Forward algorithm

➤ The edge-based hexahedral element is used.
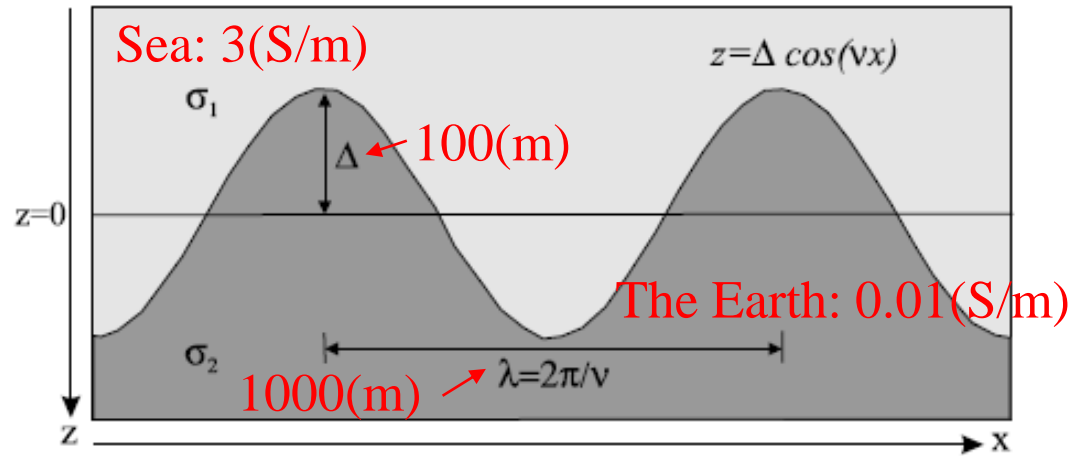
$$E(r) = \sum_{i=1}^{8} N_i(r) E_i$$
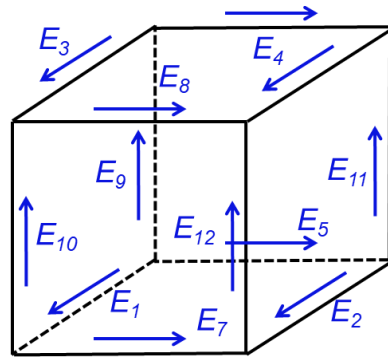
➤ As in Grayver & Burg (2014, GJI), non-conforming meshes with 1-irregular hanging nodes is used.

➤ In FEMTIC, the division number of one side can be double compared to the other side only in the horizontal direction.

➤ Except for the treatment of adjacent elements with different division numbers, the forward algorithm is based on Usui (2015) and Usui et al. (2017).

Hanging nodes
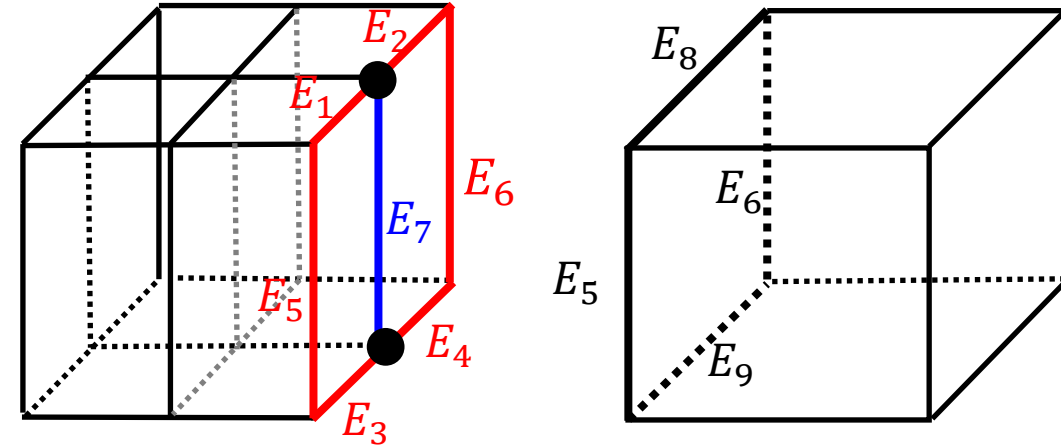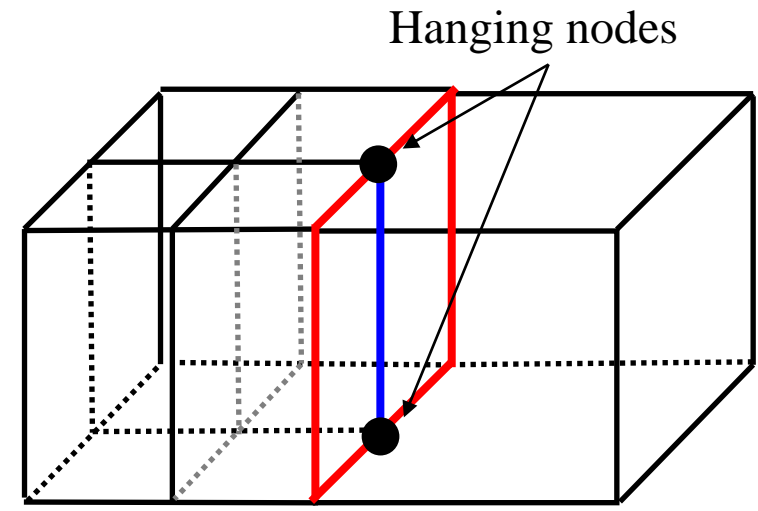
Equations for constraints
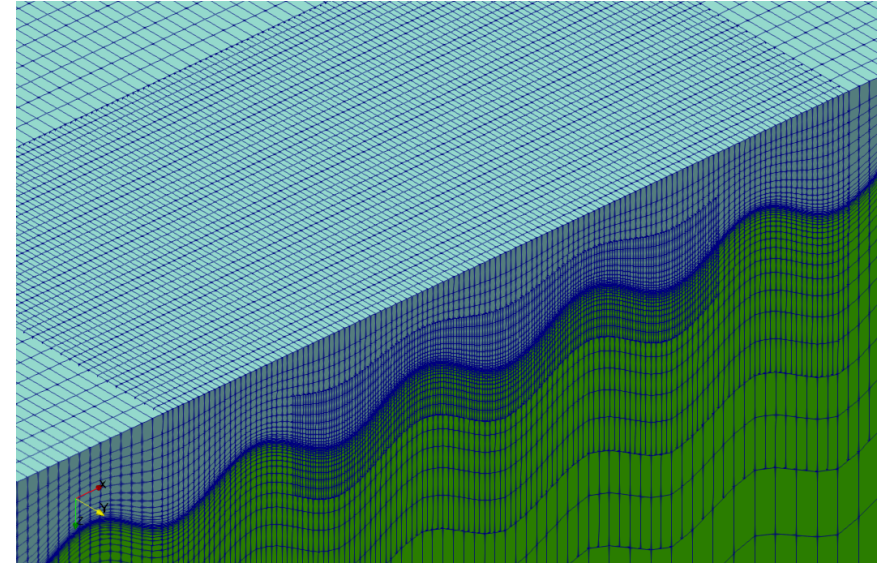
$$E_1 = E_2 = E_8$$

$$E_3 = E_4 = E_9$$

$$E_7 = \frac{E_5 + E_6}{2}$$

Test of forward calculation (1) - Seafloor with 2-D sinusoidal undulation -

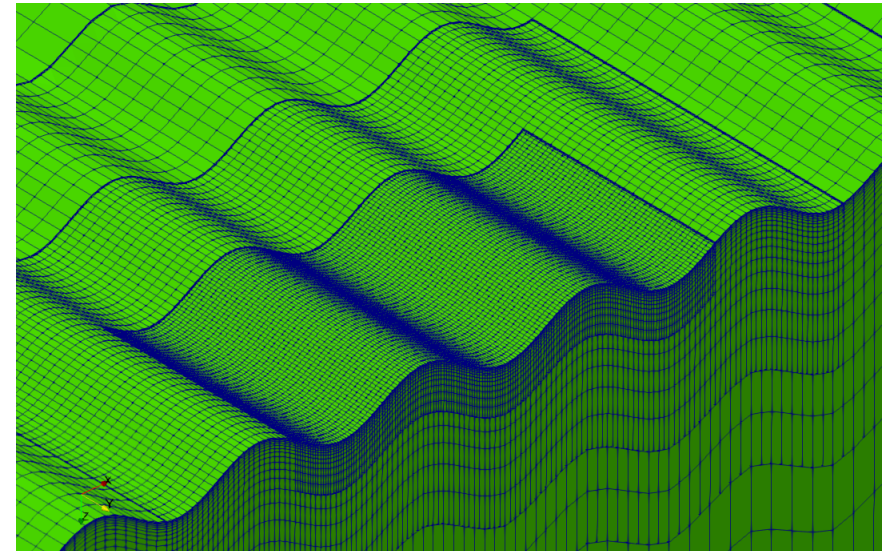Schwalenberg & Edwards (2004, GJI)

Sea: 3(S/m)

σ_1

$z = \Delta \, cos(\nu x)$

Δ ← 100(m)

z=0

The Earth: 0.01(S/m)

σ_2

1000(m) $\lambda = 2\pi/\nu$

Mesh of the sea and the subsurface

Mesh of the subsurface

➢ Schwalenberg & Edwards (2004) and Usui et al. (2018) showed semi-analytical formulation for the seafloor with 2-D sinusoidal undulation.

➢ I calculated the apparent resistivity, the phase, and the vertical magnetic transfer functions (tipper) by using developed inversion code.

➢ I compared the calculated response functions with the analytical solutions.
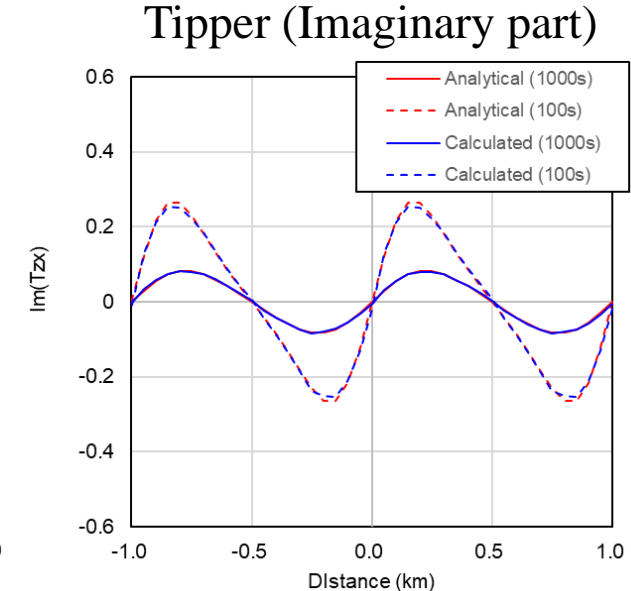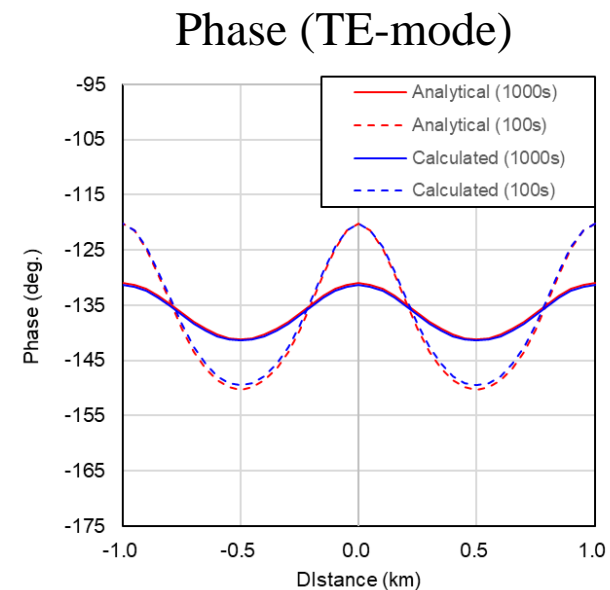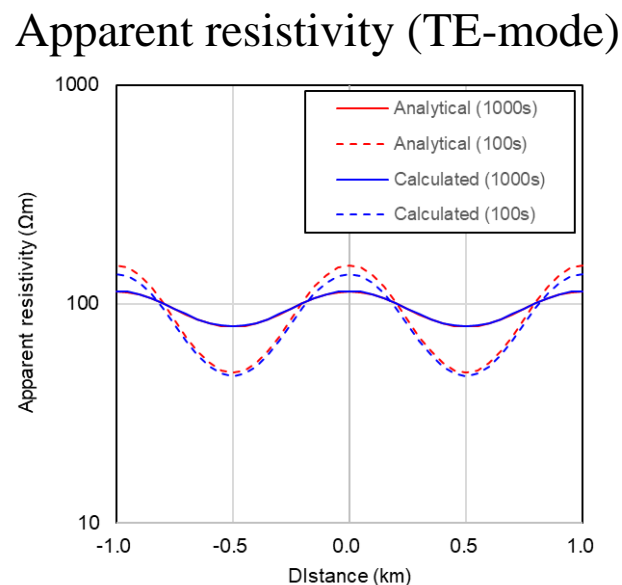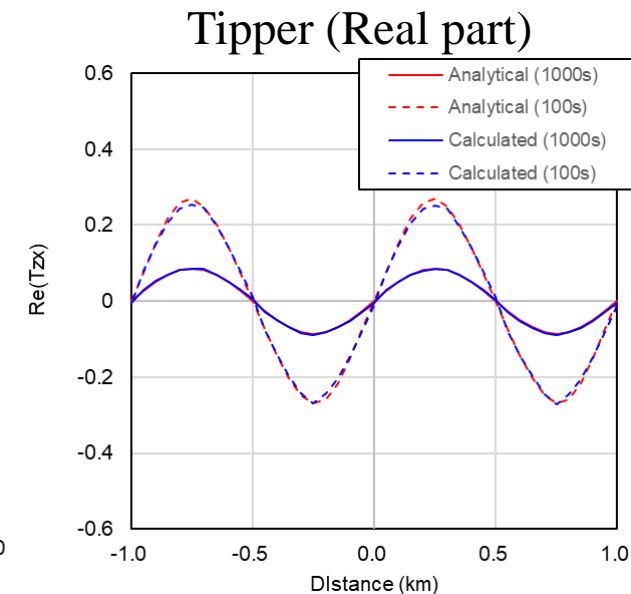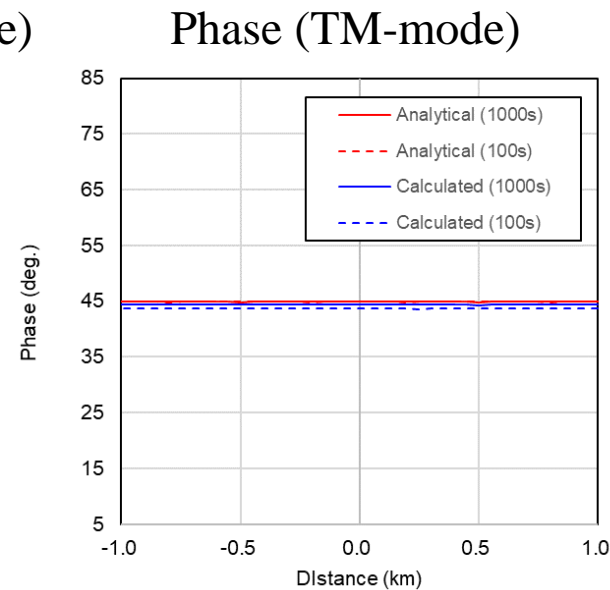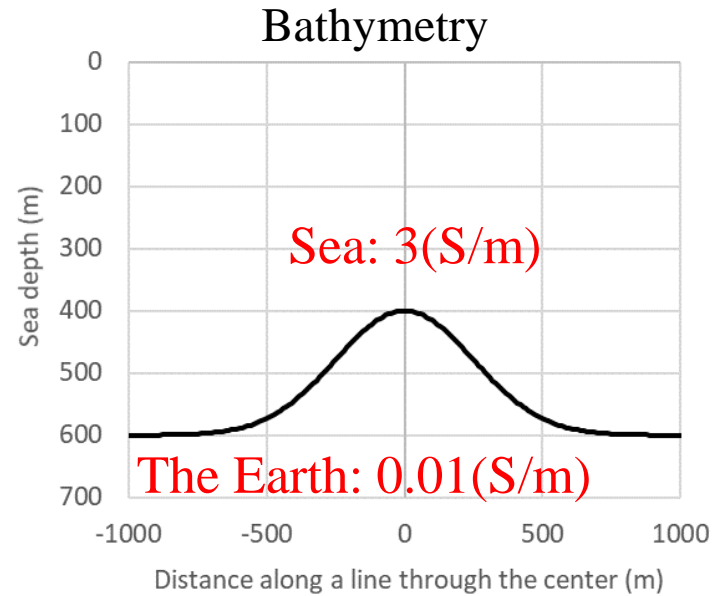
Test of forward calculation (1) - Seafloor with 2-D sinusoidal undulation -

Bathymetry

Apparent resistivity (TM-mode)

Phase (TM-mode)

Tipper (Real part)

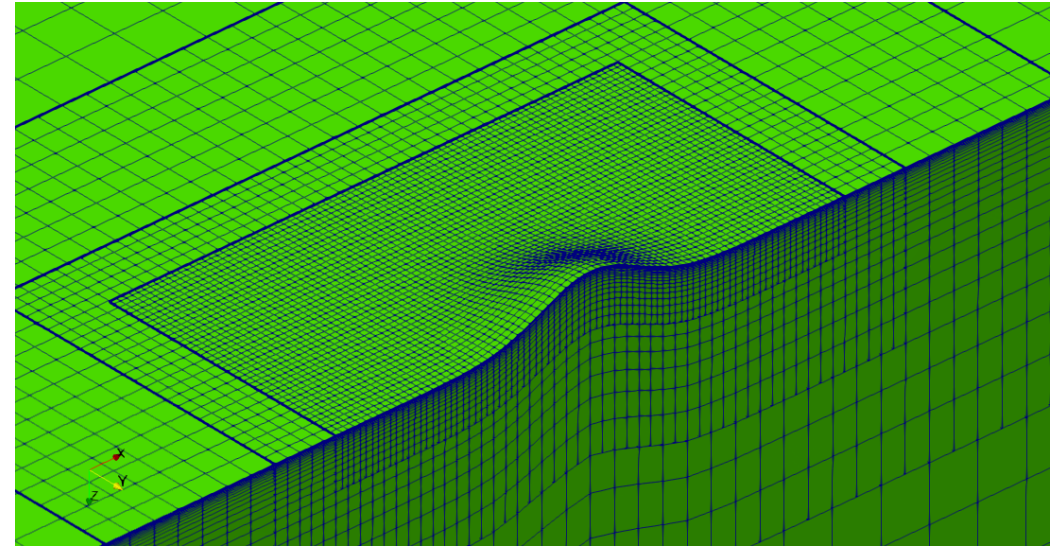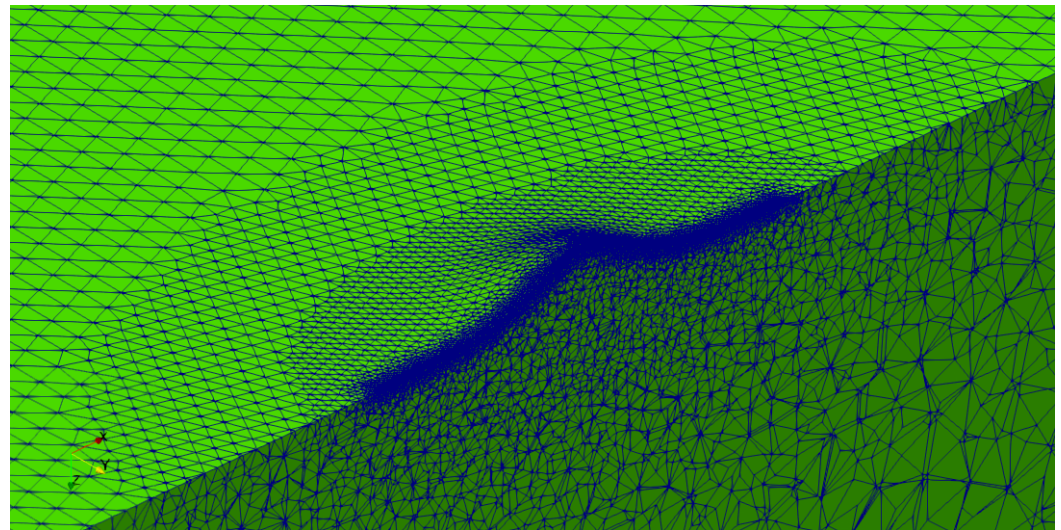Apparent resistivity (TE-mode)

Phase (TE-mode)

Tipper (Imaginary part)

Good agreement !

Test of forward calculation (2) - Seafloor with a 3-D bell-shaped sea mountain -

Non-conforming deformed hexahedral mesh

Bathymetry

Sea: 3(S/m)

The Earth: 0.01(S/m)

Sea depth (m)

Distance along a line through the center (m)

Sea depth (km)
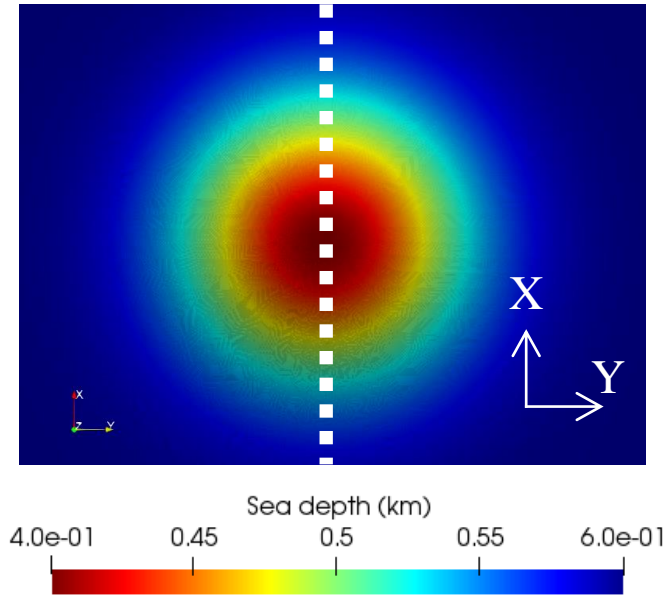
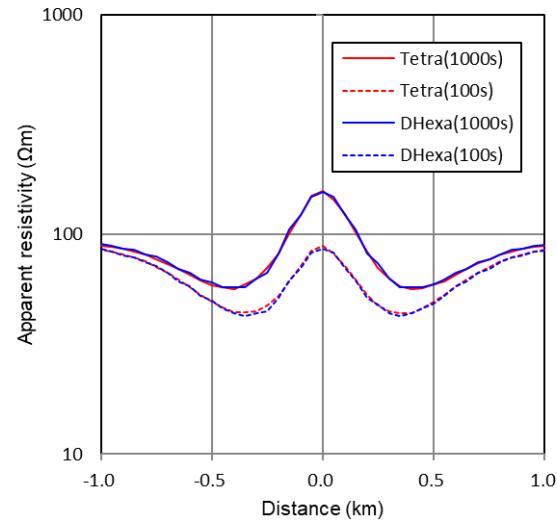4.0e-01   0.45   0.5   0.55   6.0e-01
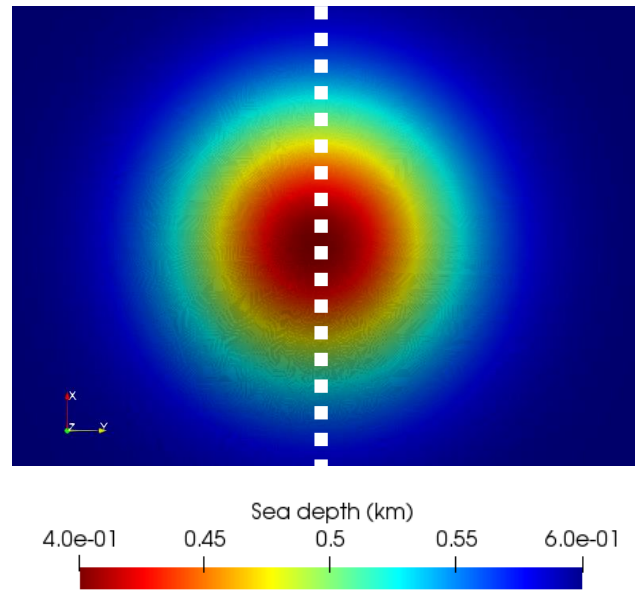
Tetrahedral mesh

➢ Analytical solutions of the 3-D bathymetry is not available.

➢ I compared the calculated response function by a non-conforming deformed hexahedral mesh with those obtained by a tetrahedral mesh.
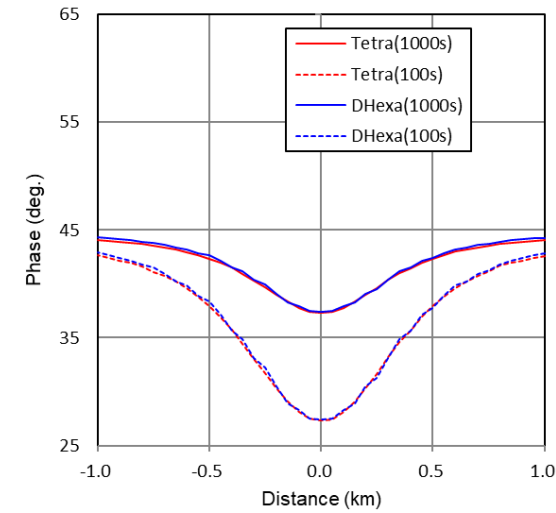
Test of forward calculation (2) - Seafloor with a 3-D bell-shaped sea mountain -
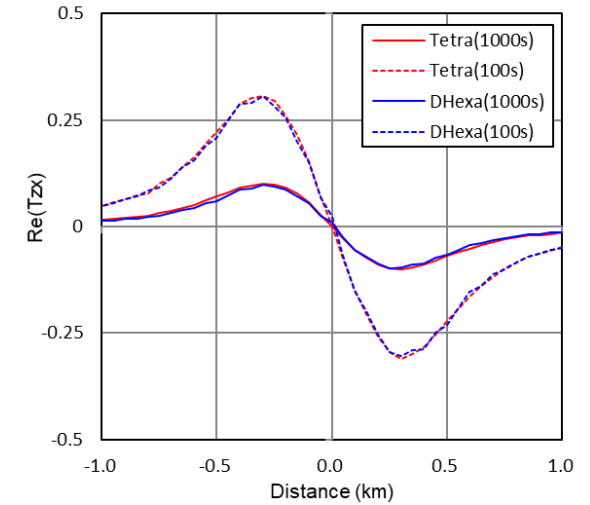

Sea depth (km)

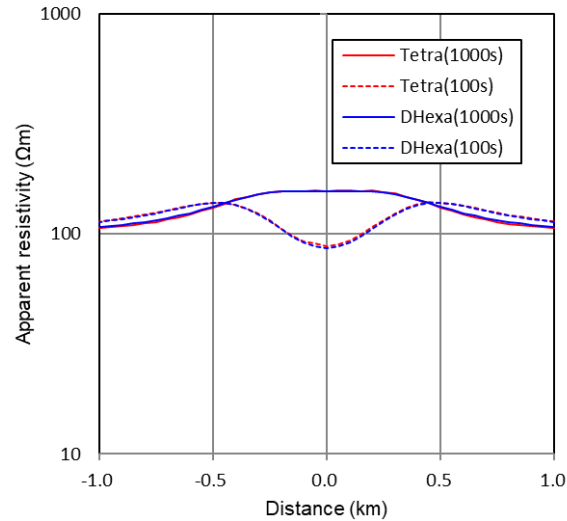Good agreement !

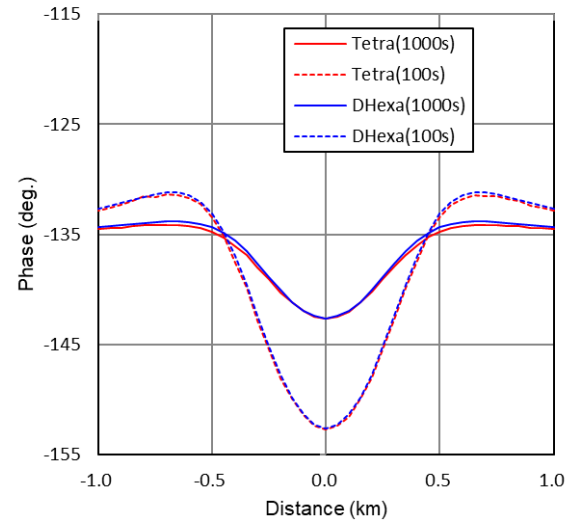### Apparent resistivity (XY)

Phase (XY)

Tipper (Real ZX)

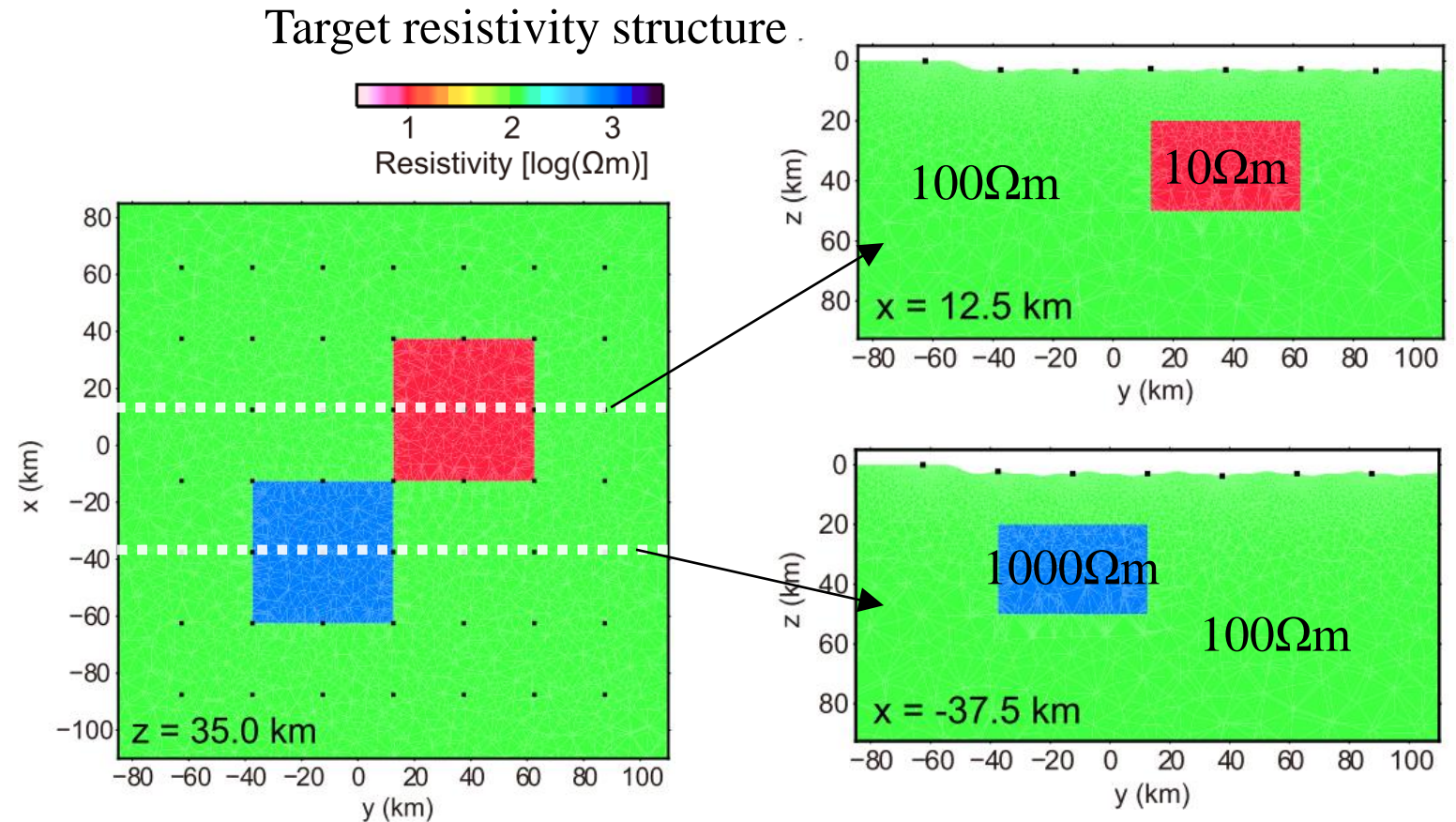### Apparent resistivity (YX)

Phase (YX)

Tipper (Imaginary ZX)

Test of inversion

Bathymetry
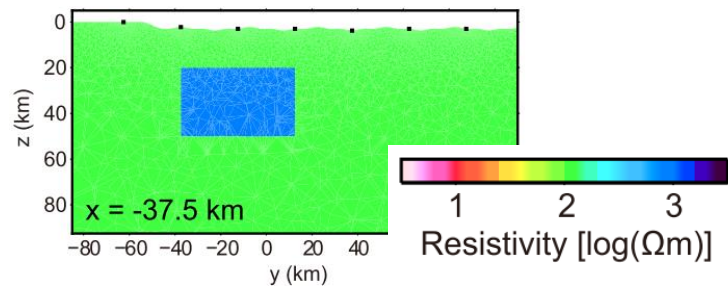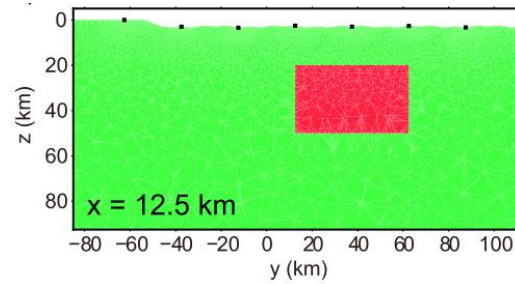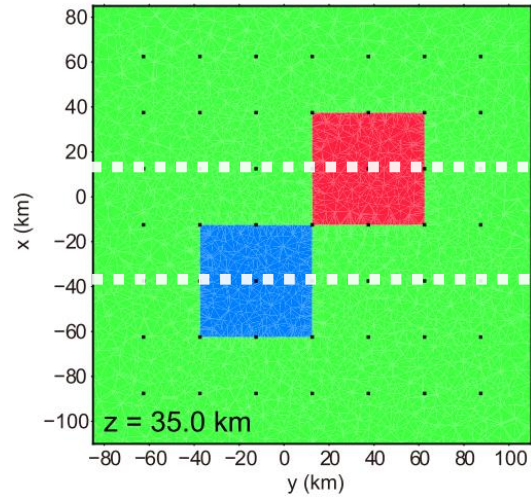

Usui et al. (2018)

Target resistivity structure
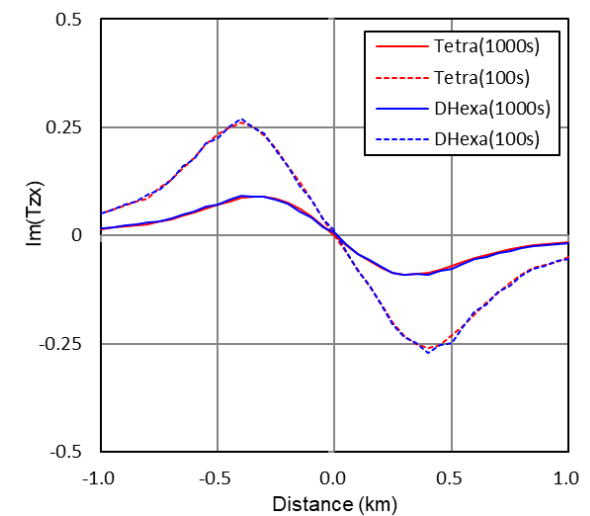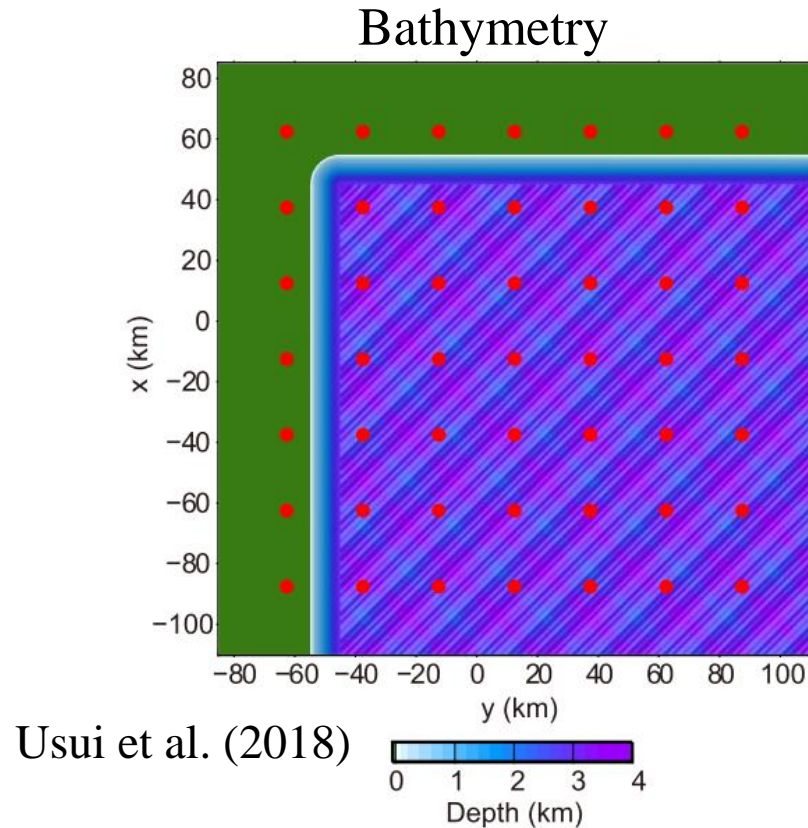
➢ I used the impedance tensor and the tipper calculated by a tetrahedral mesh as input data.
➢ Periods: 16 periods from 31.6 to 10,000 s
➢ Gaussian noise was added to the synthetic data.
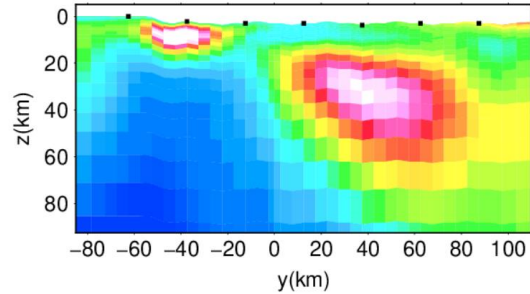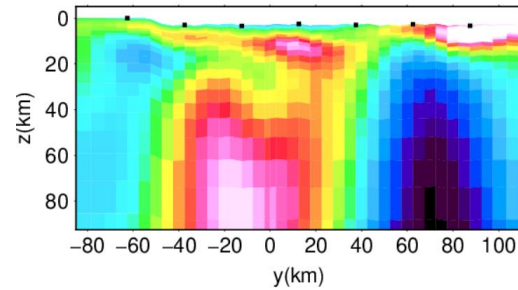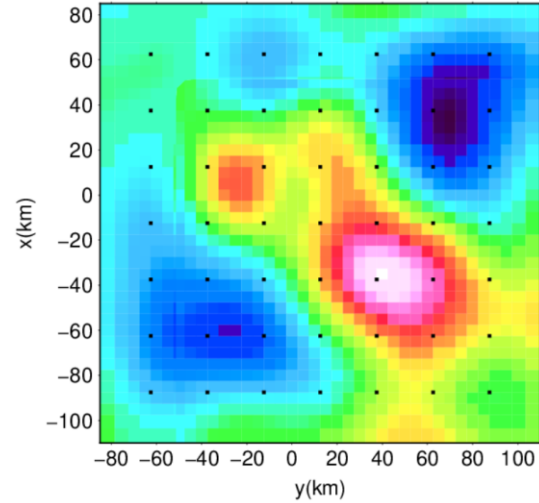 Standard deviation for the impedance tensor components: $0.05 \times \max(|Z_{xy}|, |Z_{yx}|)$
  Standard deviation for the tipper components: $0.05 \times \max(|T_{zx}|, |T_{zy}|, 1.0)$
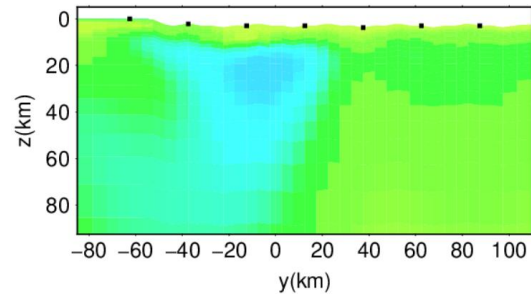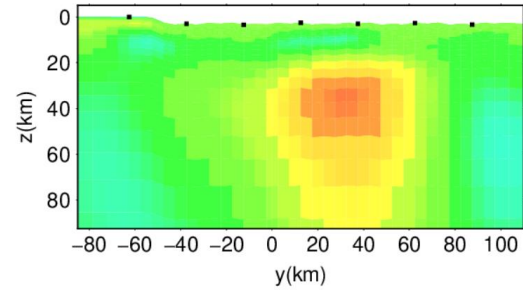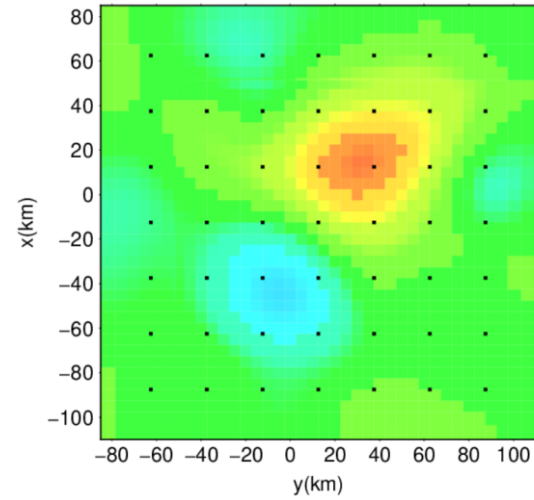
Test of inversion

True structure

From 10 Ωm
RMS = 3.70

From 100 Ωm
RMS = 1.03

From 1000 Ωm
RMS = 1.03

Resistivity [log(Ωm)]