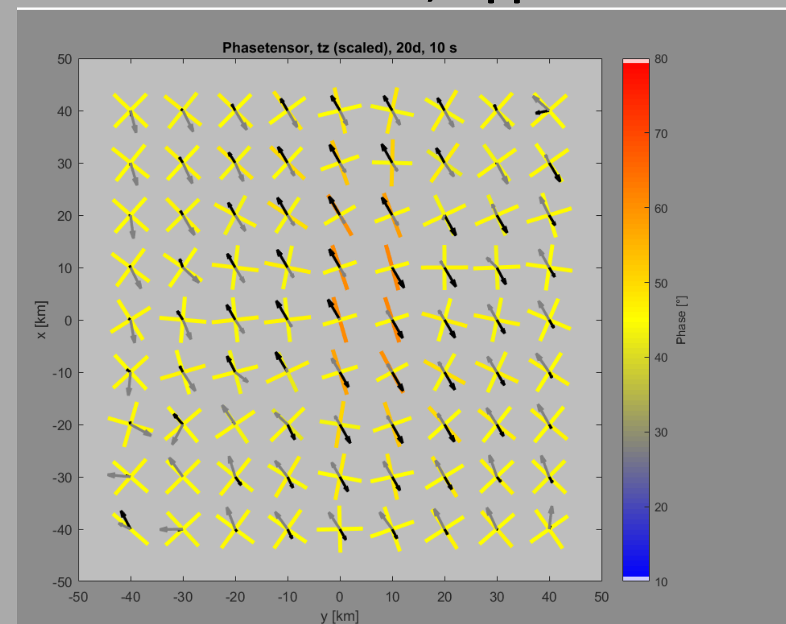


Figure1-20e Figure2-20e Figure3-20e Figure4-20e Figure5-20e Figure6-20e Figure7-20e Figure8-20e Figure9-20e Figure10-20e Figure11-20e F

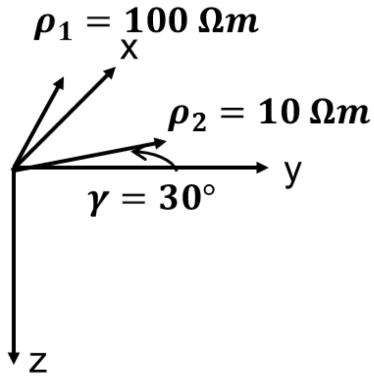
Current Density



Phase Tensor, Tipper



current density Hx polarization
plane view
z = 4 km (above cube)
arrows: (J_x, J_y)
colors: J_z (red: downward)
period: 10 s



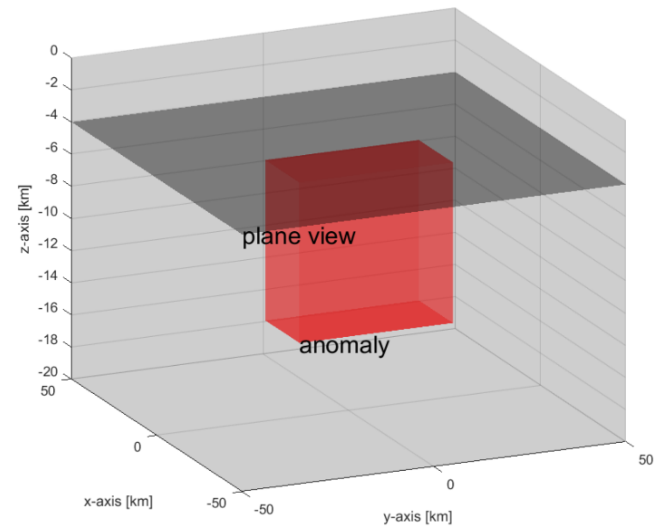
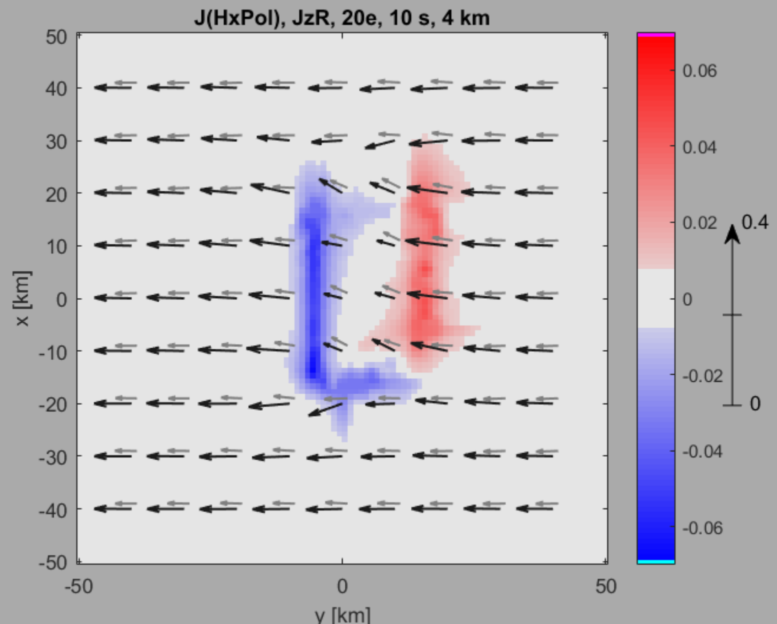
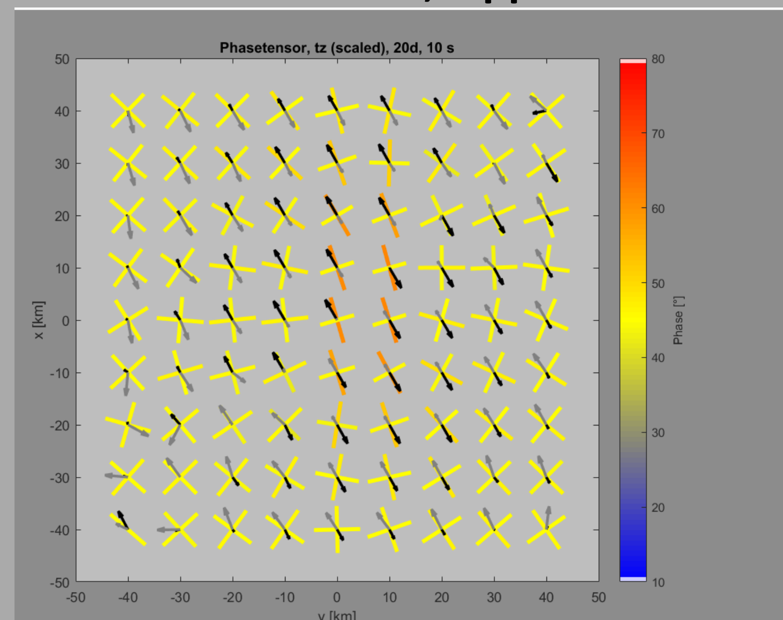


Figure1-20e Figure2-20e Figure3-20e Figure4-20e Figure5-20e Figure6-20e Figure7-20e Figure8-20e Figure9-20e Figure10-20e Figure11-20e Fi

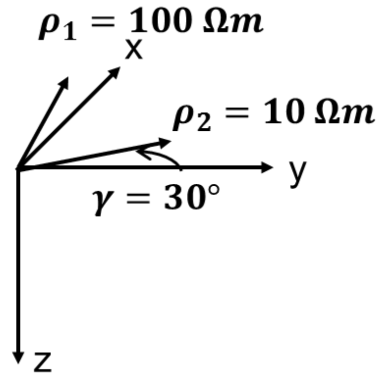
Current Density



Phase Tensor, Tipper



current density Hy polarization
plane view
z = 6 km (inside cube)
arrows: (J_x, J_y)
colors: J_z (red: downward)
period: 10 s



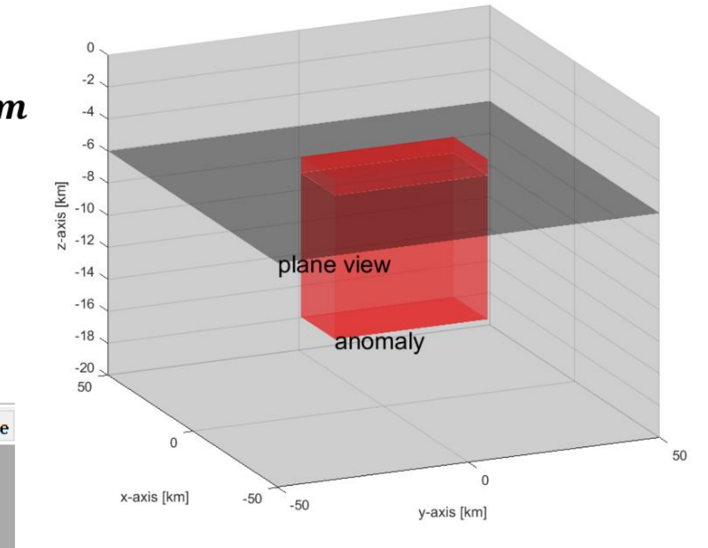
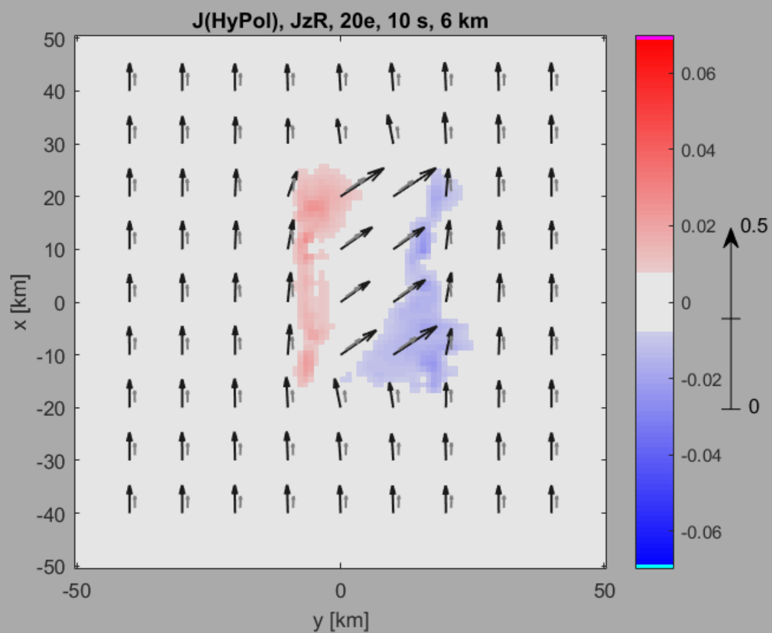
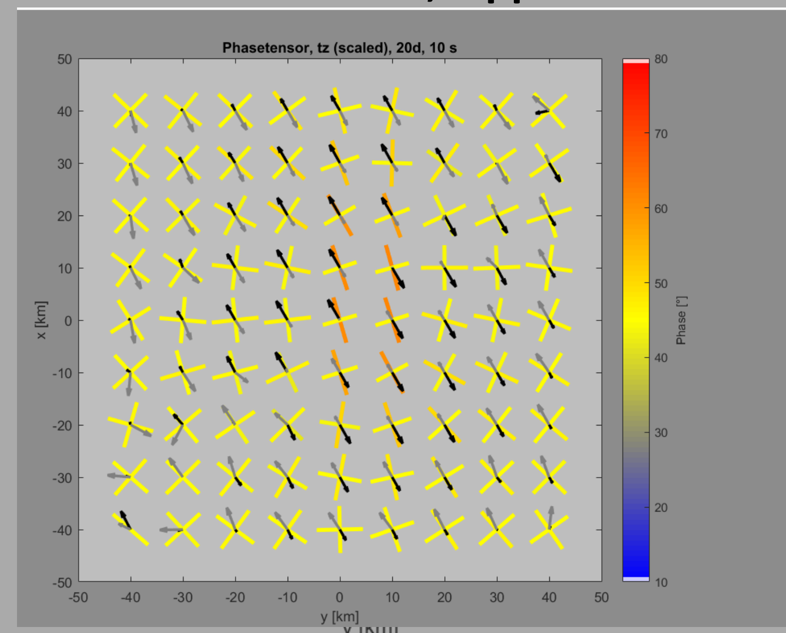


Figure1-20e Figure2-20e Figure3-20e Figure4-20e Figure5-20e Figure6-20e Figure7-20e Figure8-20e Figure9-20e Figure10-20e Figure11-20e

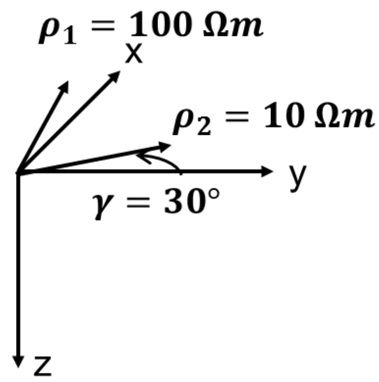
Current Density



Phase Tensor, Tipper



current density Hy polarization
plane view
z = 4 km (above cube)
arrows: (J_x, J_y)
colors: J_z (red: downward)
period: 10 s



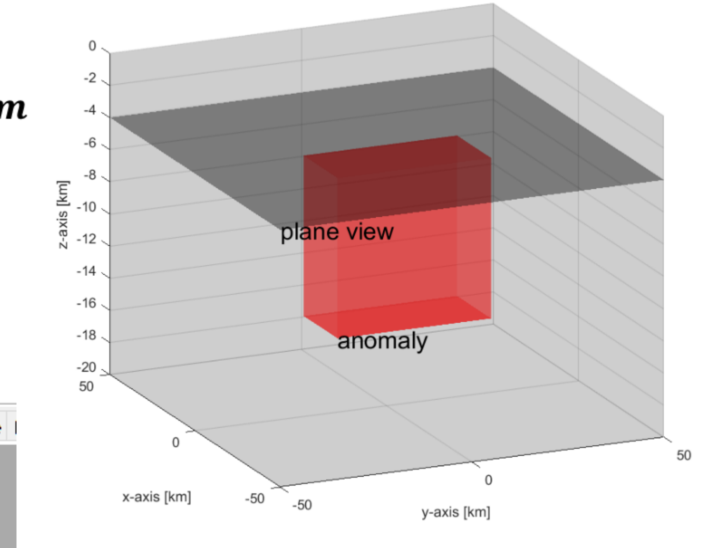
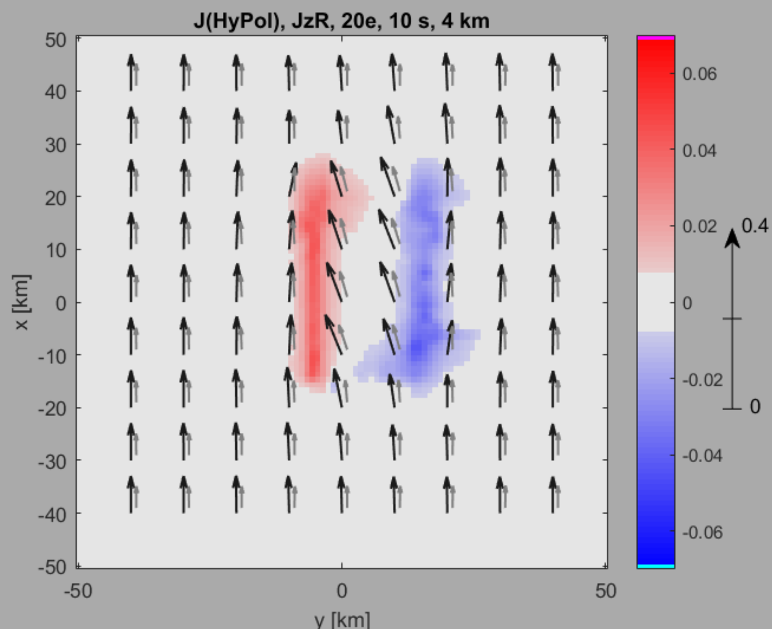
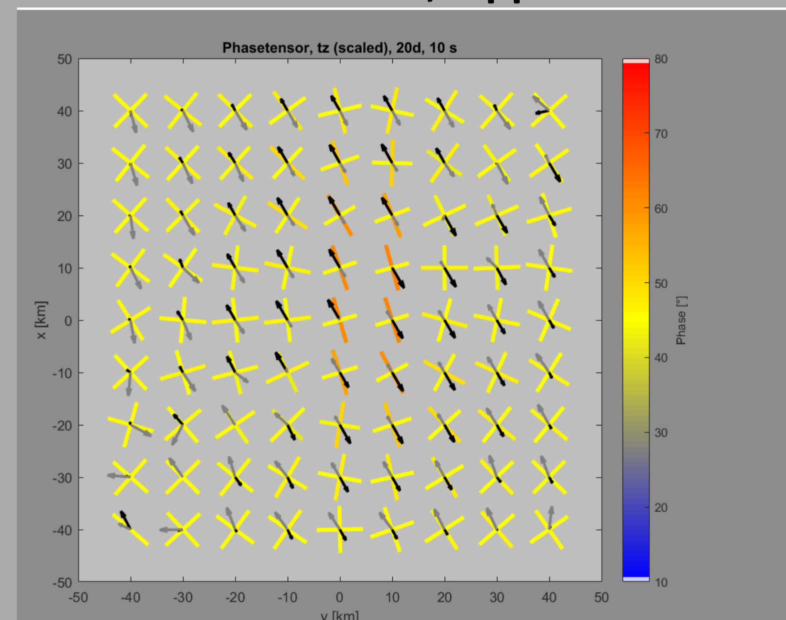


Figure1-20e Figure2-20e Figure3-20e Figure4-20e Figure5-20e Figure6-20e Figure7-20e Figure8-20e Figure9-20e Figure10-20e Figure11-20e

Current Density

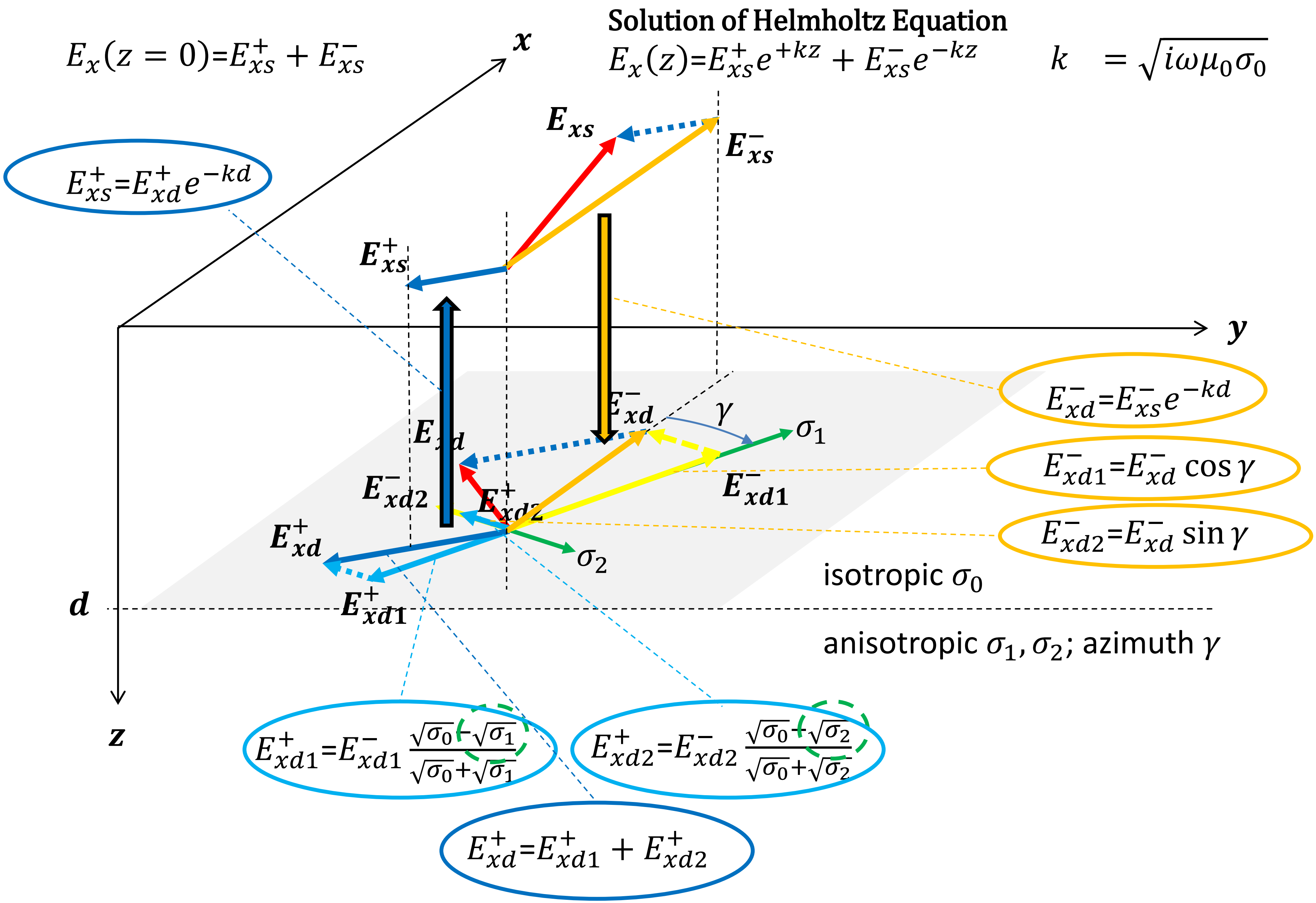


Phase Tensor, Tipper

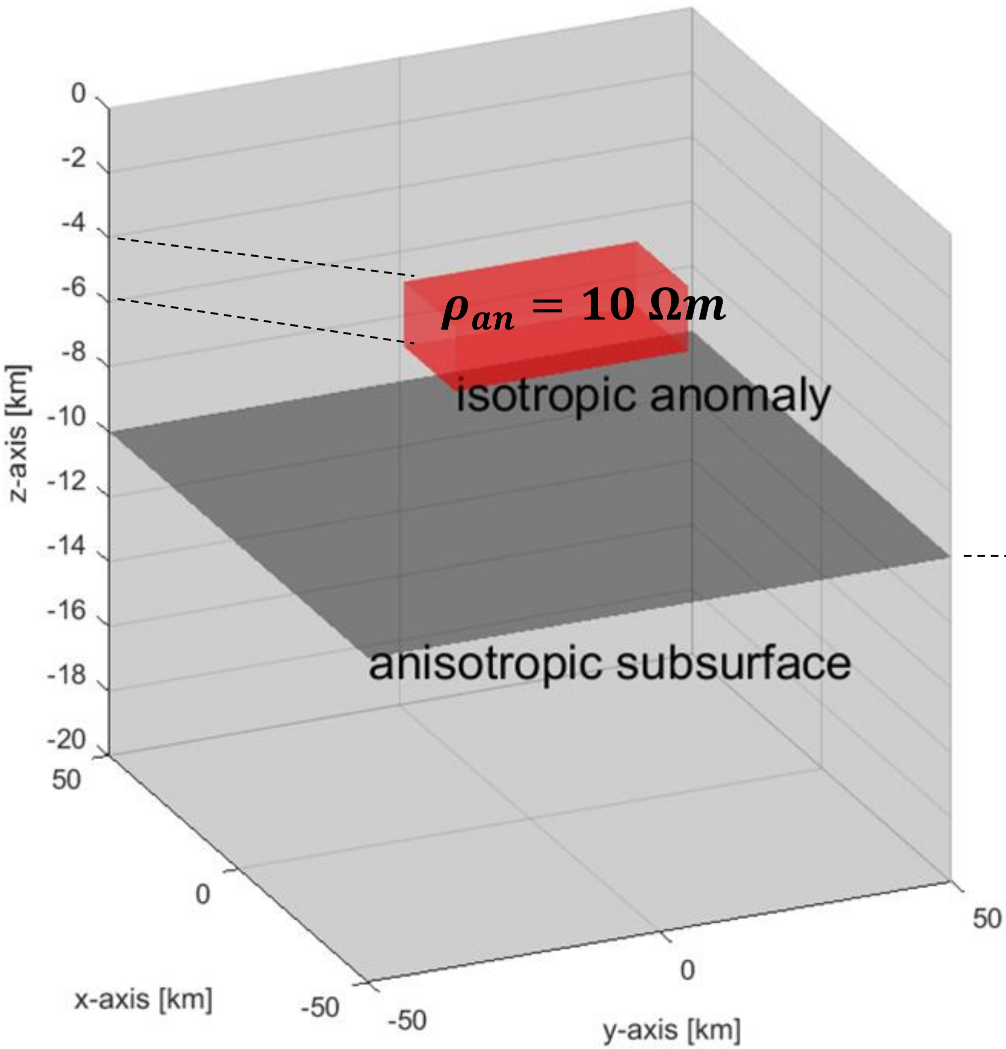


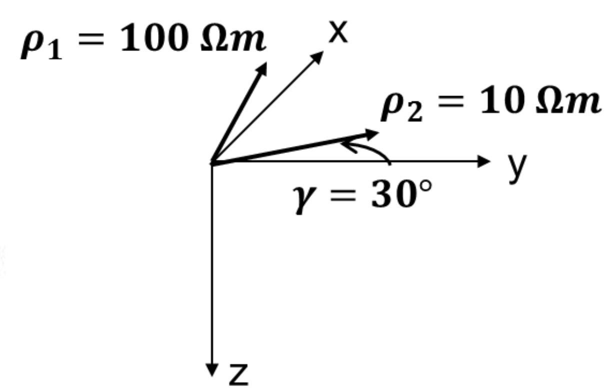
How can we explain the rotation of the field vectors?

Downward – Upward Propagating Wave



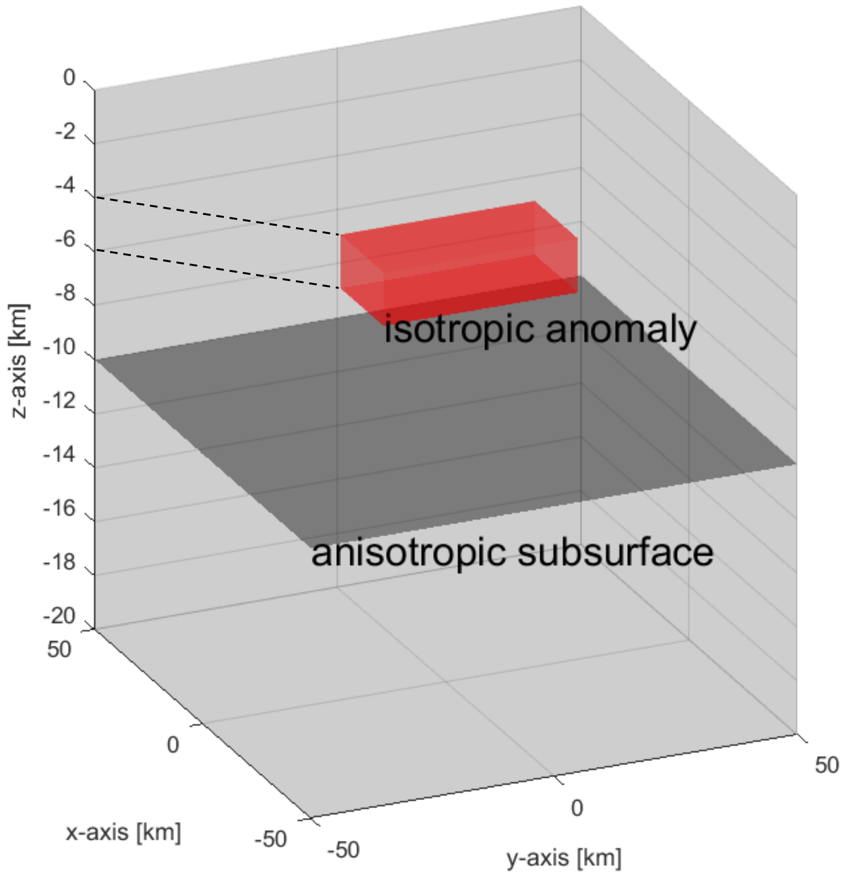
Isotropic Cube above anisotropic half space

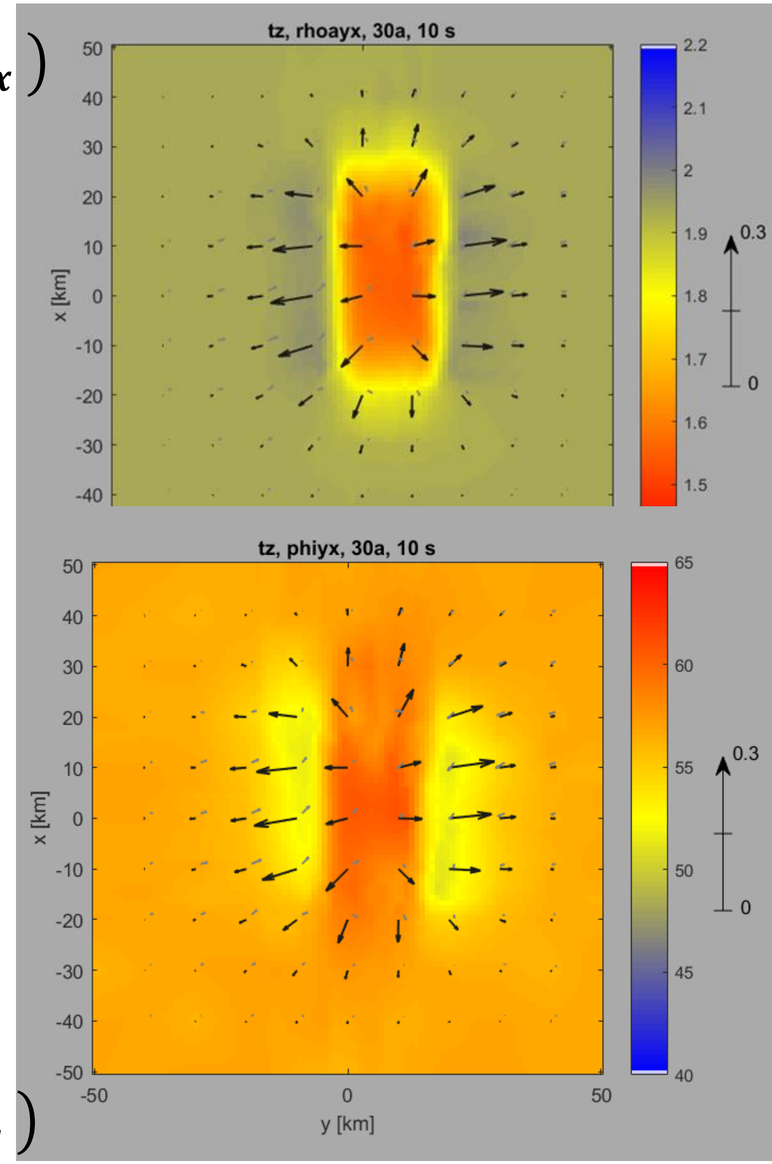




Isotropic Cube above anisotropic half space

Apparent resistivity ($\rho_{a,yx}$)

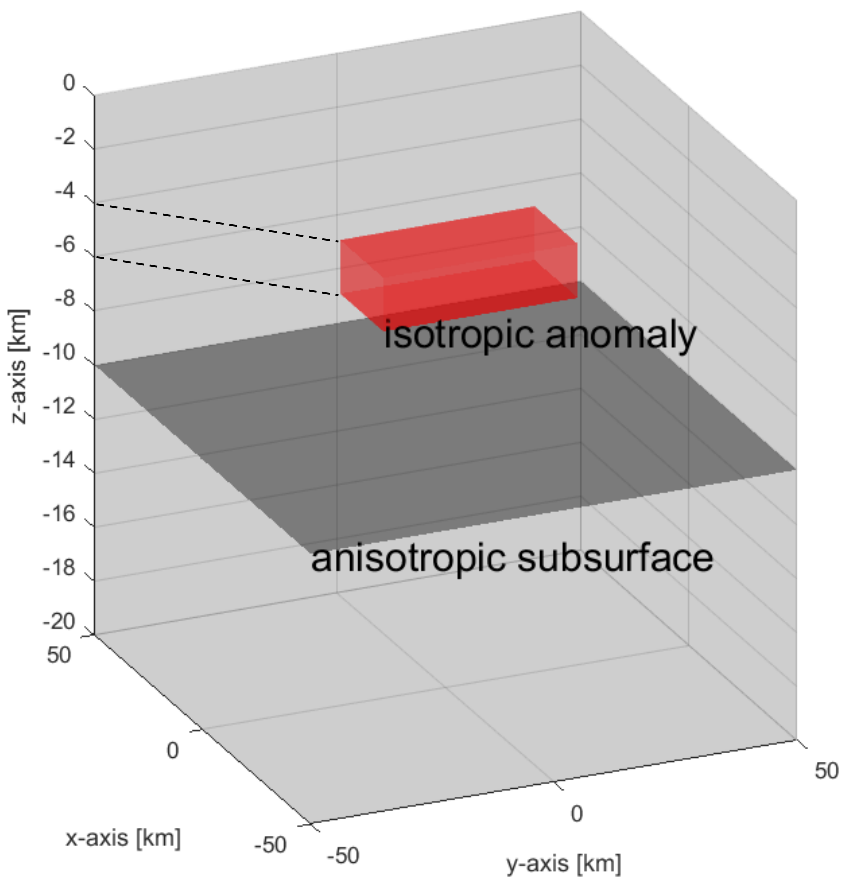


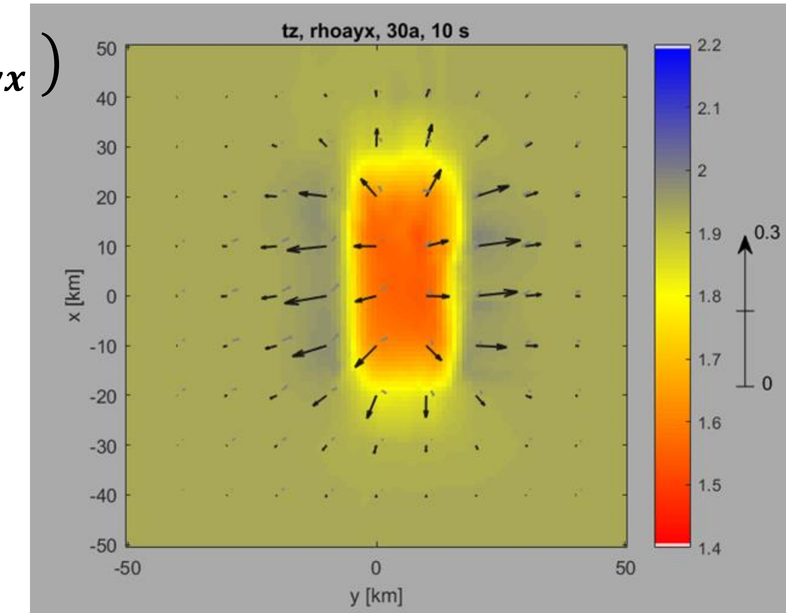


Phase (φ_{yx})

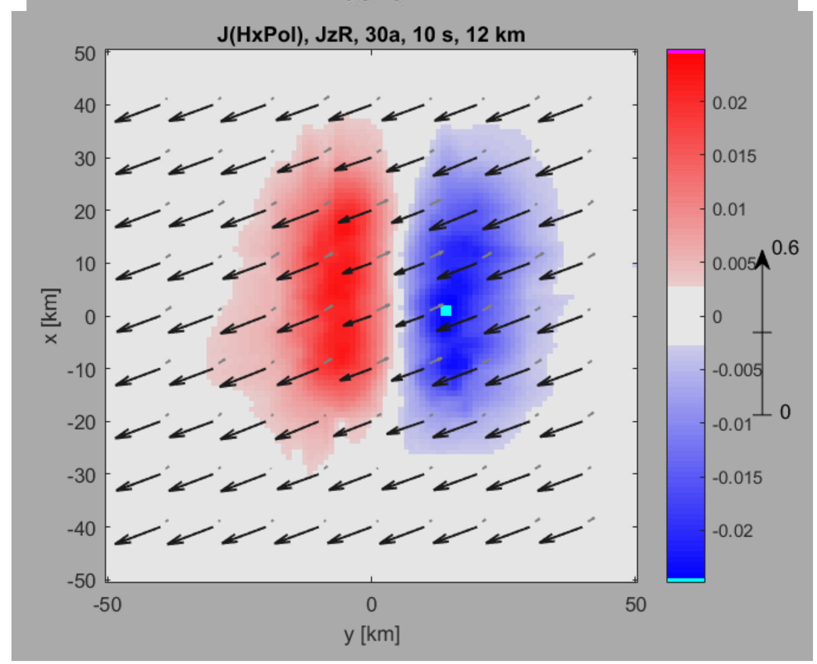
Isotropic cube above anisotropic half space

Apparent resistivity $(\rho_{a,yx})$



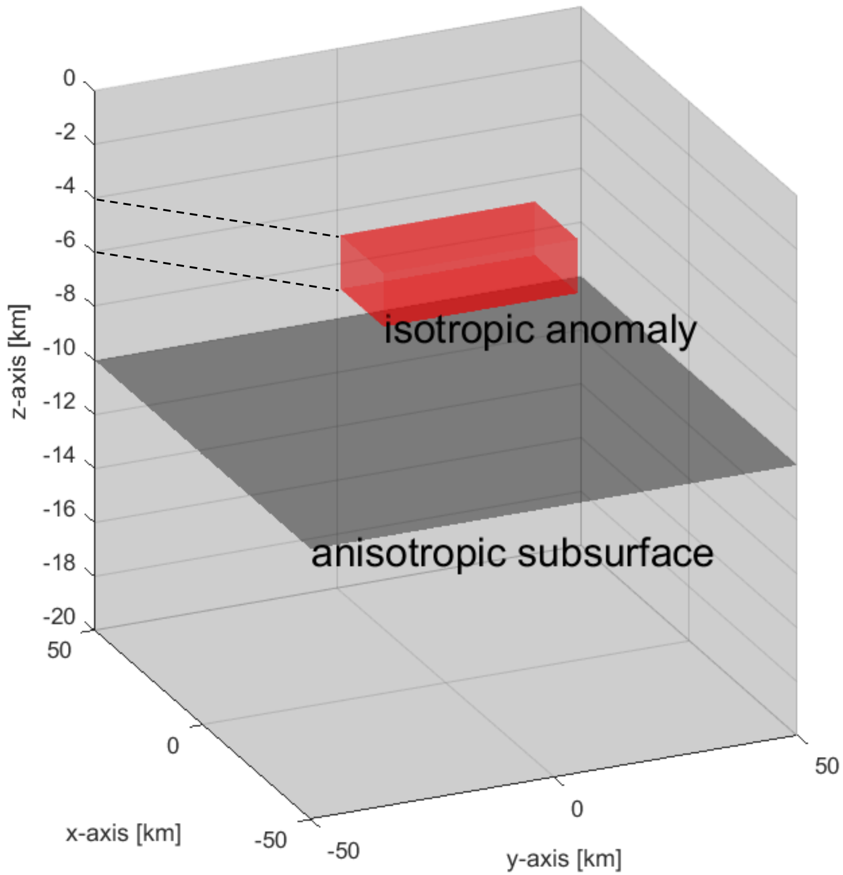


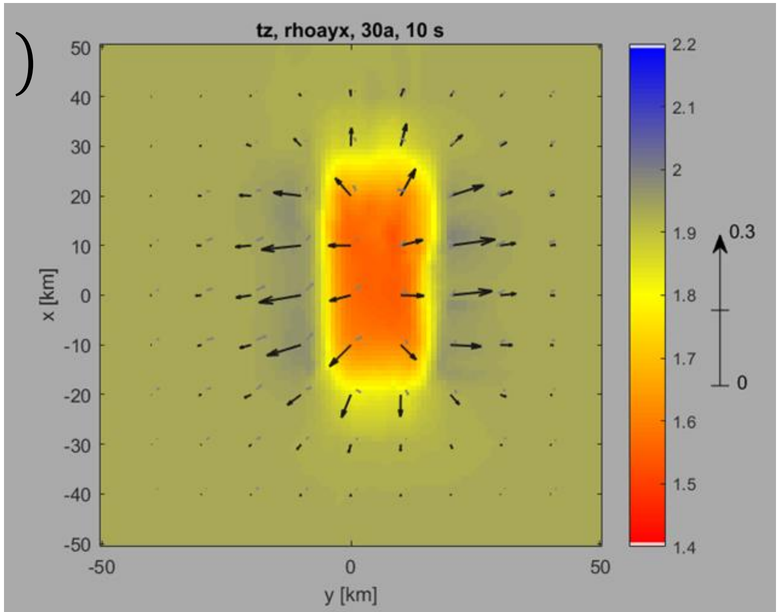
Current density in 12 km depth

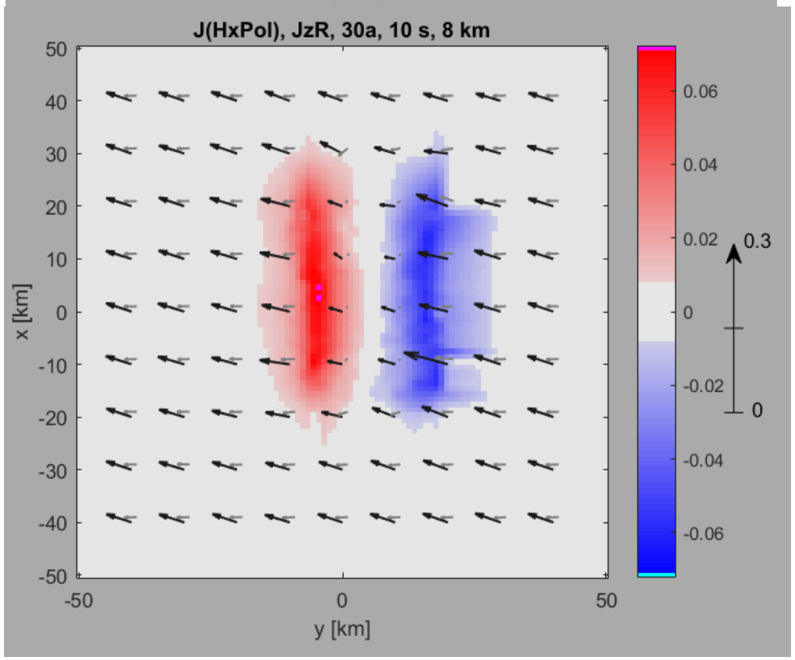


Isotropic cube above anisotropic half space

Apparent resistivity $(\rho_{a,yx})$



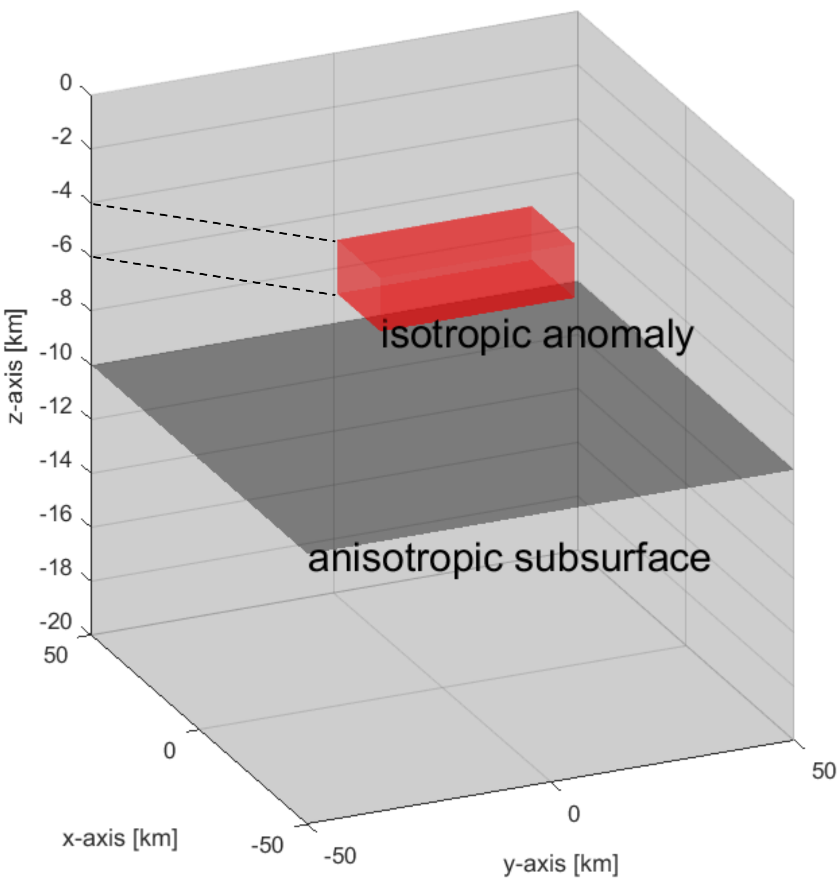


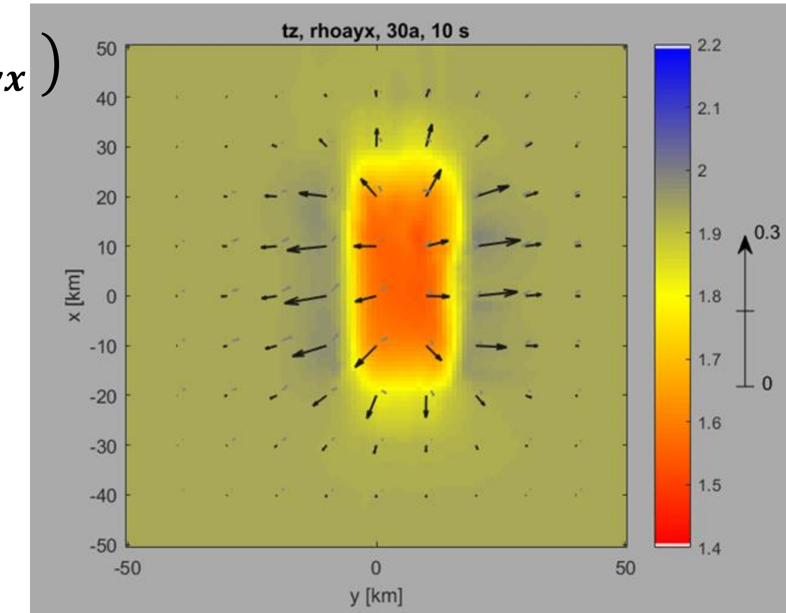


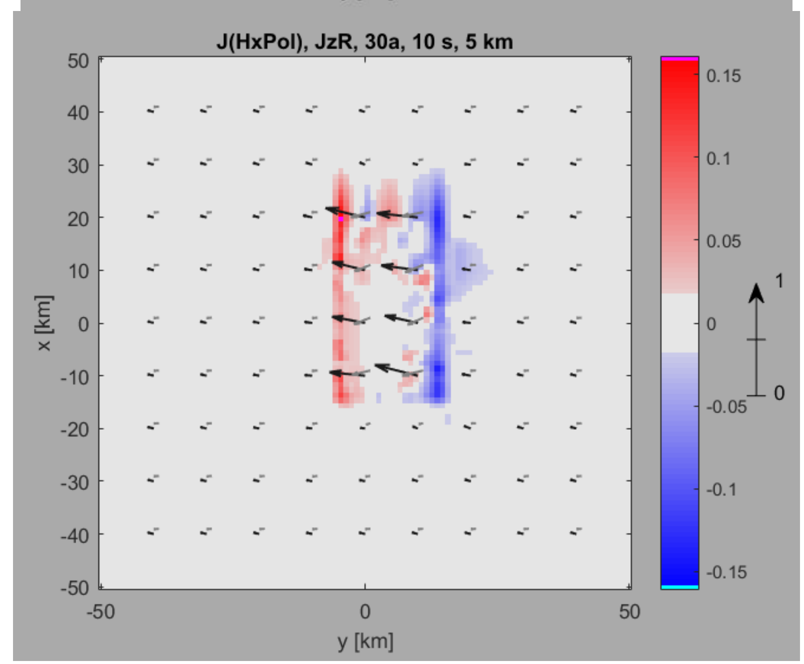
Current density in 8 km depth

Isotropic cube above anisotropic half space

Apparent resistivity $(\rho_{a,yx})$





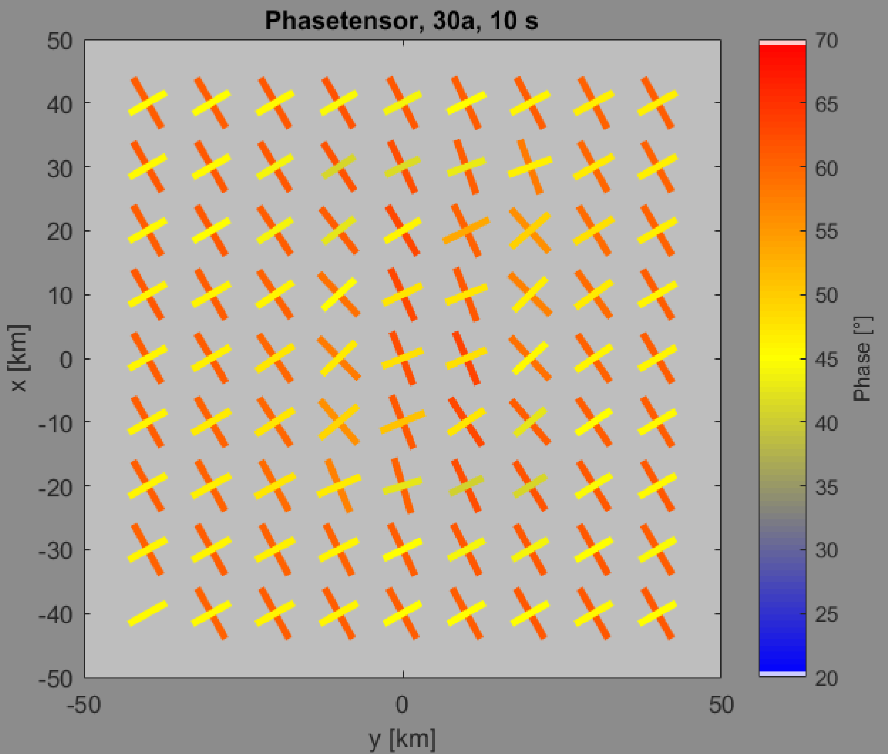


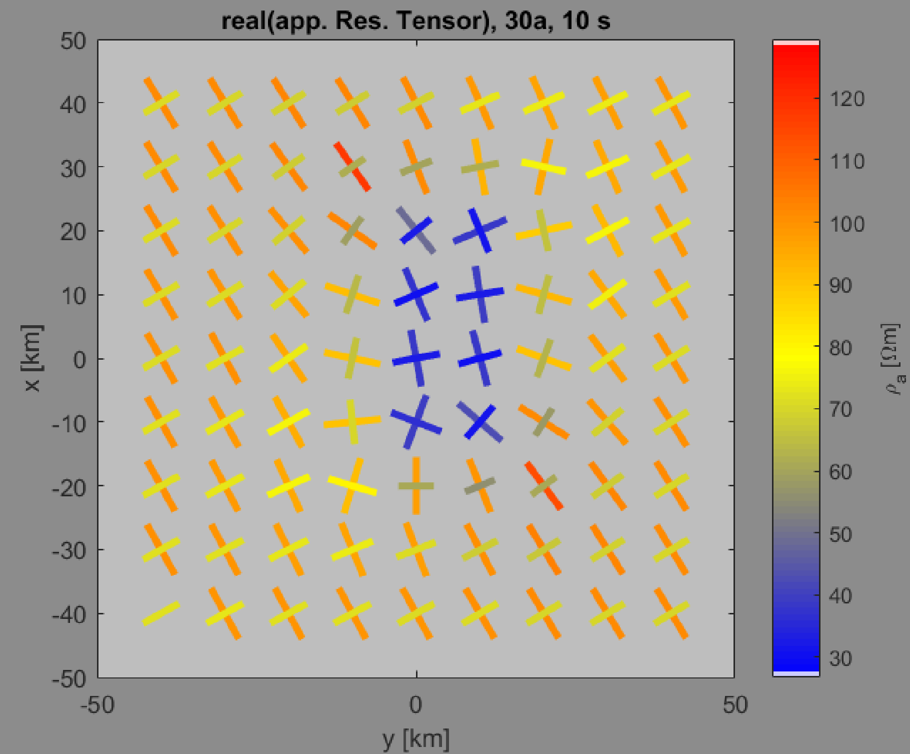
Current density within anomaly

Transfer functions: phase tensor, app.res. tensor

plane view, period 10 sec

$\boldsymbol{\phi}$ $\Re\boldsymbol{\rho}$

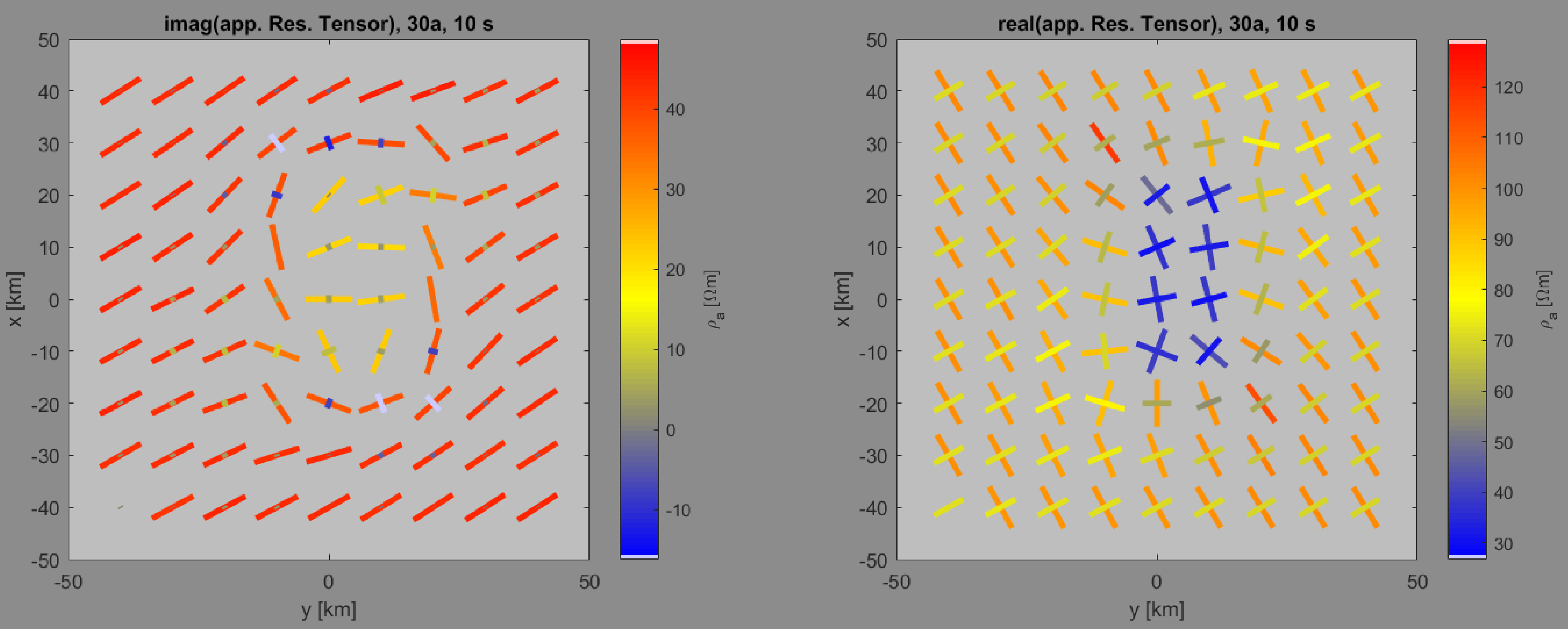




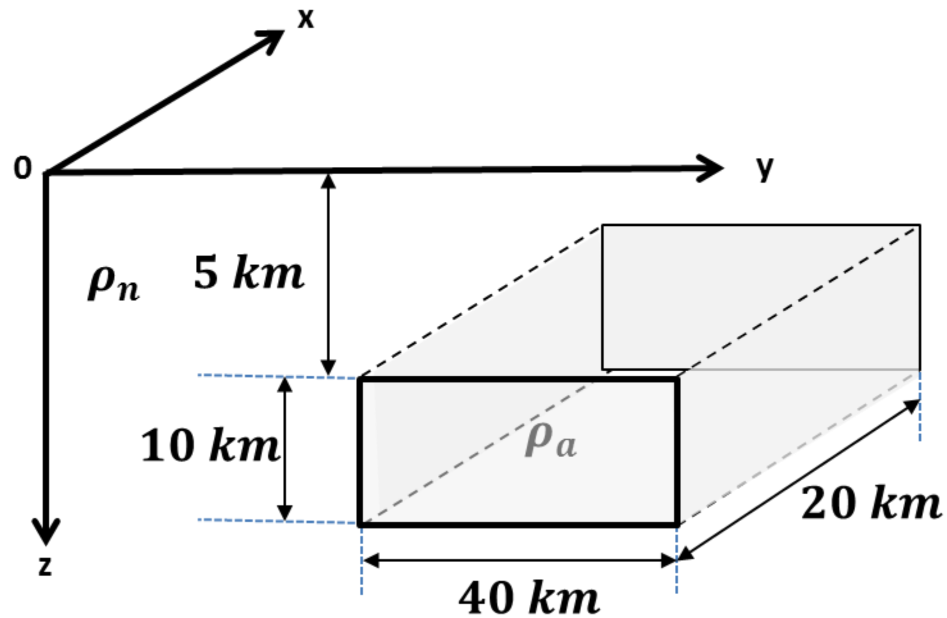
Transfer functions: phase tensor, app.res. tensor

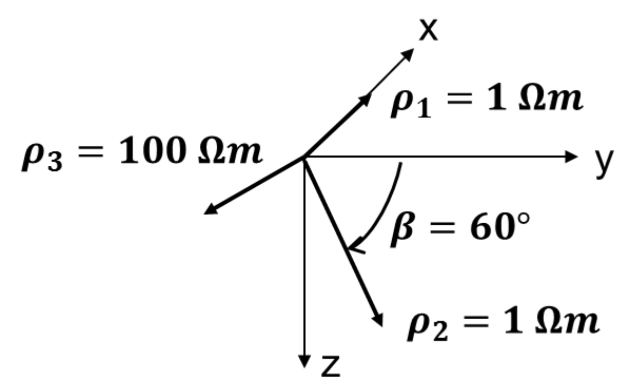
plane view, period 10 sec

$\Im\boldsymbol{\rho}$ $\Re\boldsymbol{\rho}$



Dipping Anisotropy





ρ_a anisotropic: $\rho_1 = 1\ \Omega m$

$\rho_2 = 1\ \Omega m$

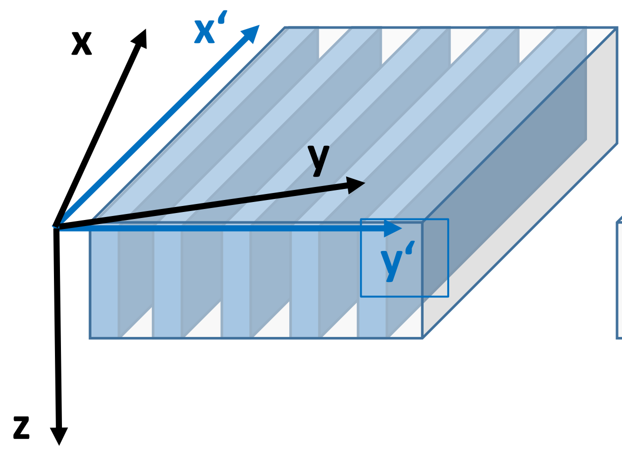
$\rho_3 = 100\ \Omega m$

background: $\rho_n = 100\ \Omega m$

1D isotropic - anisotropic: What happens inside the body?

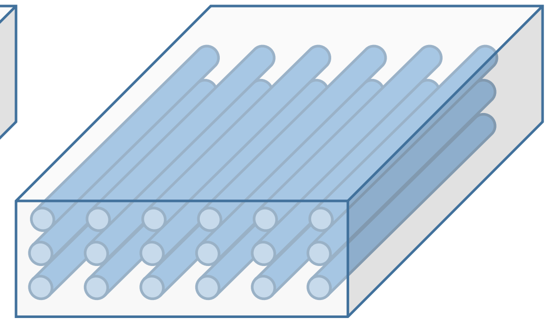
Azimuthal anisotropic Conductivity

„Dyke“



$$\begin{pmatrix} \sigma_{x'x'} & 0 & 0 \\ 0 & \sigma_{y'y'} & 0 \\ 0 & 0 & \sigma_{x'x'} \end{pmatrix}$$

„Pipe“

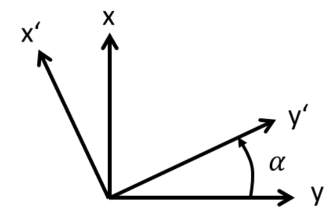


$$\begin{pmatrix} \sigma_{x'x'} & 0 & 0 \\ 0 & \sigma_{y'y'} & 0 \\ 0 & 0 & \sigma_{y'y'} \end{pmatrix}$$

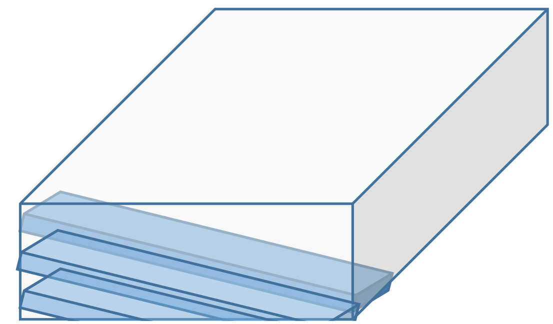
$\sigma_{x'x'} = \sigma_{zz}$

$$\begin{pmatrix} \sigma_{xx} & \sigma_{xy} & 0 \\ \sigma_{xy} & \sigma_{yy} & 0 \\ 0 & 0 & \sigma_{zz} \end{pmatrix}$$

$\sigma_{y'y'} = \sigma_{zz}$



Dipping anisotropy

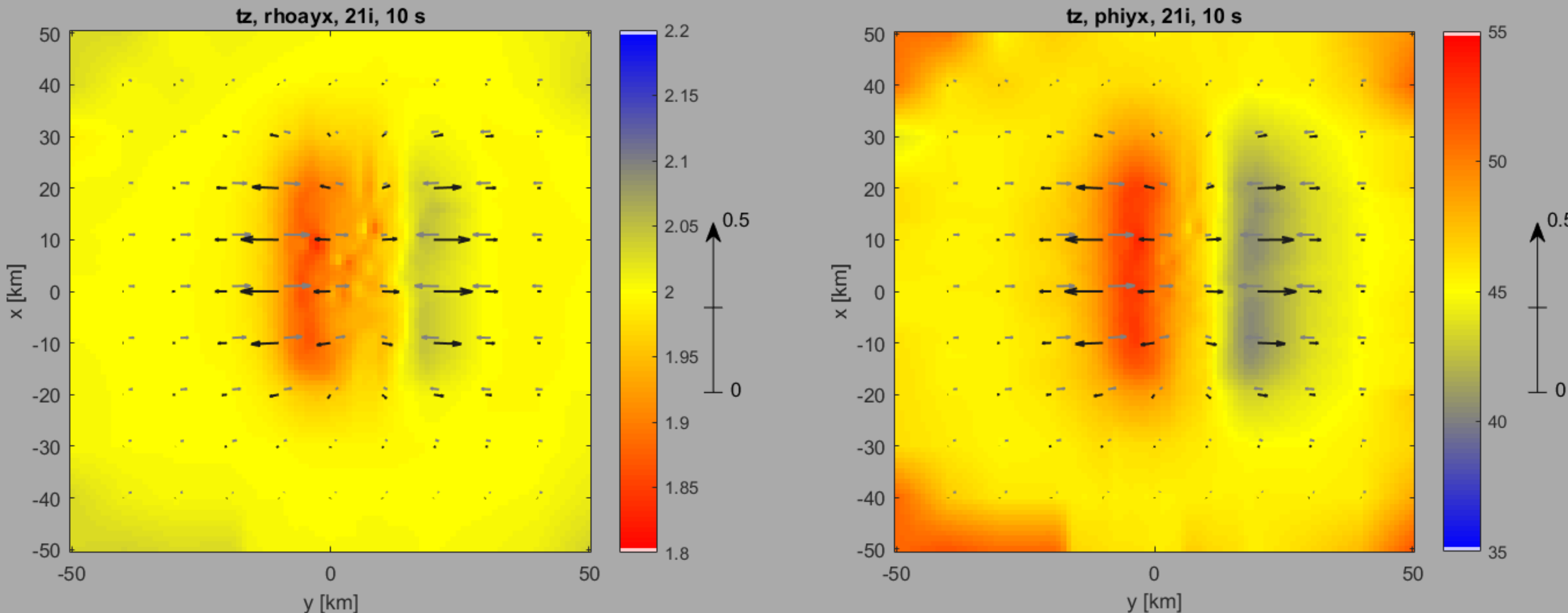


$$\begin{pmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{xy} & \sigma_{yy} & \sigma_{yz} \\ \sigma_{xz} & \sigma_{yz} & \sigma_{zz} \end{pmatrix}$$

Transfer functions: Apparent Resistivity, Phase, Tipper

plane view, period 10 sec

$\rho_{a,yx}$ φ_{yx}

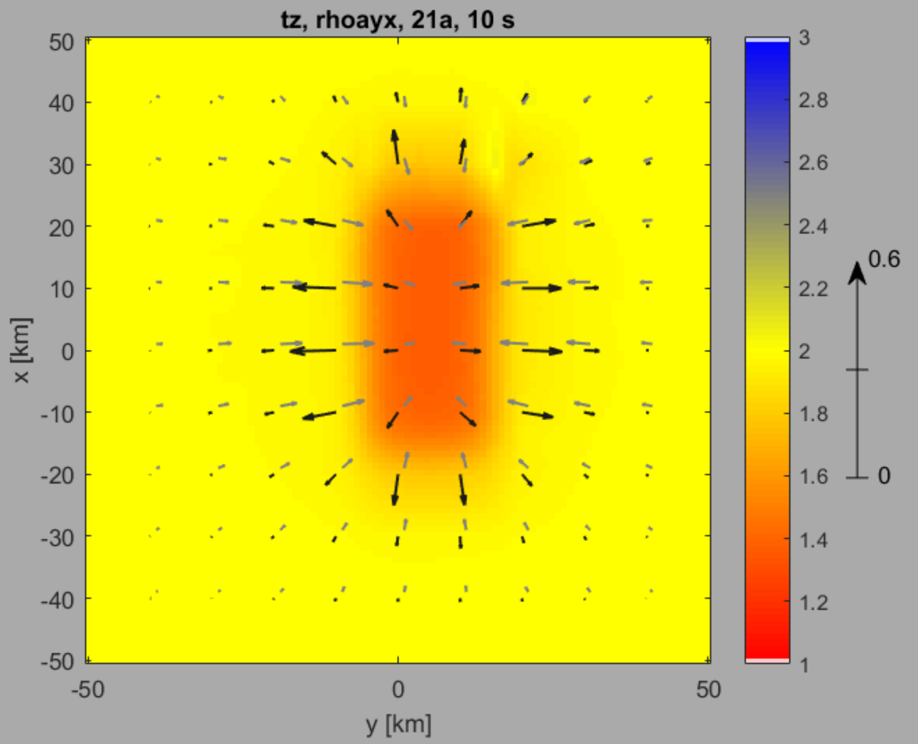


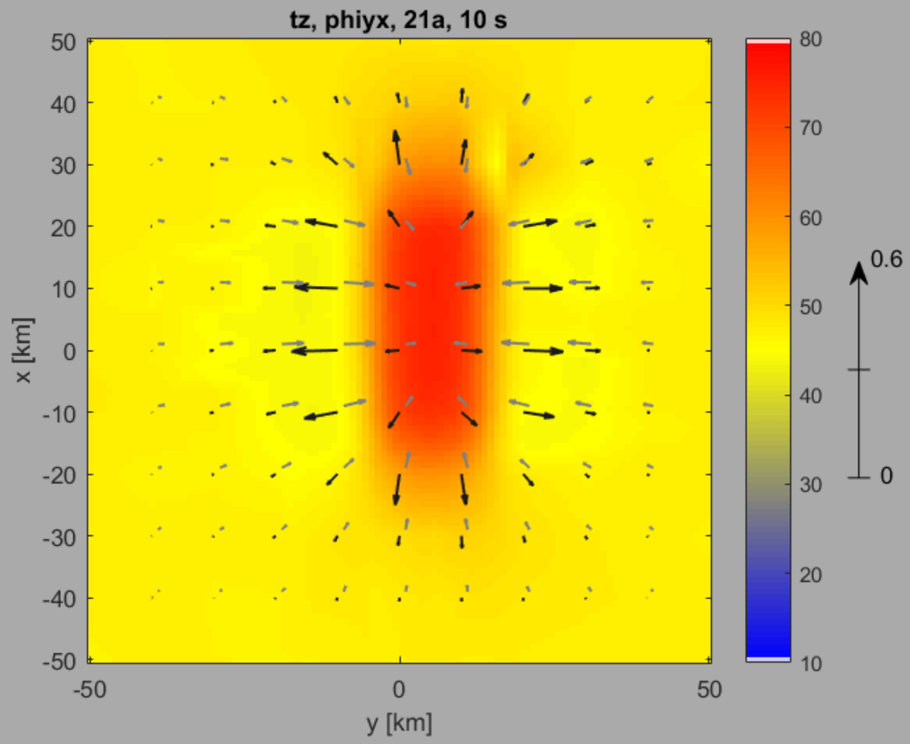
Transfer functions: phase tensor, app.res. tensor

plane view, period 10 sec

$\rho_{a,yx}$ φ_{yx}

Comparison: Isotropic Cube



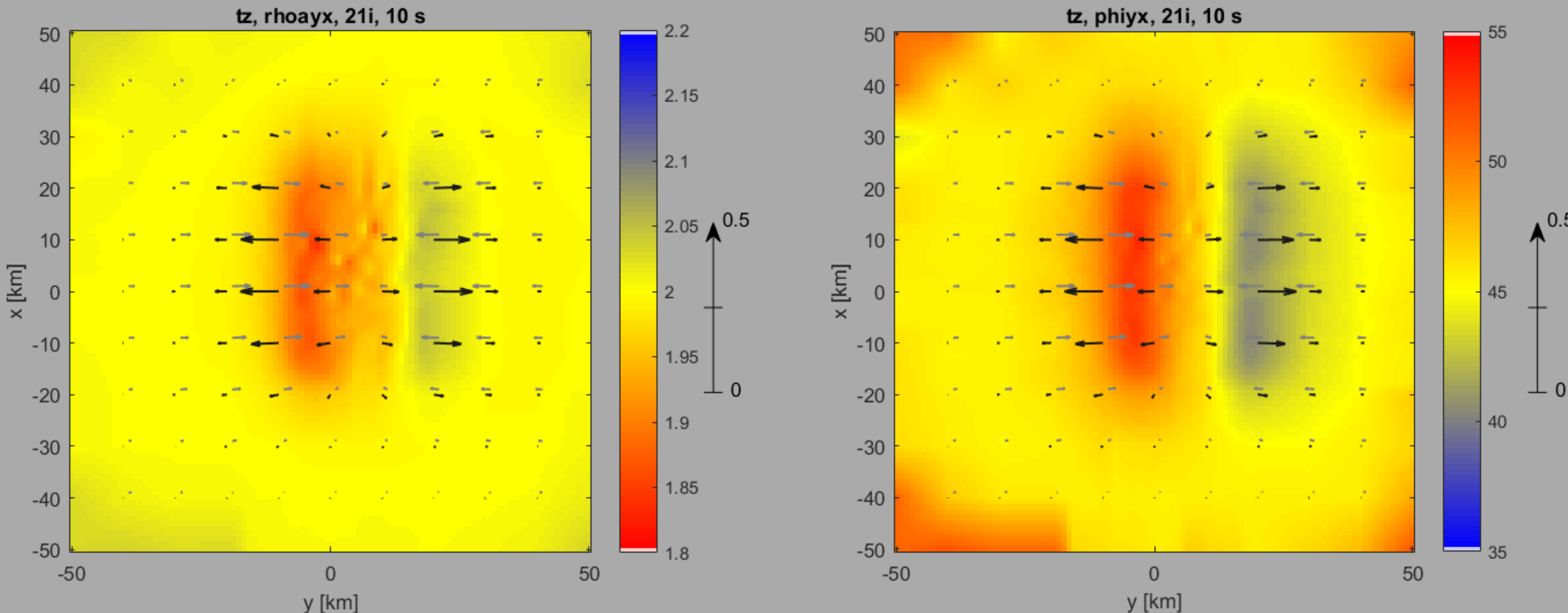


Transfer functions: Apparent Resistivity, Phase, Tipper

plane view, period 10 sec

$\rho_{a,yx}$ φ_{yx}

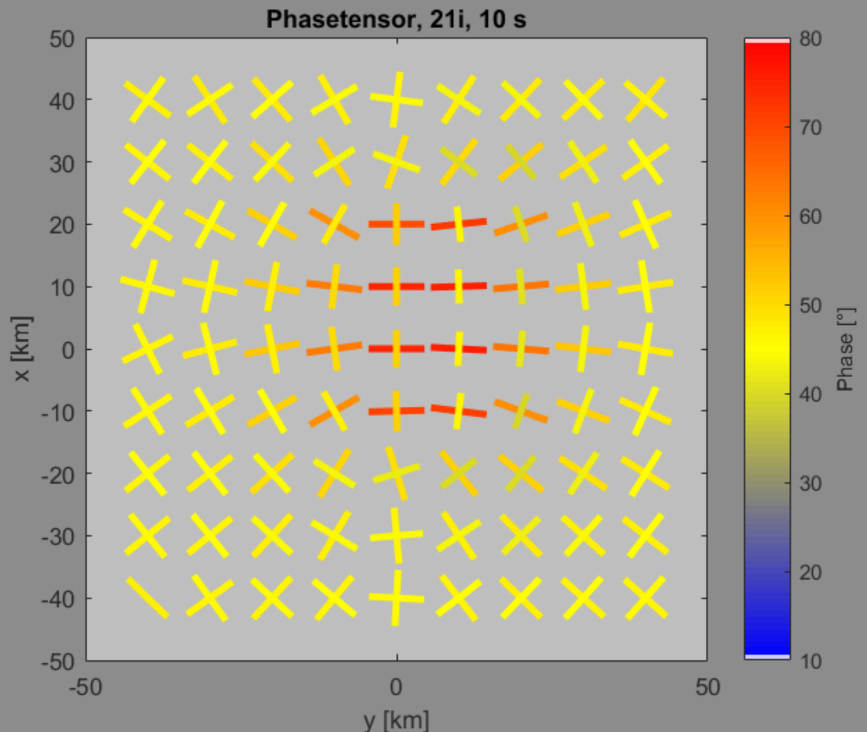
Anisotropic Cube

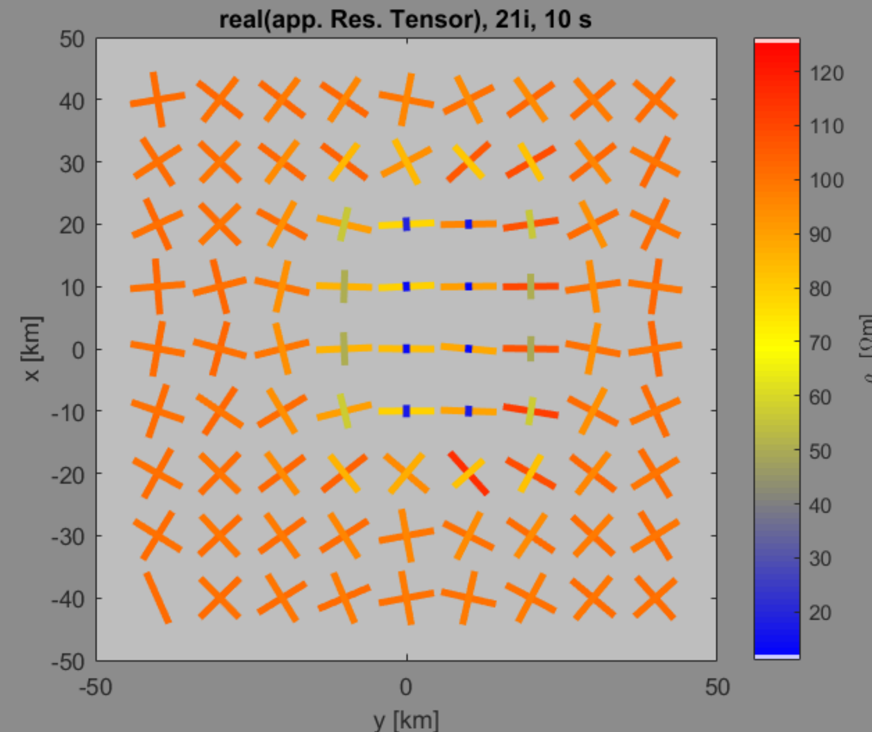


Transfer functions: phase tensor, app.res. tensor

plane view, period 10 sec

$\boldsymbol{\phi}$ $\Re\boldsymbol{\rho}$

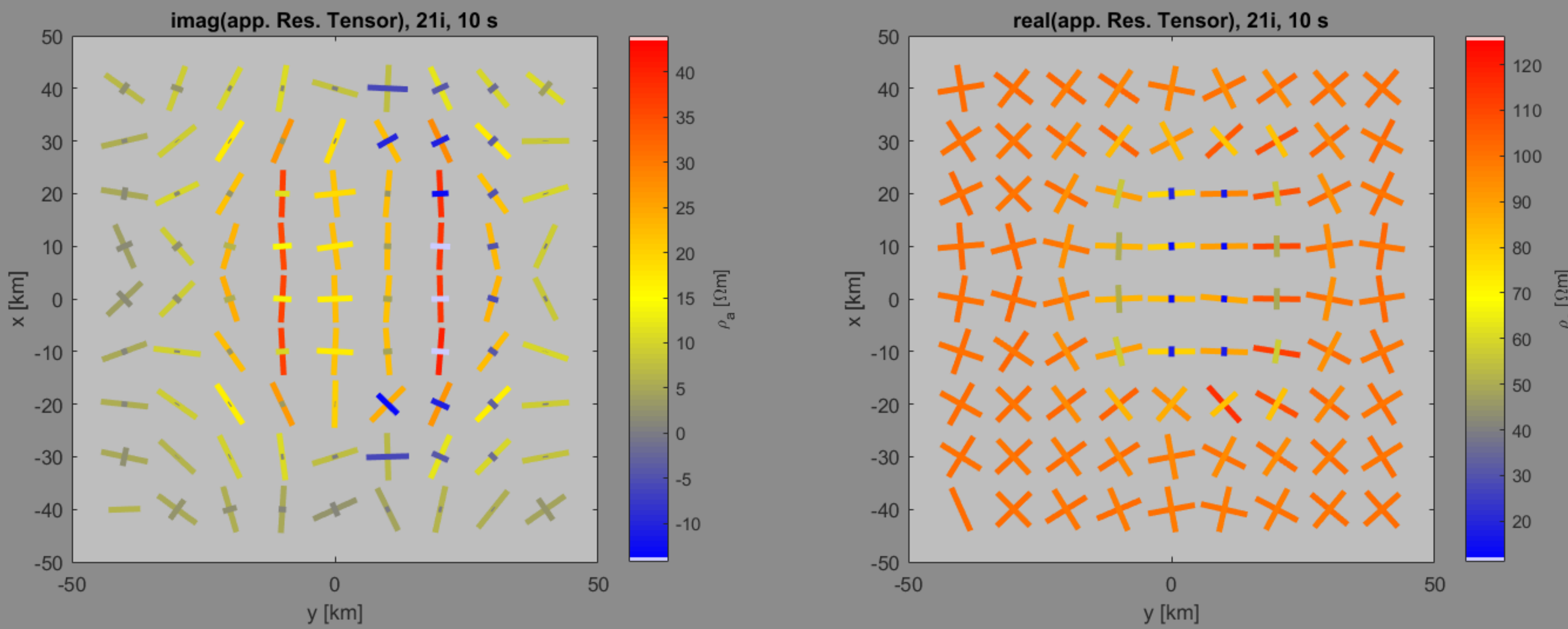




Transfer functions: phase tensor, app.res. tensor

plane view, period 10 sec

$\Im \boldsymbol{\rho}$ $\Re \boldsymbol{\rho}$



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- Motivation – why anisotropy rather than isotropy?
- Numerical simulations in 3D
- **The real world**
  - **Case 1: African Rift (Häuser&Junge, GJI 2011)**
  - Case 2: Tierra del Fuego (Gonzales et al., Nat.Sci.Rep. 2019)
  - Case 3: Ceboruco (Hering, Diss. 2019)

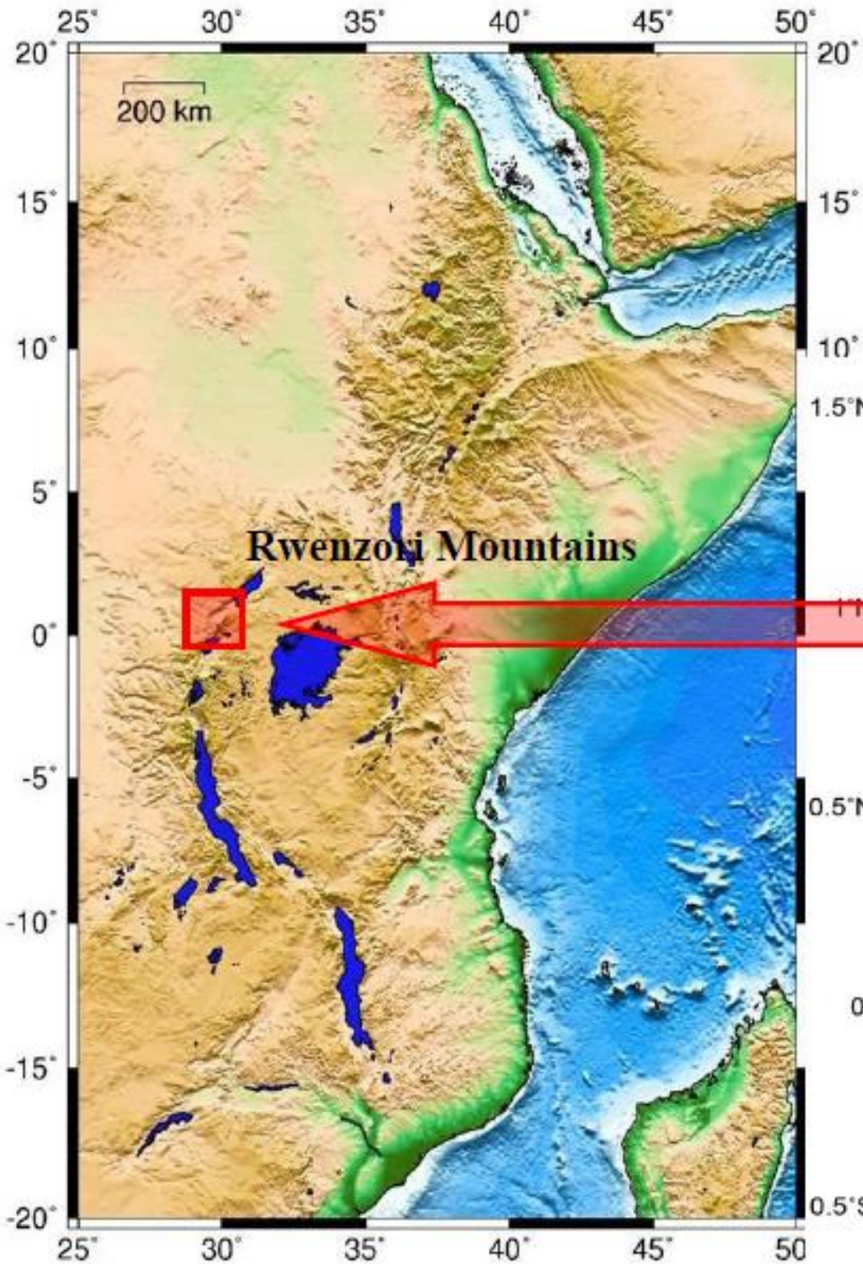
Case Study 1: East African Rift

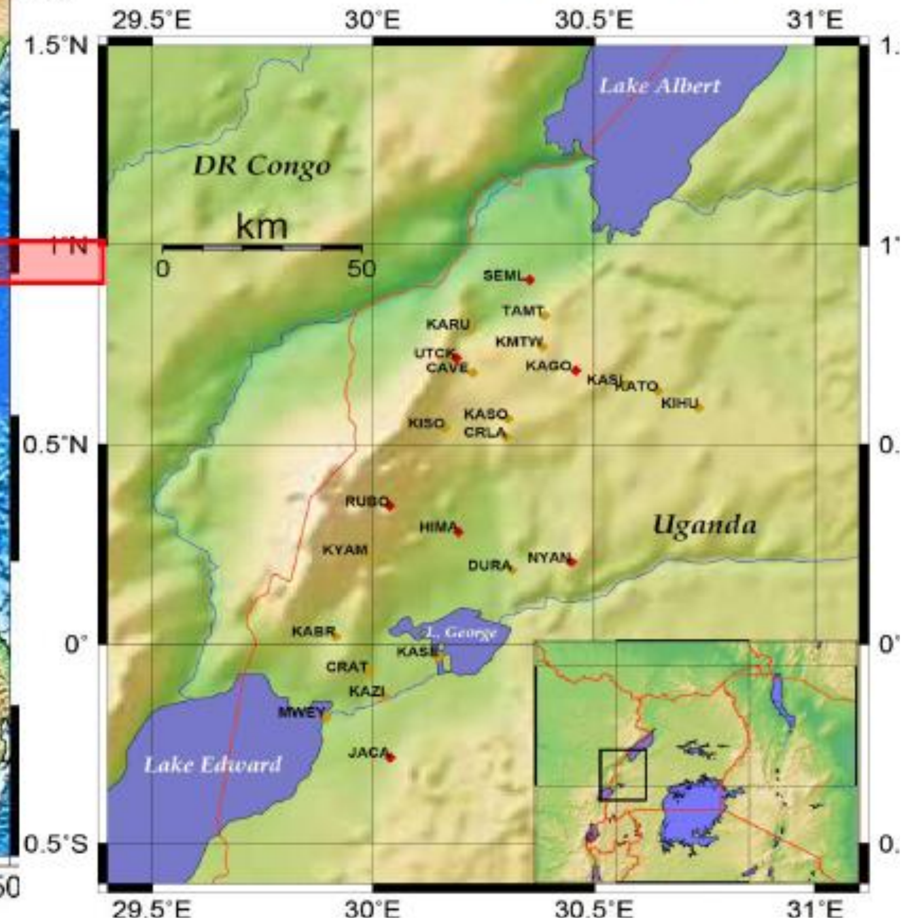
Electrical mantle anisotropy and crustal conductor: a 3-D conductivity model of the Rwenzori Region in western Uganda

Häuserer, M. and Junge, A., GJI 2011

East African Rift System
Rwenzori Mountains

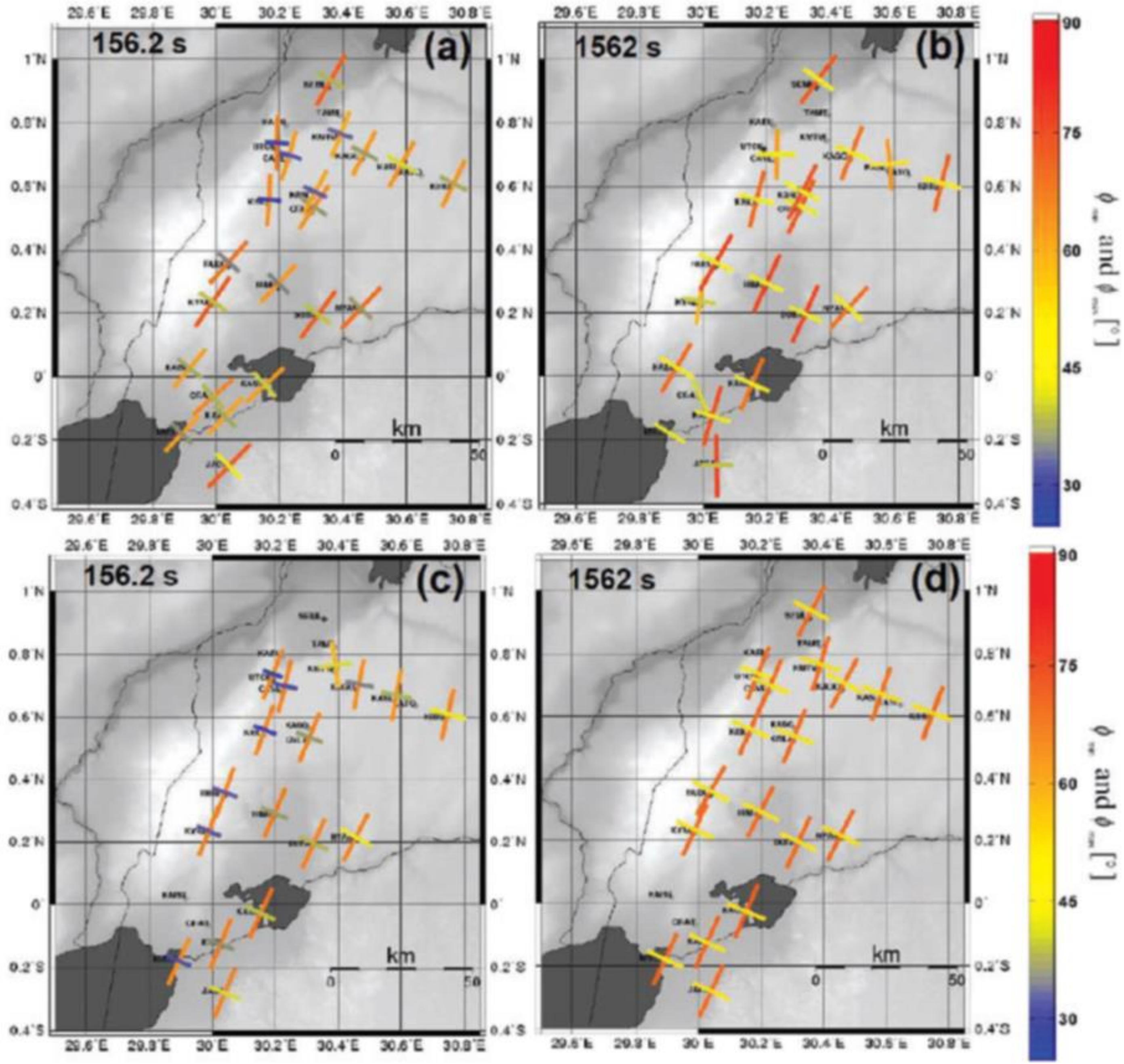
- 23 LMT sites 10 - 10.000sec
- 13 AMT sites 0,001 - 50sec

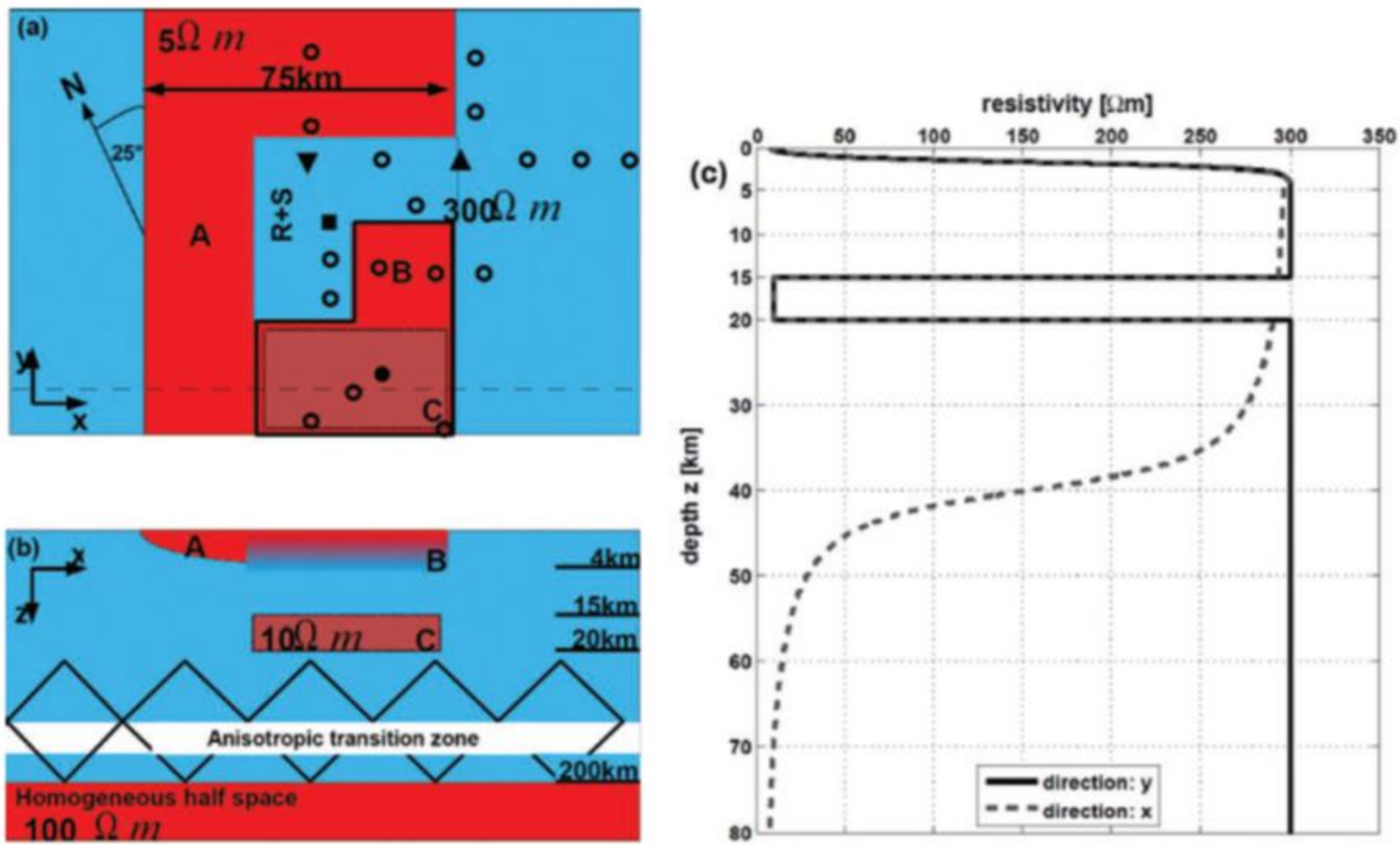


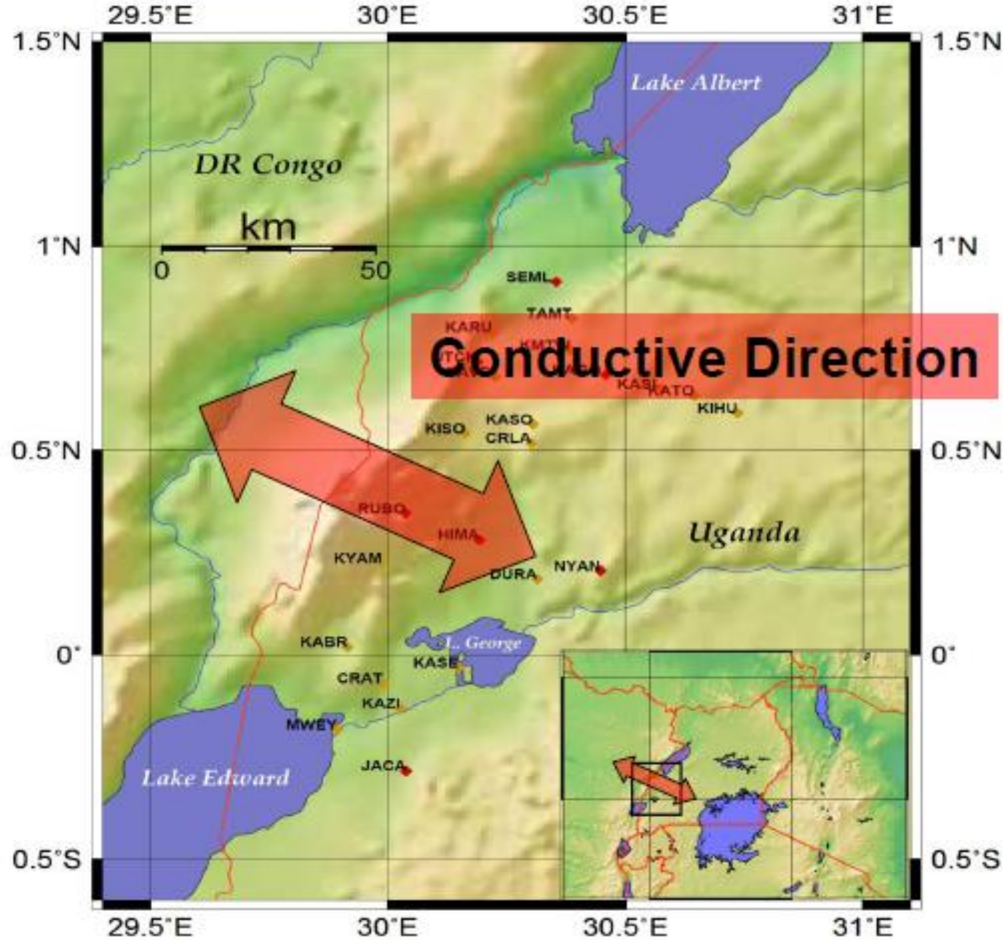


Observed Data

Modeled Data




(a)
5Ω m
75km
N
25°
A
R+S
300Ω m
B
C
y
x
(b)
x
z
A
B
4km
15km
10Ω m
C
20km
Anisotropic transition zone
200km
Homogeneous half space
100 Ω m
(c)
resistivity [Ωm]
0
50
100
150
200
250
300
350
depth z [km]
0
5
10
15
20
30
40
50
60
70
80
direction: y
direction: x



29.5°E
30°E
30.5°E
31°E
1.5°N
1°N
0.5°N
0°
0.5°S
Lake Albert
DR Congo
km
0
50
SEML
TAMT
KARU
Conductive Direction
KASI
KATO
KIHU
KASO
KISO
CRLA
RUSO
HIMA
Uganda
KYAM
NYAN
DURA
KABR
L. George
KASE
CRAT
KAZI
MWEY
JACA
Lake Edward

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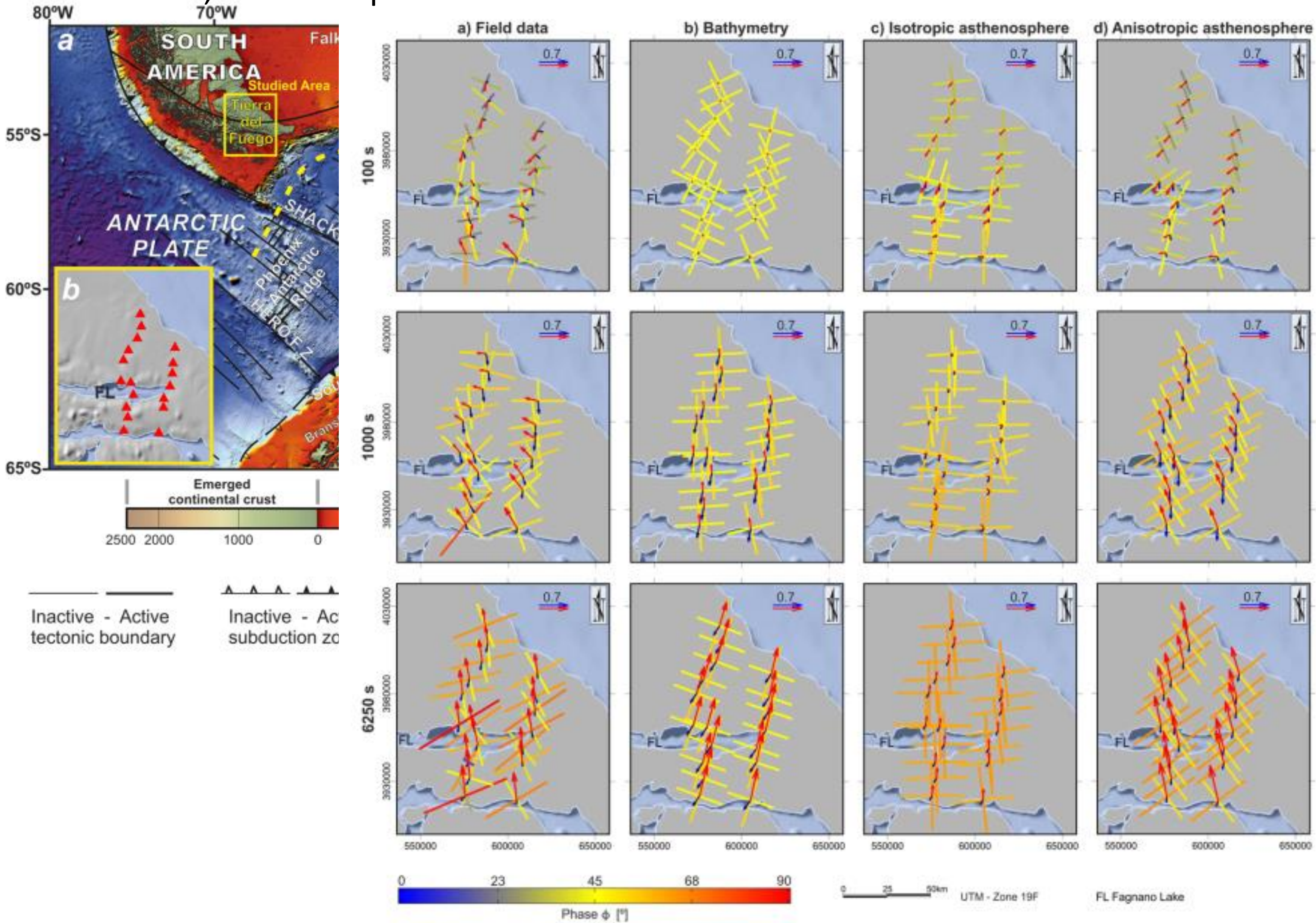
Case Study 2: Tierra Del Fuego

Mantle flow and deep electrical anisotropy in a main gateway: MT study in Tierra del Fuego
Gonzales et al., Nat.Sci.Rep. 2019



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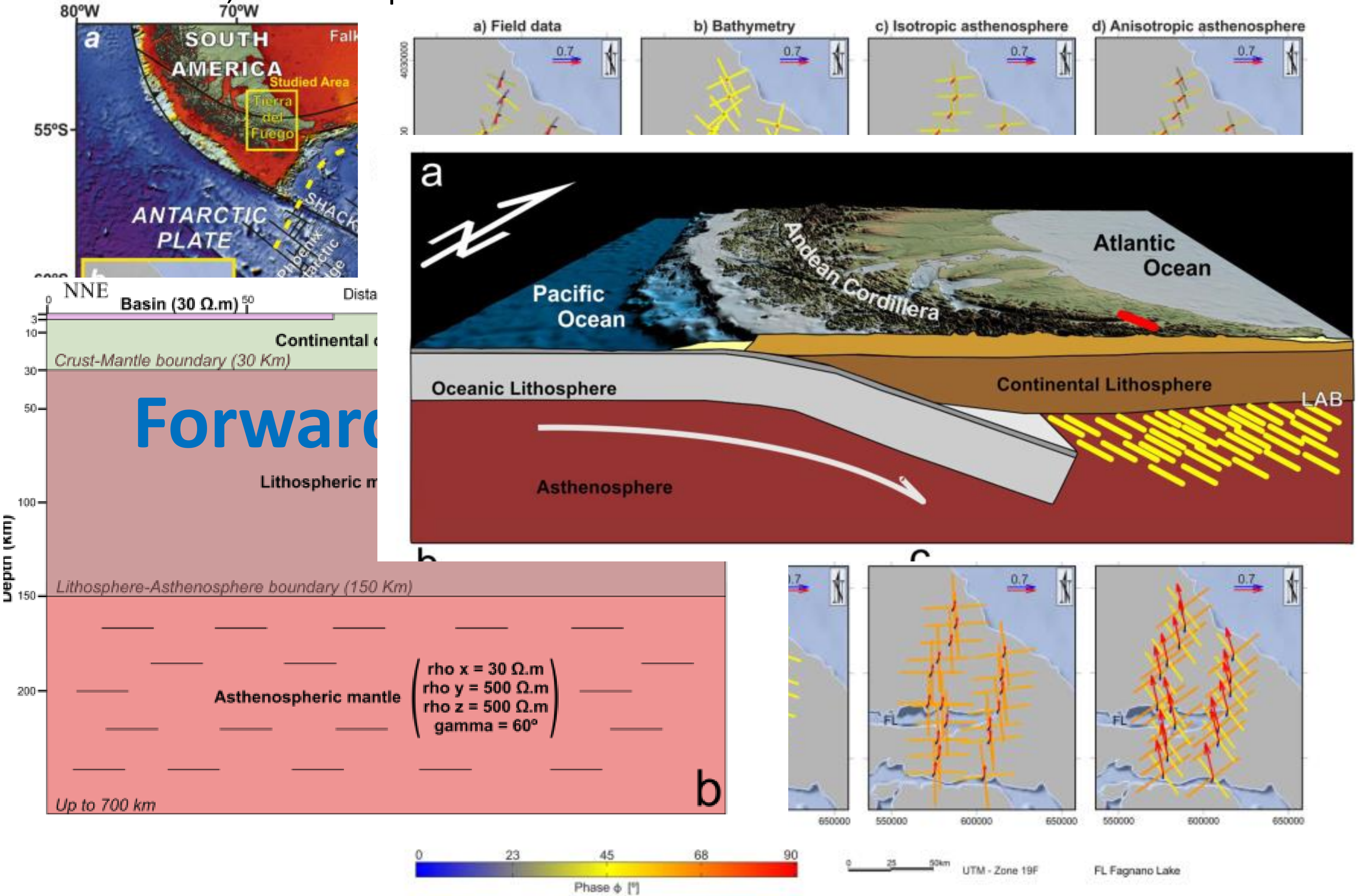

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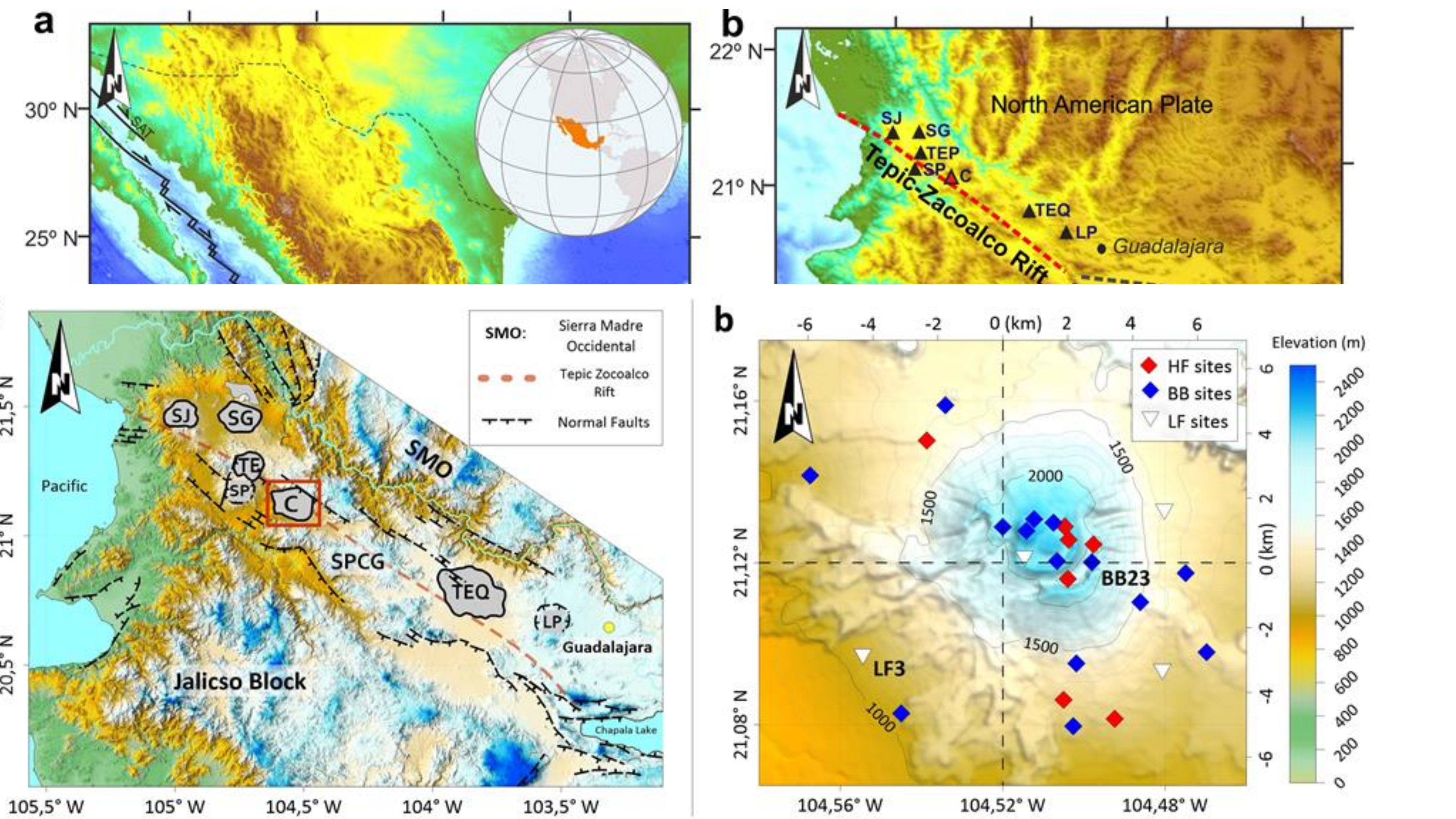
Case Study 3: Ceboruco

Advances in Magnetotelluric Data Processing, Interpretation and Inversion, illustrated by a Three-Dimensional Resistivity Model of the Ceboruco Volcano, Philip Hering, Dissertation GU Frankfurt, 2019



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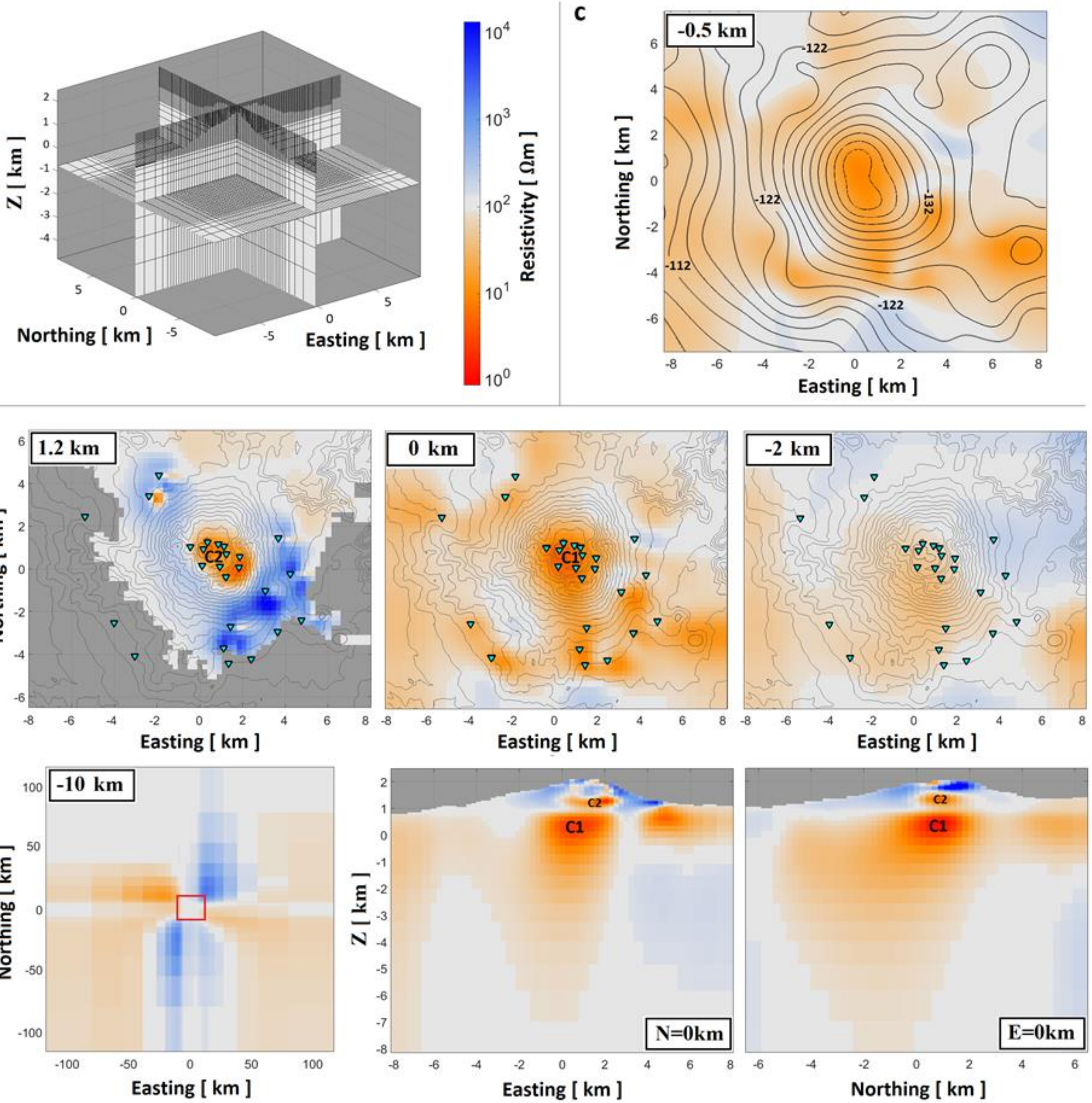
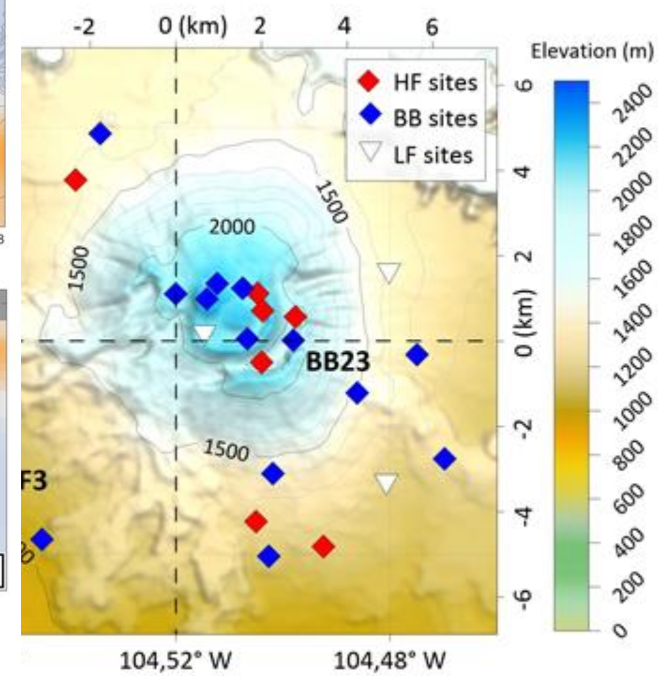


Inversion Results (ModEM)



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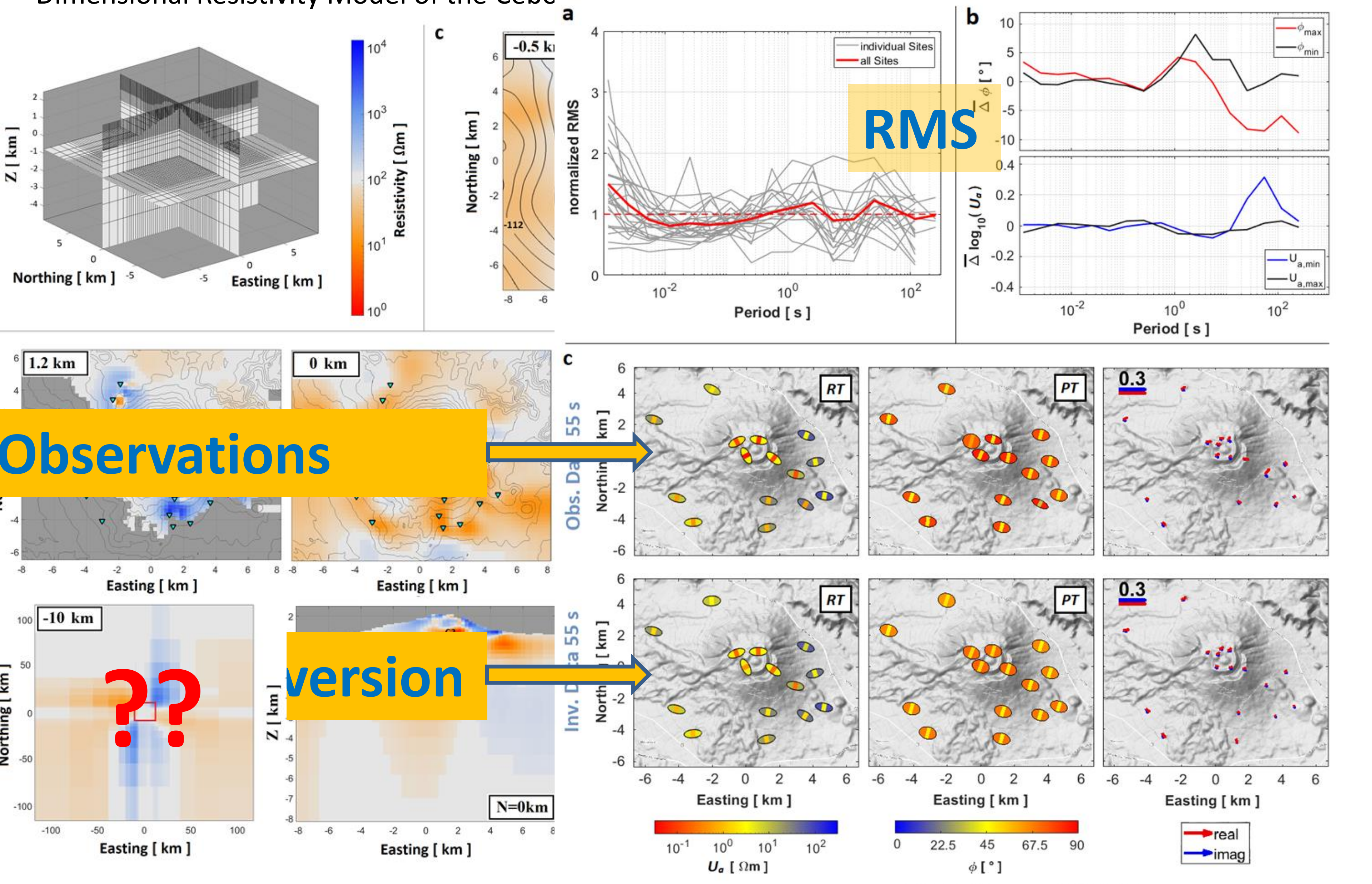

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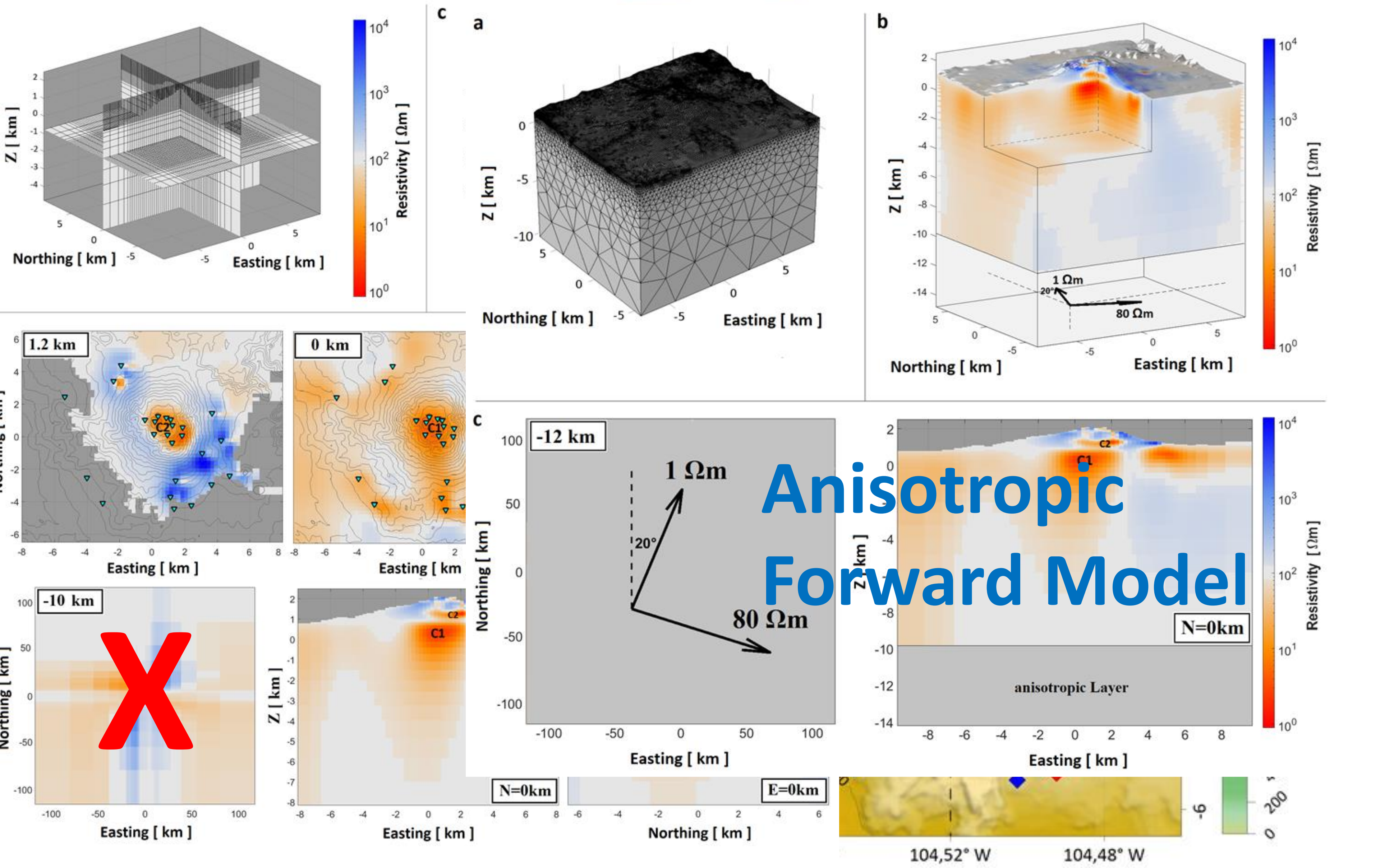
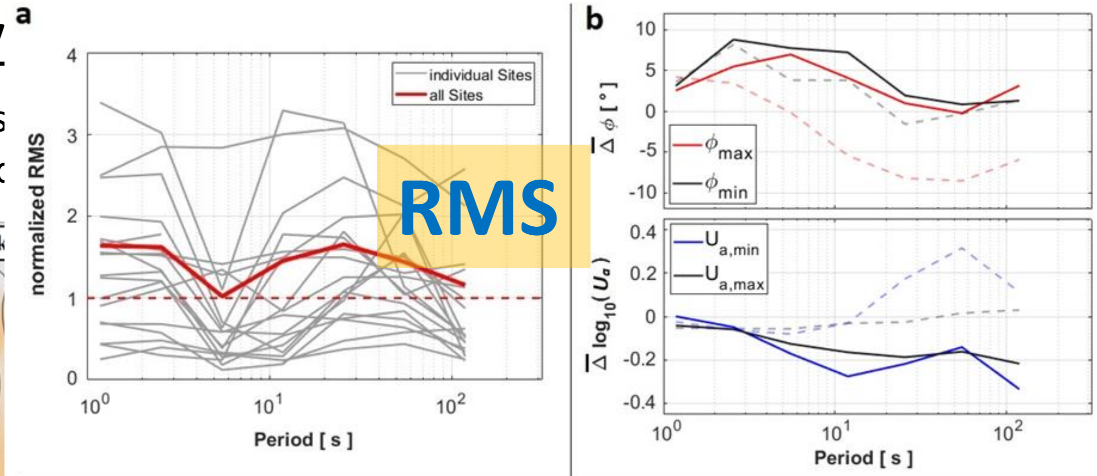
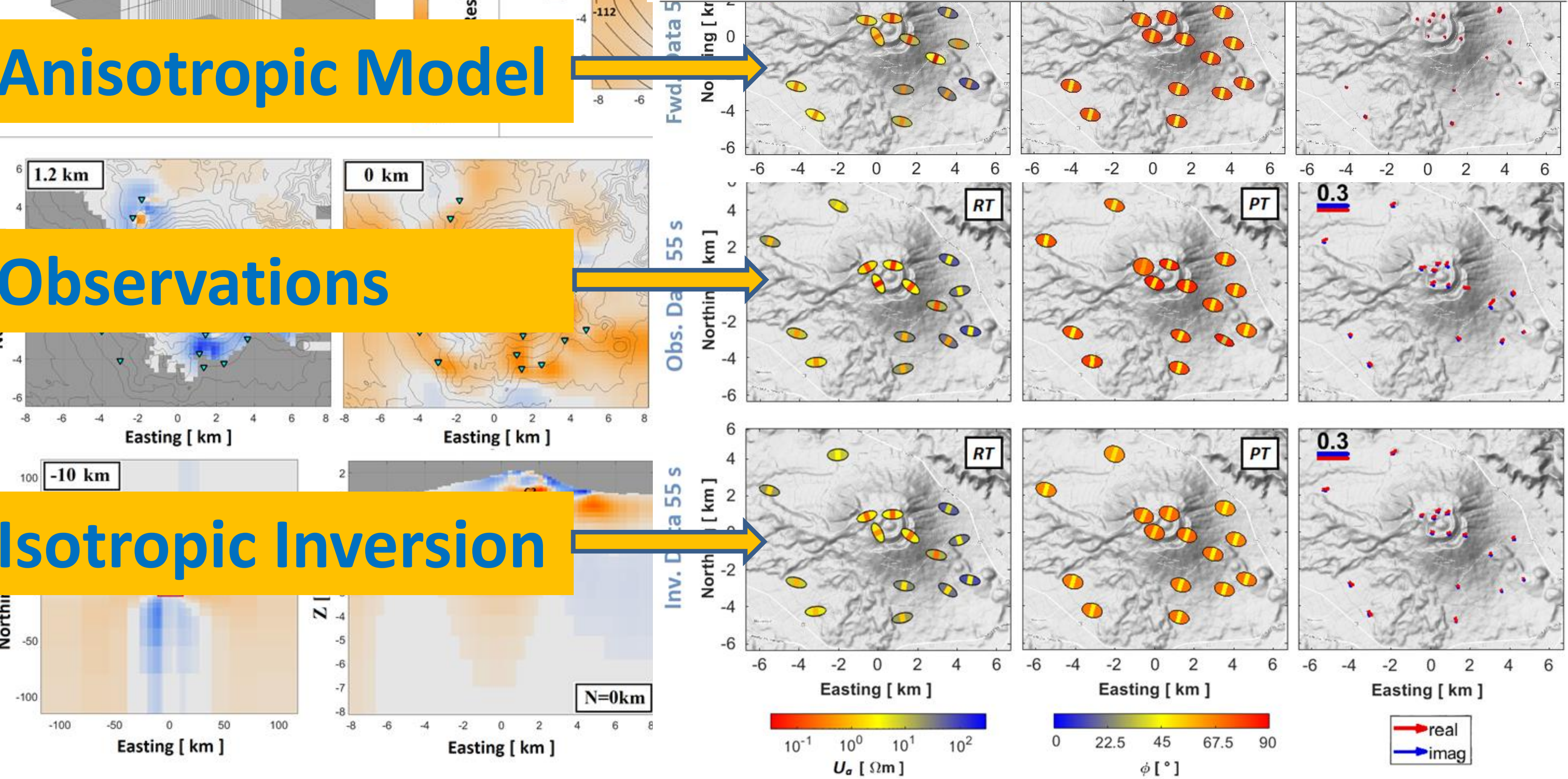


Case Study

Advances in Magnetotelluric Data Process
Dimensional Resistivity Model of the Cebc





How to deal with existing isotropic 3D models?

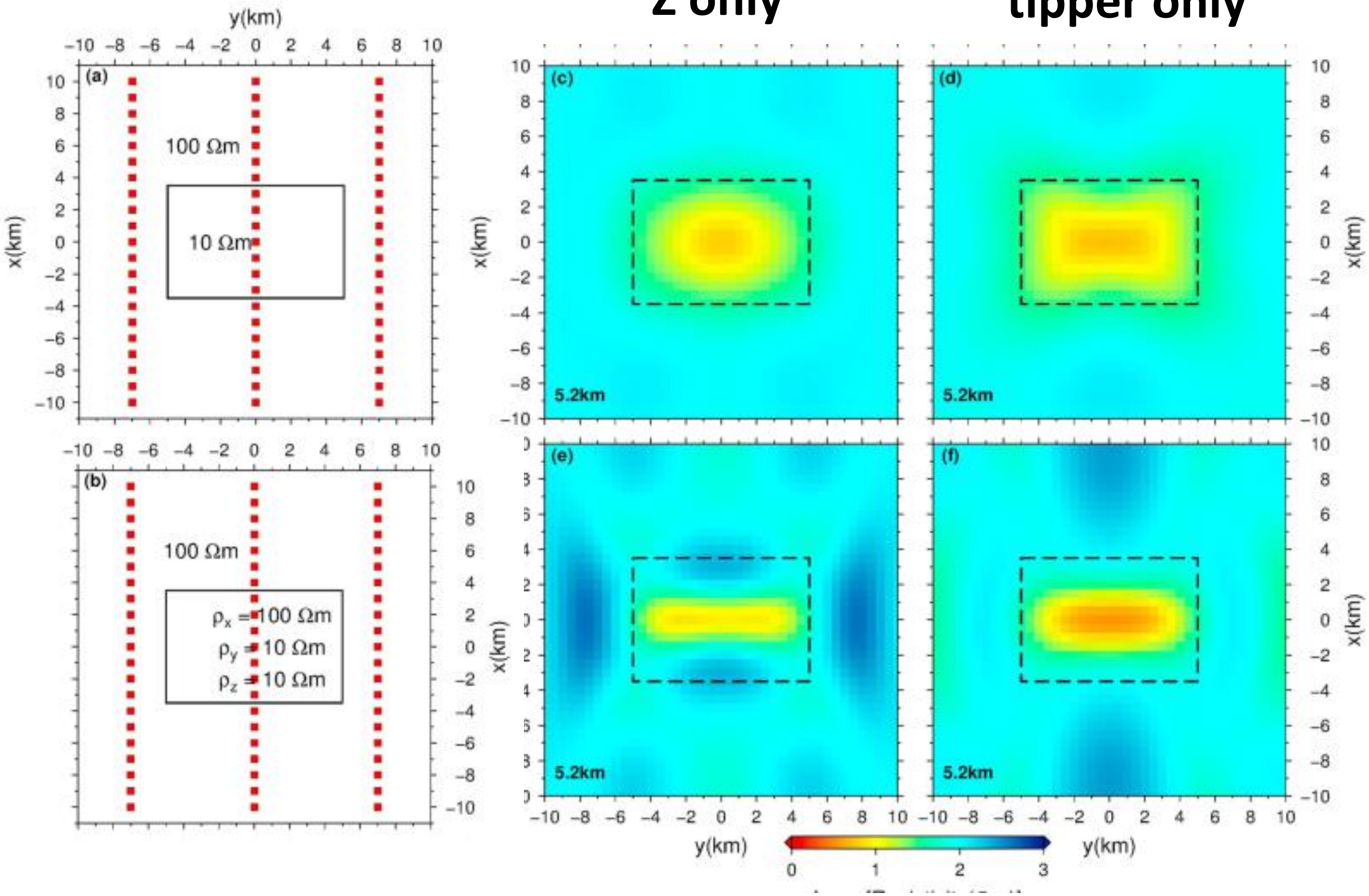
Isotropic inversion (ModEM)

Z only

tipper only

isotropic

anisotropic

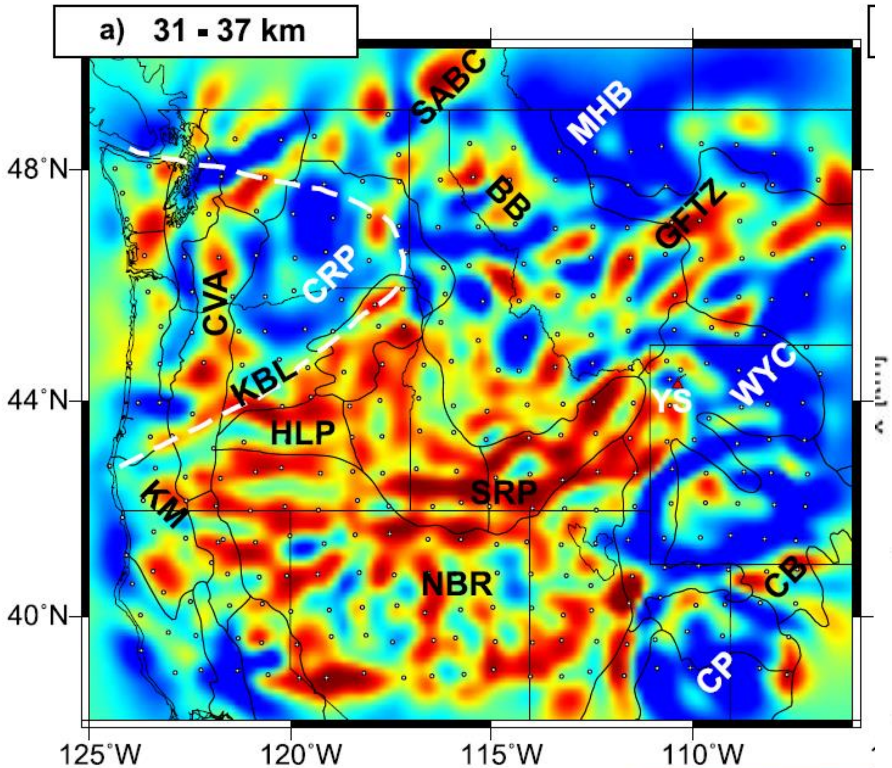


Ying et al., JGR 2019

How to deal with existing isotropic 3D models?

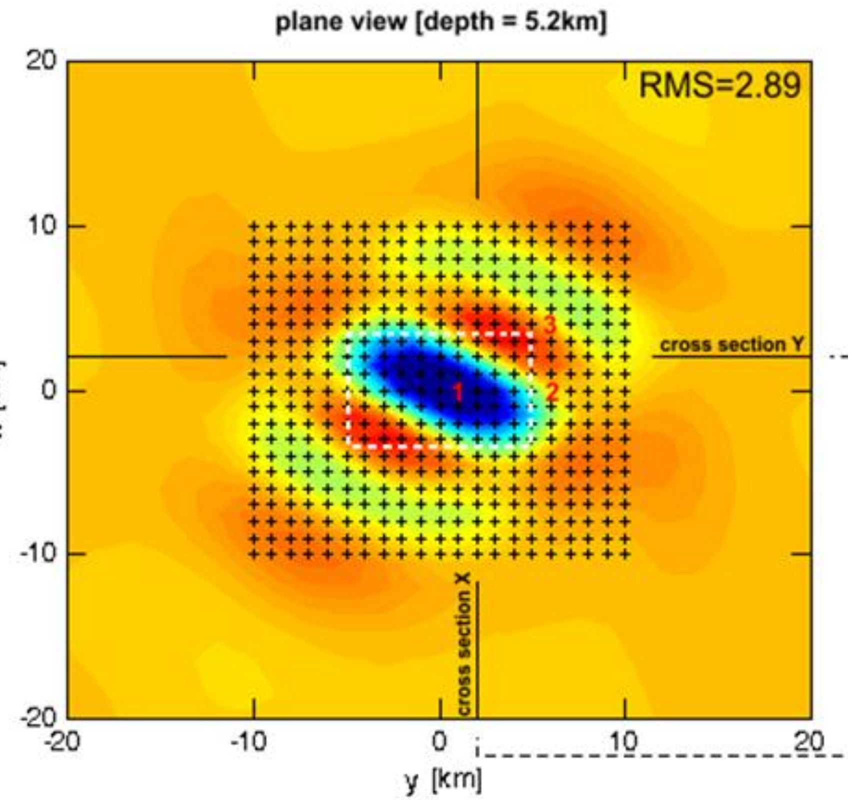
Observations

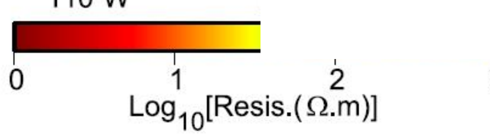
Meqbel et al, EPSL 2014



Case study

Löwer&Junge, PAGEOPH, 2017





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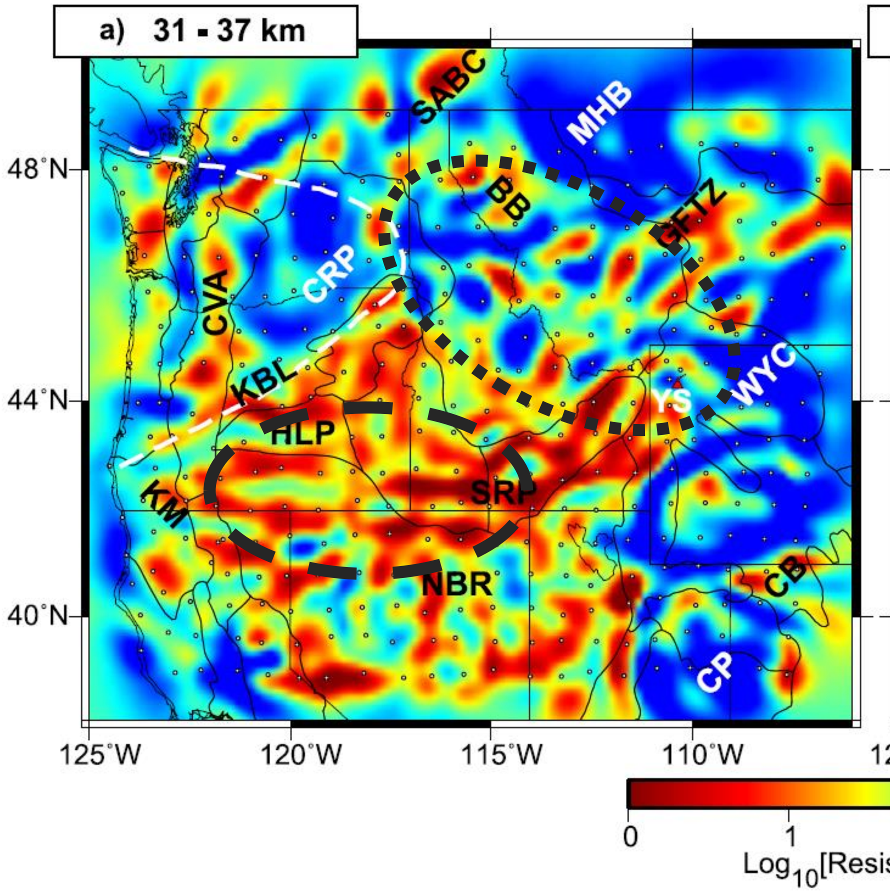
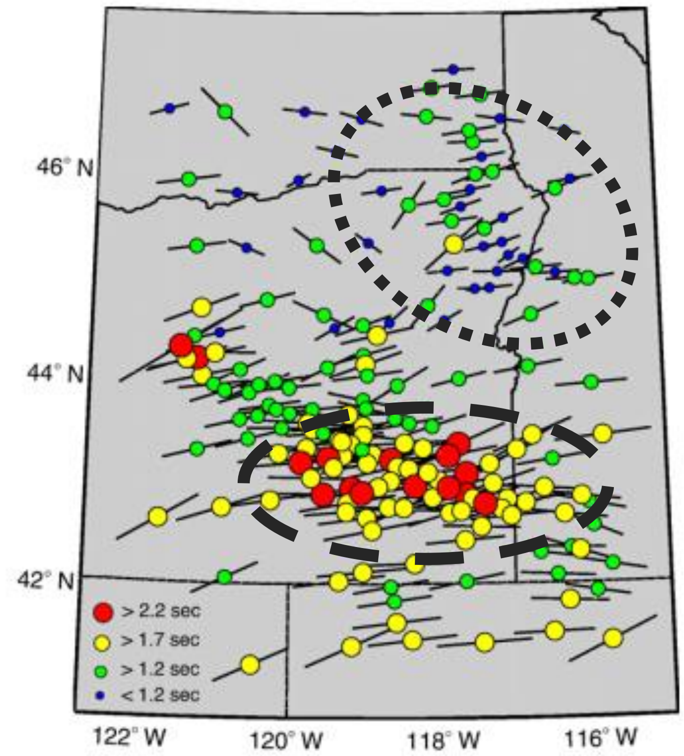
Meqbel et al, EPSL 2014



SKS Wave Splitting – Fast Axis

Long et al, EPSL, 2009



How to deal with existing isotropic 3D models?

Compared to isotropic dyke models with unrealistic high resisitivity contrast

Bulk Anisotropy yields realistic moderate resistivities

Conclusions

- Indications for anisotropic conductivity in crust and mantle
- Magnetotelluric is the (only?) method to detect deep electrical anisotropy
- Array site distribution necessary
- Preferable observables: Complex Resistivity Tensor and Tipper
  (Brown, JGR 2017, Hering et al., JGR 2019)
- Comparison with seismic anisotropy (spatial pattern)
- Important parameter for understanding geodynamic processes

Thank you for your attention