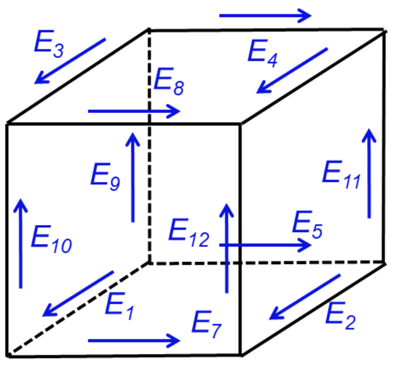
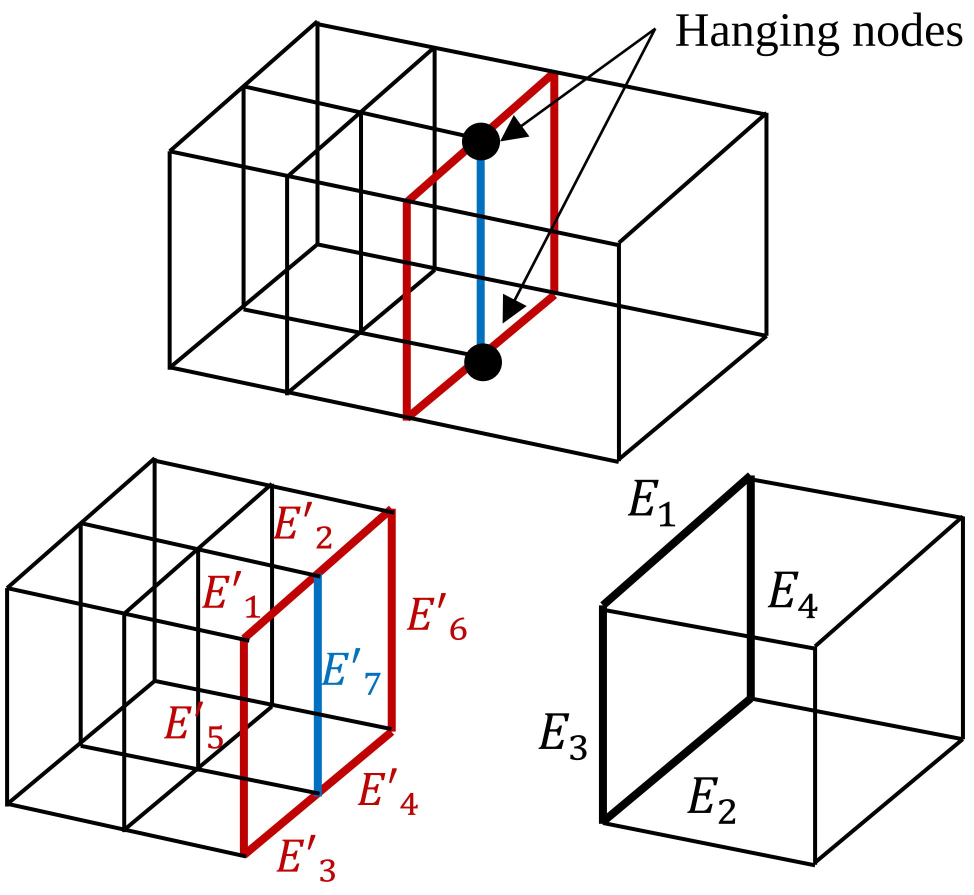
Forward algorithm

- The edge-based hexahedral element is used.

$$\boldsymbol{E}(\boldsymbol{r}) = \sum_{i=1}^{8} \boldsymbol{N}_i(\boldsymbol{r}) E_i$$



- 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).

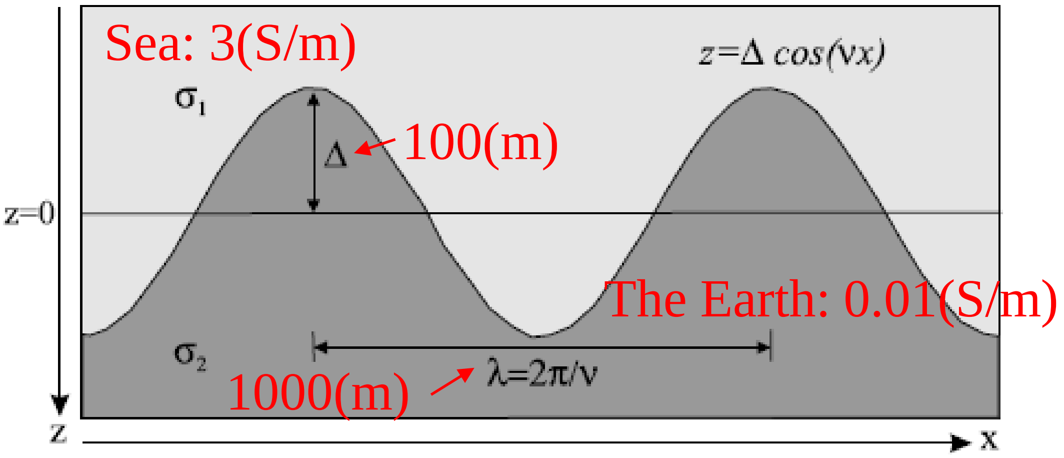


$$E'_1 = E'_2 = E_1 \qquad E'_5 = E_3$$

$$E'_3 = E'_3 = E_2 \qquad E'_6 = E_4$$

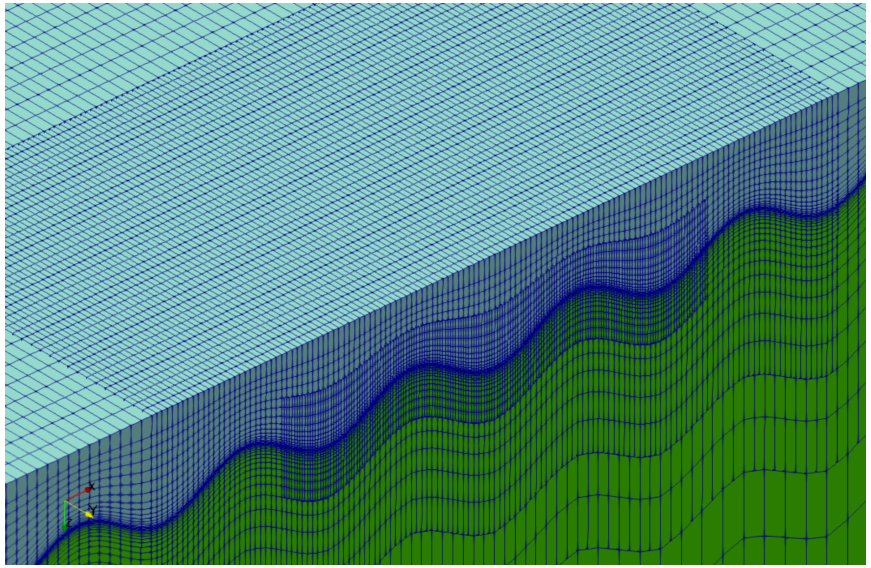
$$E'_7 = \frac{E'_5 + E'_6}{2} = \frac{E_3 + E_4}{2}$$

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

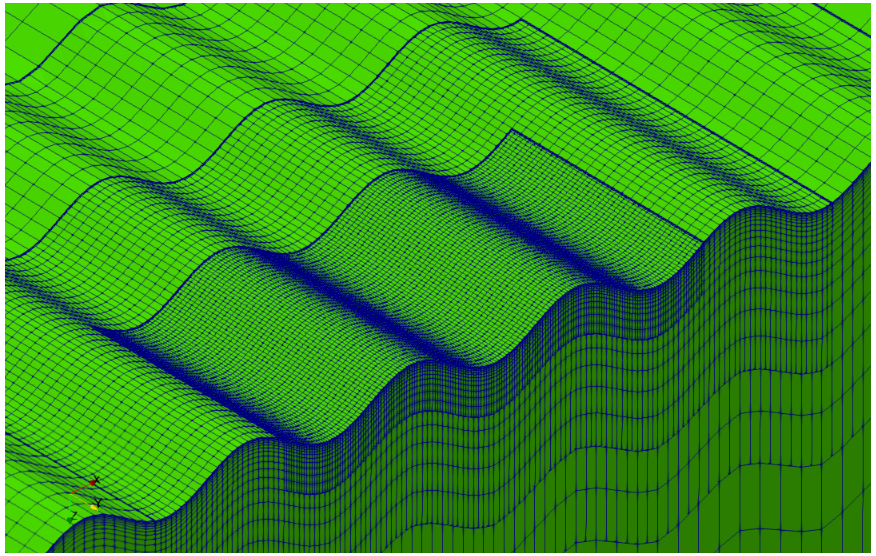


Schwalenberg & Edwards (2004, GJI)

Mesh of the sea and the subsurface



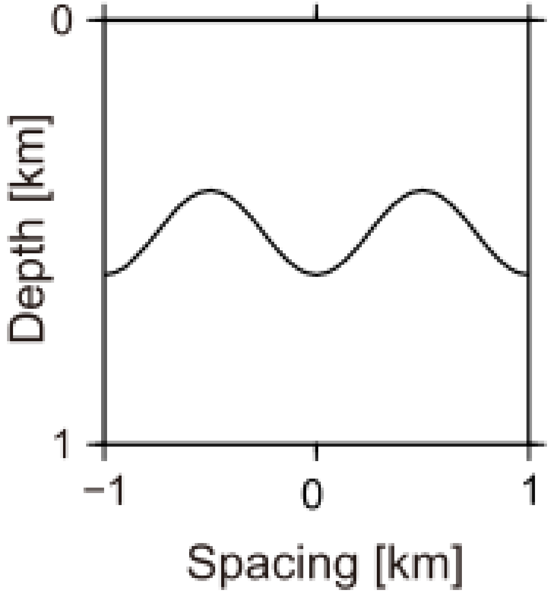
Mesh of the subsurface



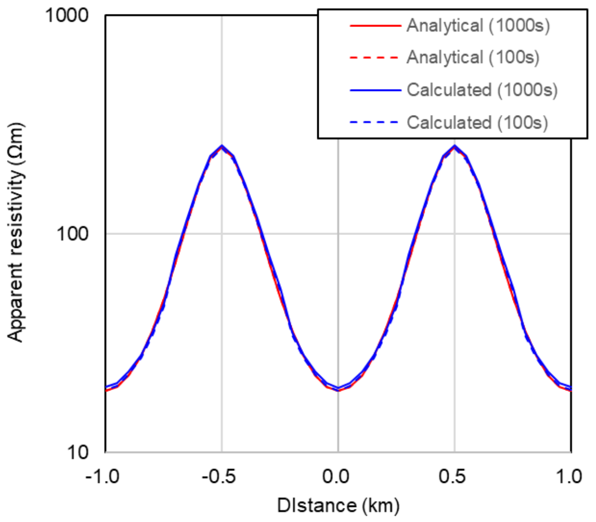
- Schwalenberg & Edwards (2004) and Usui et al. (2018) showed semi-analytical formulation for the seafloor with 2-D sinusoidal undulation.
- I calculated the apparent resistivity, the phase, and the vertical magnetic transfer functions (tipper) by using developed inversion code.
- I compared the calculated response functions with the analytical solutions.

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

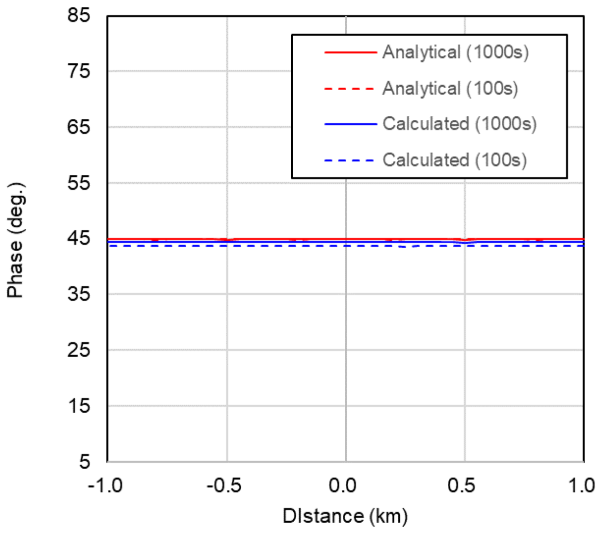
Bathymetry



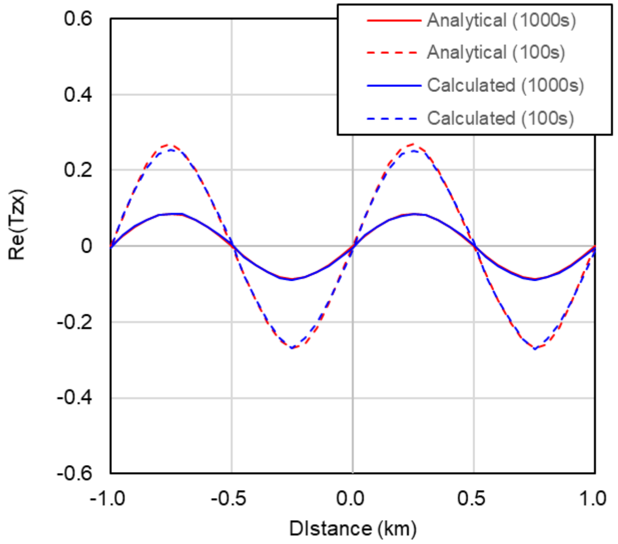
Apparent resistivity (TM-mode)



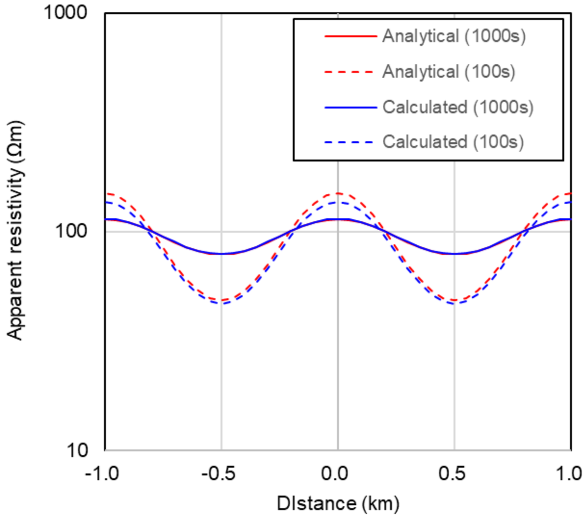
Phase (TM-mode)



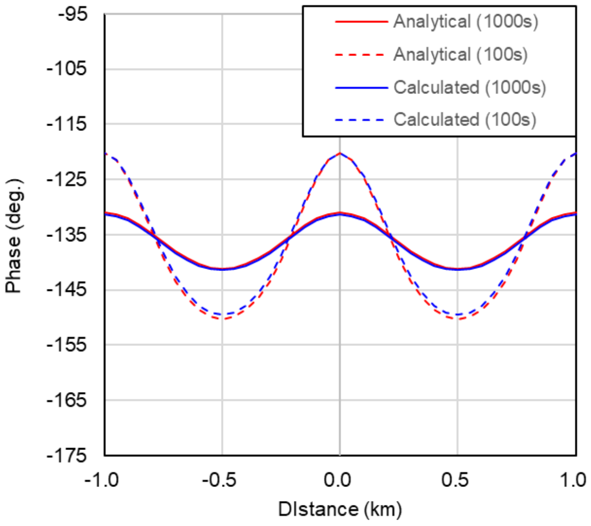
Tipper (Real part)



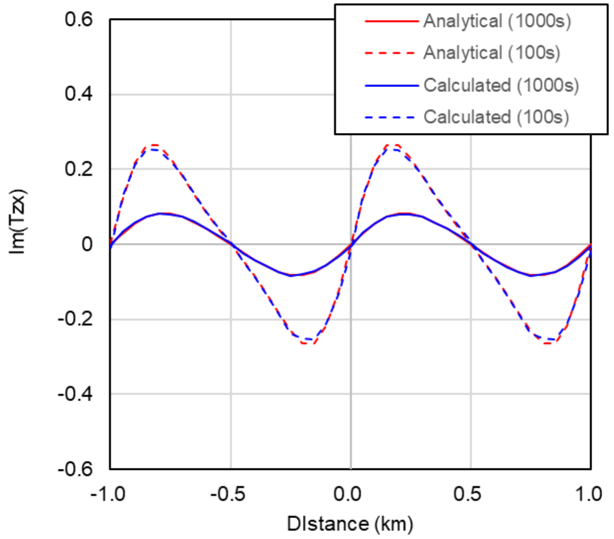
Apparent resistivity (TE-mode)



Phase (TE-mode)

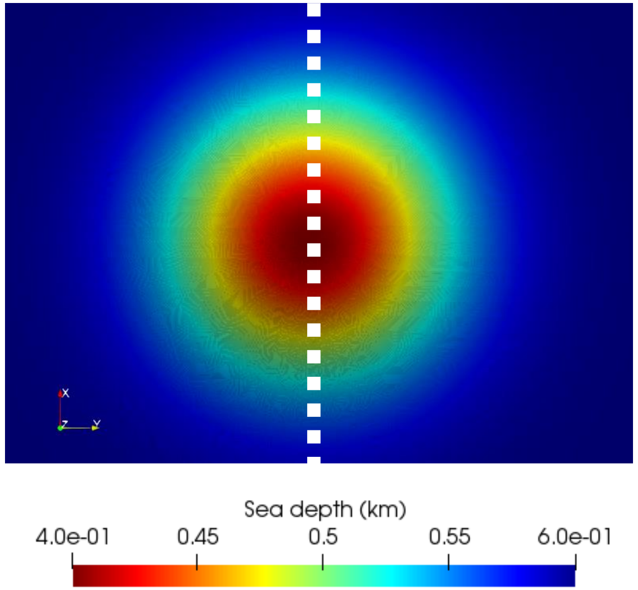


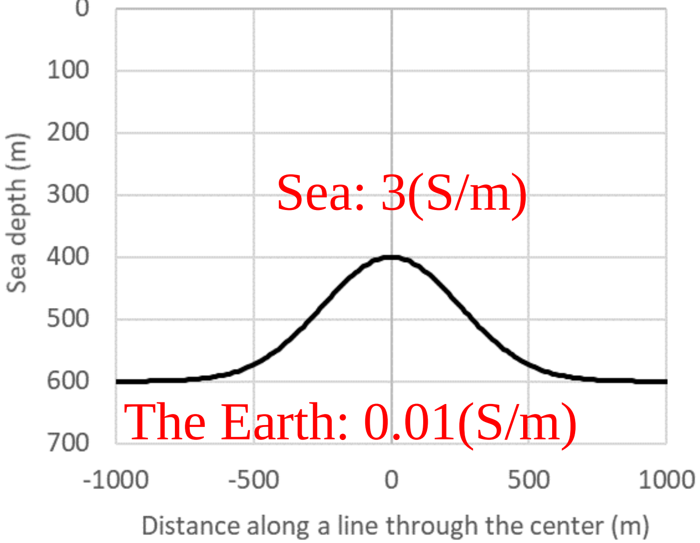
Tipper (Imaginary part)



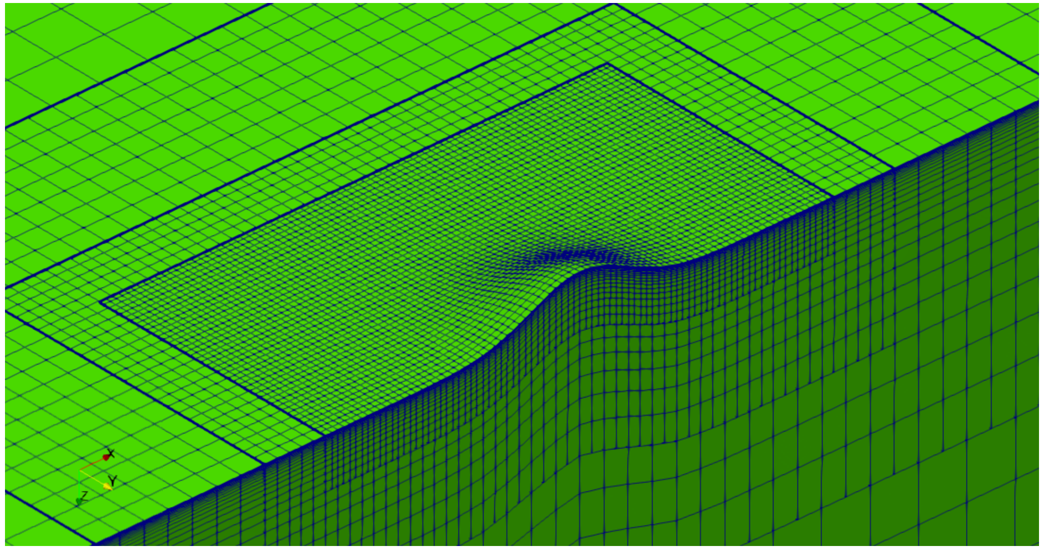
Good agreement !

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

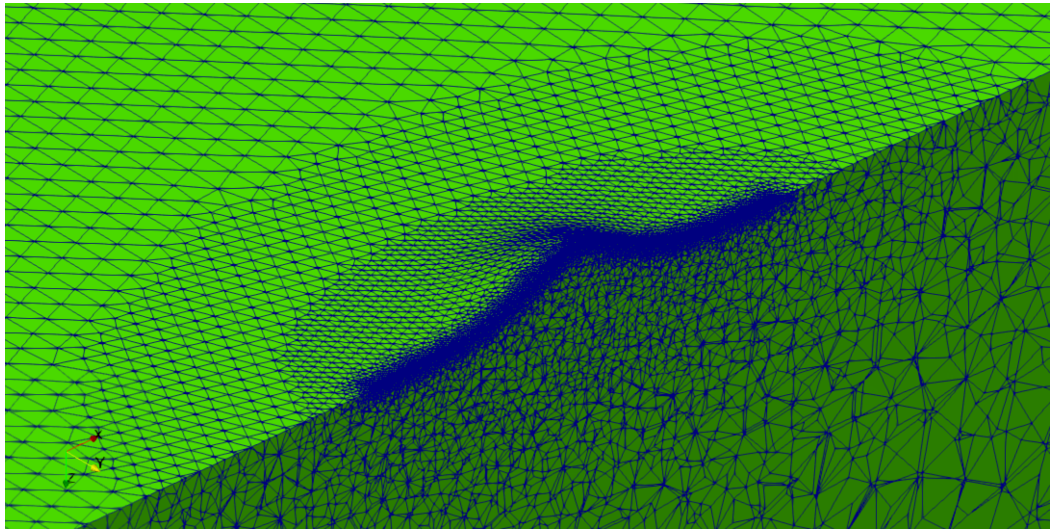




Non-conforming deformed hexahedral mesh

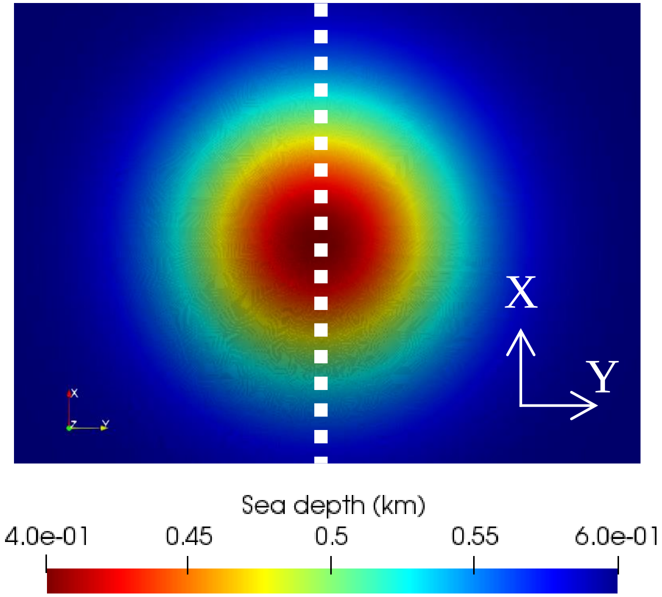


Tetrahedral mesh

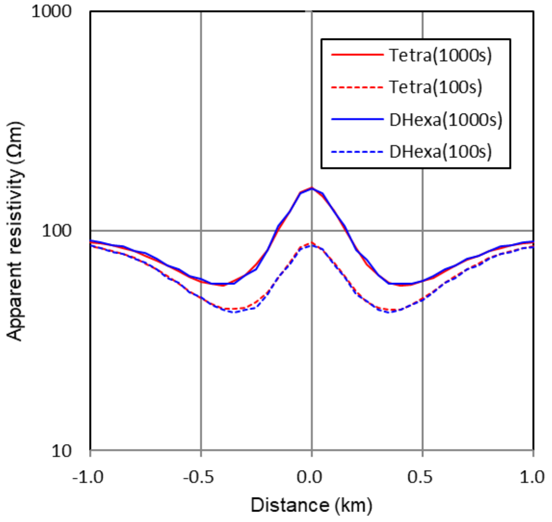


- Analytical solutions of the 3-D bathymetry is not available.
- I compared the calculated response function by a non-conforming deformed hexahedral mesh with those obtained by a tetrahedral mesh.

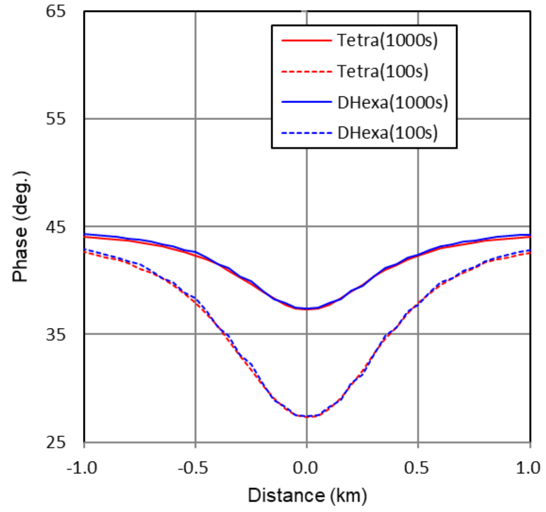
Test of forward calculation (2) - Seafloor with a 3-D bell-shaped sea mountain -



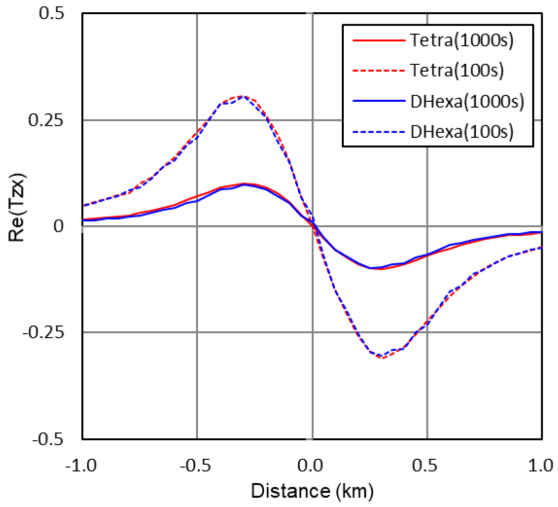
Apparent resistivity (XY)



Phase (XY)

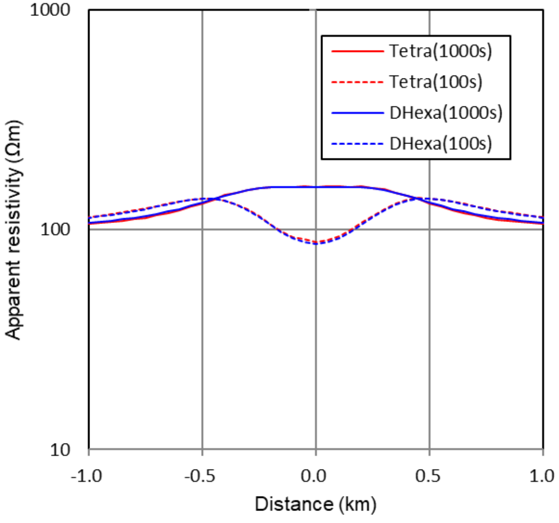


Tipper (Real ZX)

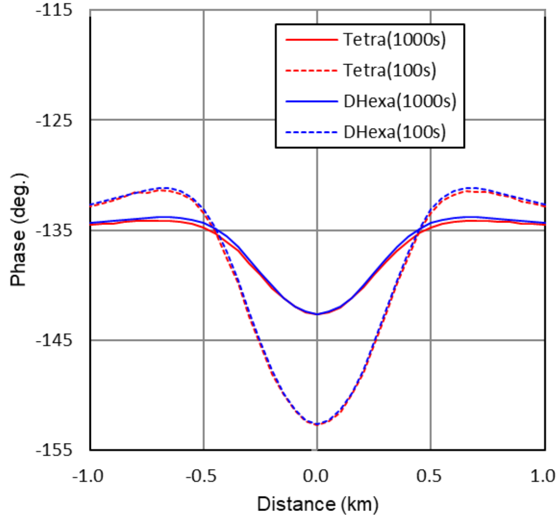


Good agreement !

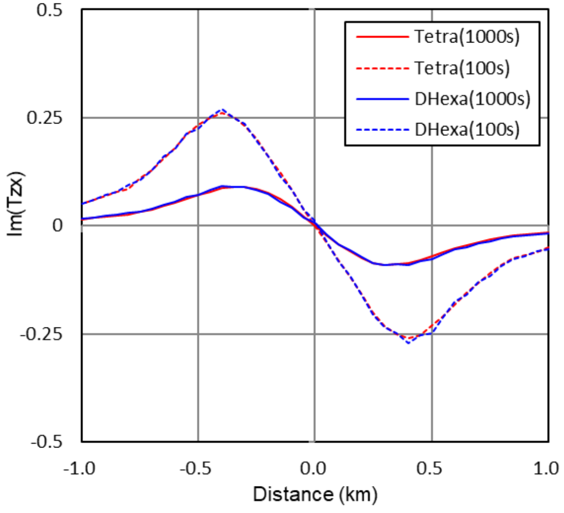
Apparent resistivity (YX)



Phase (YX)

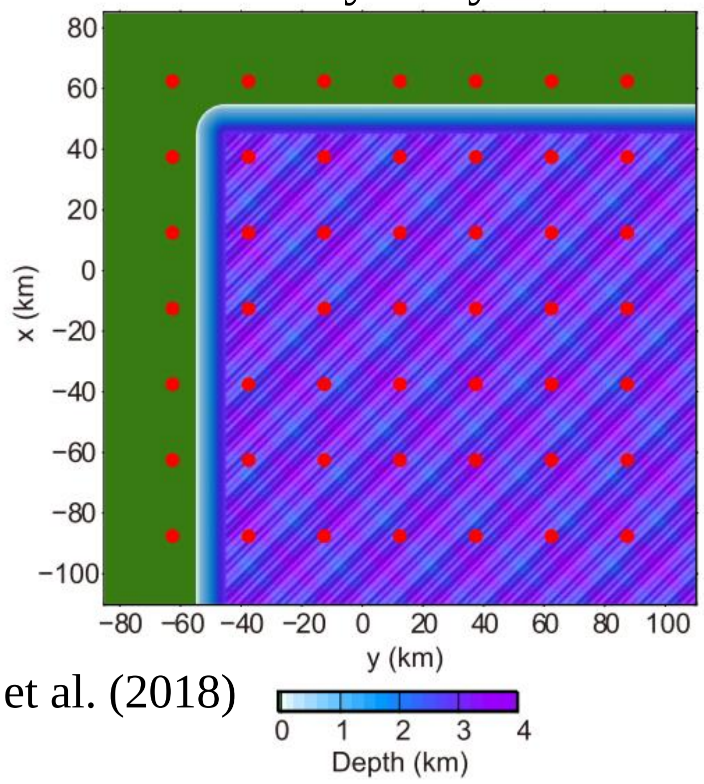


Tipper (Imaginary ZX)



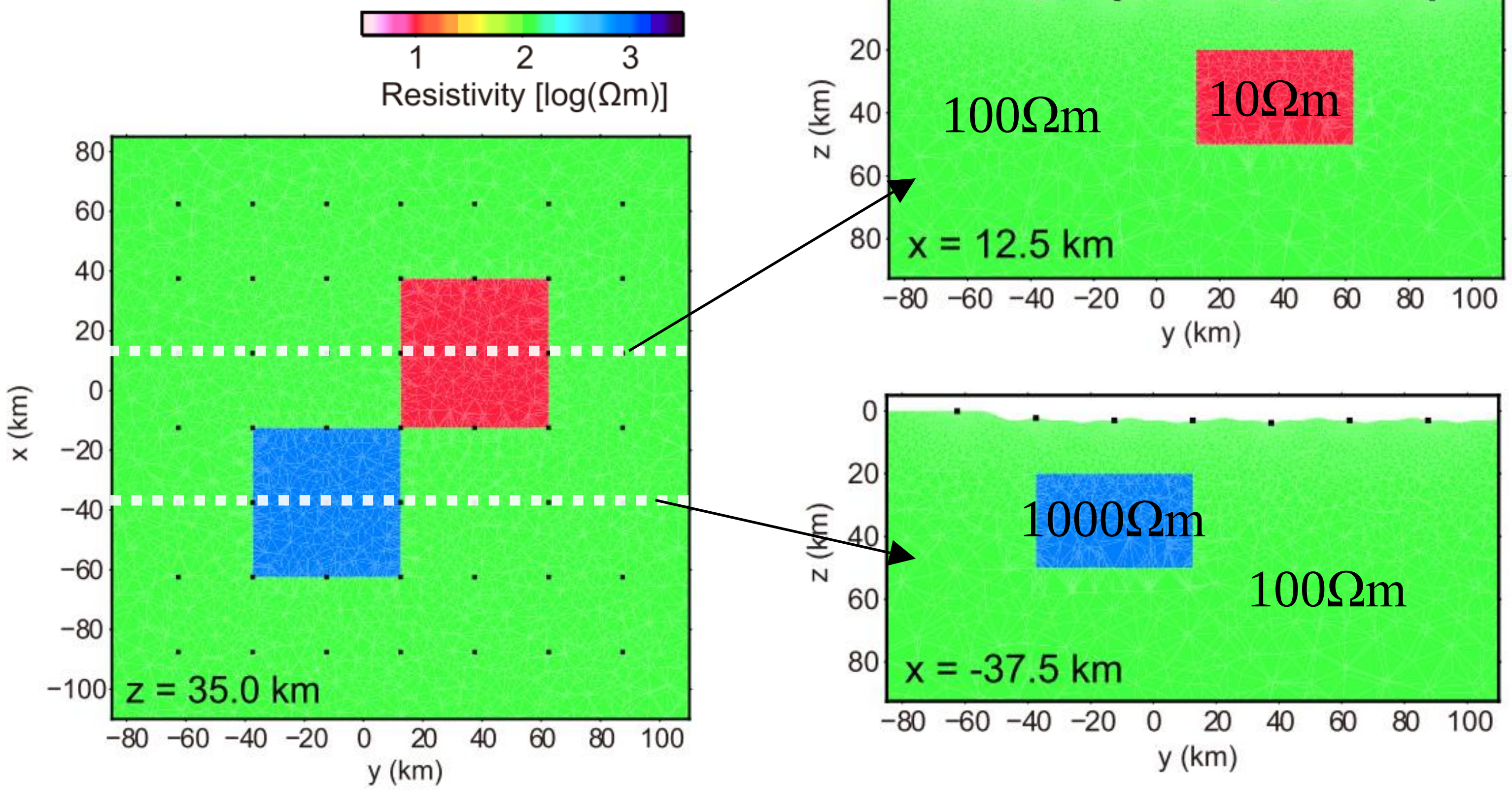
Test of inversion

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