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On Boundary Conditions for CSEM Finite Element Modeling, I

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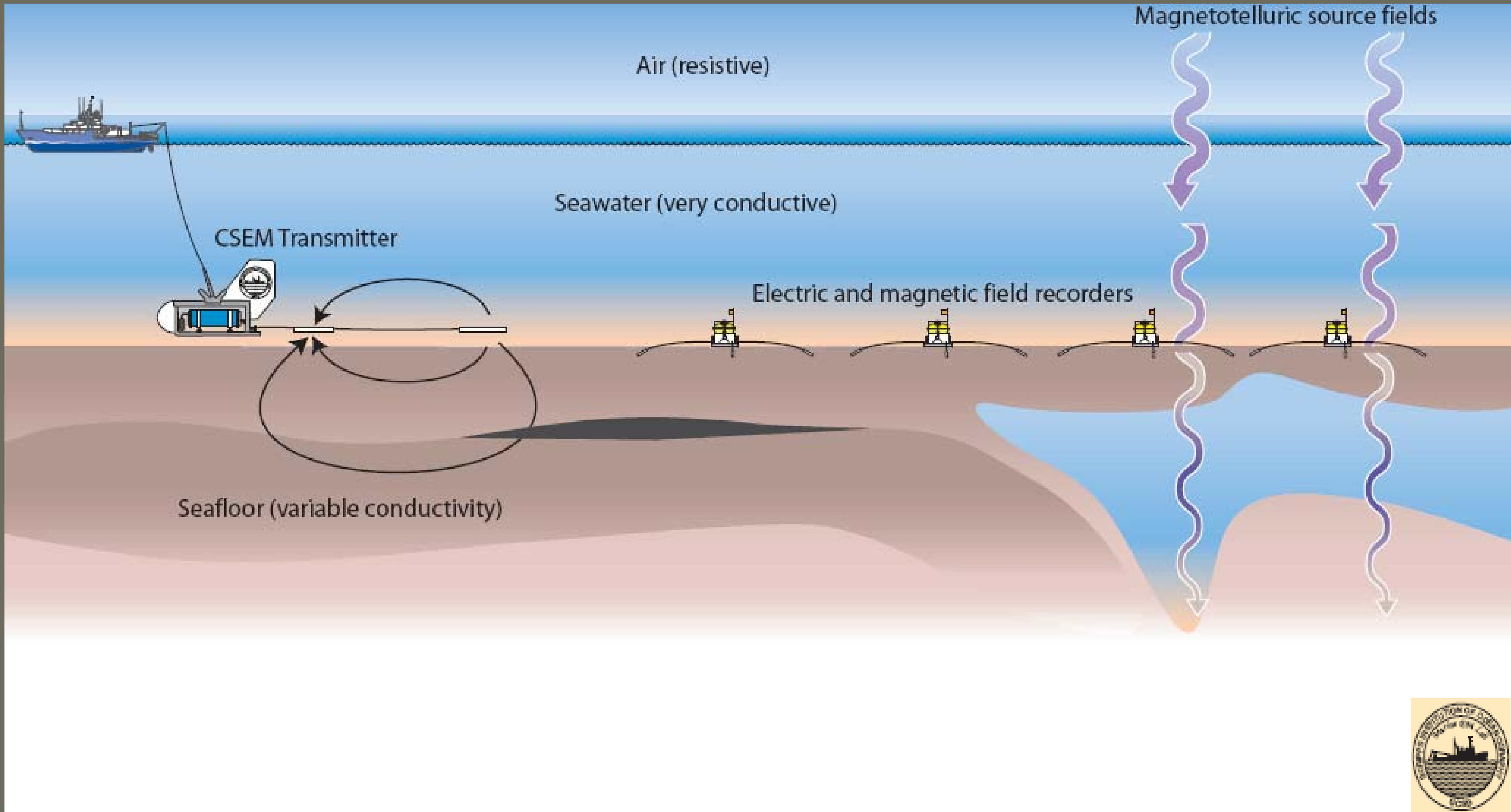
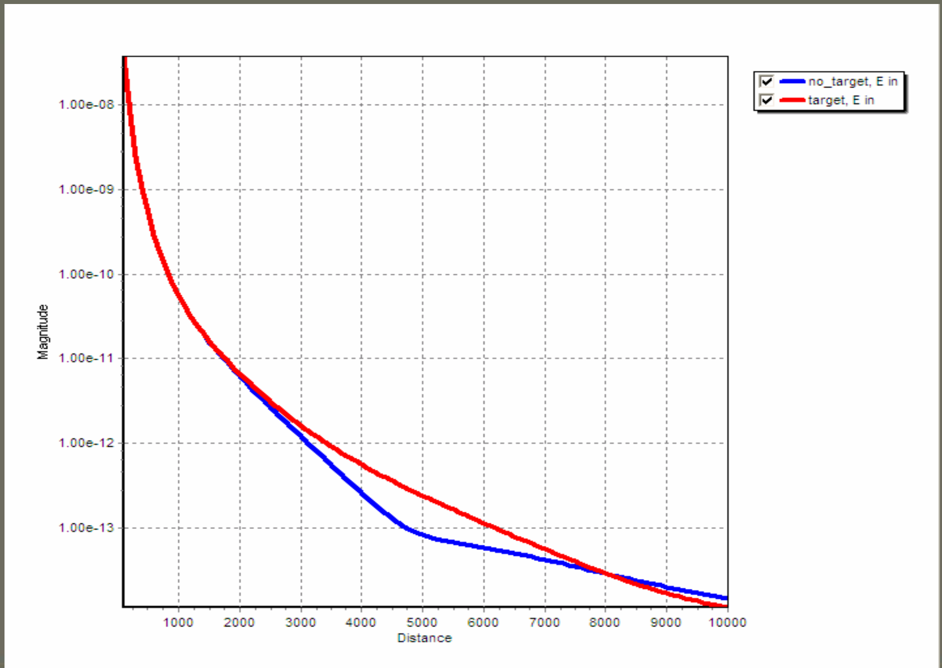
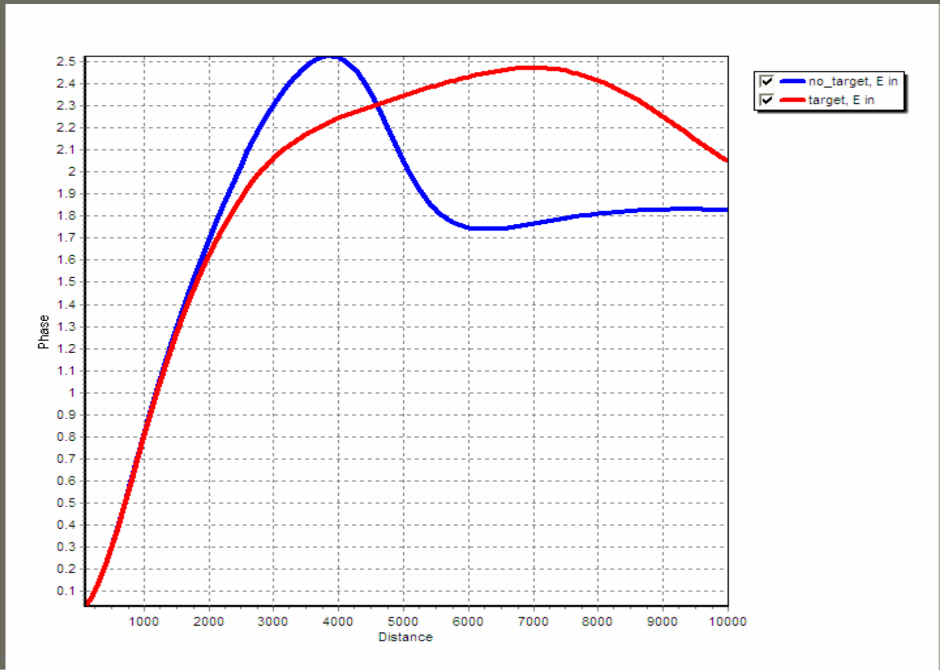
Marine CSEM: high conductive, low frequency of 0.1 ~ 10 Hz



marine CSEM: measured data types

- Amplitude vs. offset (AVO) curves, “log-scale”
- Phase vs. offset (PVO) curves





2.5D modeling and EM equation

- 2D geological structure in many cases, i.e. $\varepsilon=\varepsilon(x,z)$, $\mu=\mu(x,z)$, and $\sigma=\sigma(x,z)$.
- 3D unit-dipole source in use.
- 2.5D modeling (2D geological structure; 3D point source) is the most practical!

$$\frac{\partial}{\partial x}\left[\frac{i\omega\varepsilon}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial E_y}{\partial x}\right]+\frac{\partial}{\partial z}\left[\frac{i\omega\varepsilon}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial E_y}{\partial z}\right]-i\omega\varepsilon E_y-\frac{\partial}{\partial x}\left[\frac{ik_y}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial H_y}{\partial z}\right]+\frac{\partial}{\partial z}\left[\frac{ik_y}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial H_y}{\partial x}\right]=\frac{\partial}{\partial x}\left[\frac{ik_y}{k_y^2-\omega^2\mu\varepsilon}J_{sx}\right]$$

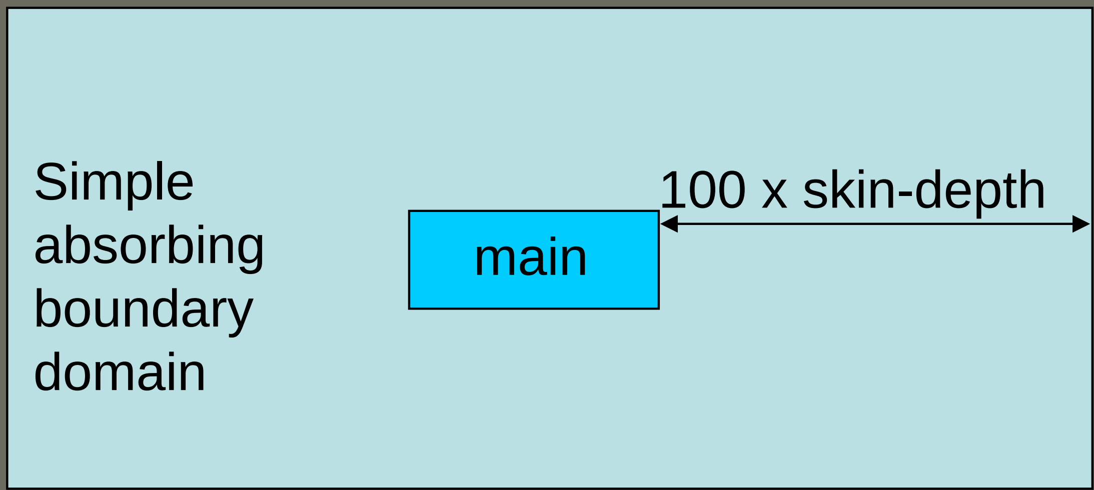
$$\frac{\partial}{\partial x}\left[\frac{i\omega\mu}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial H_y}{\partial x}\right]+\frac{\partial}{\partial z}\left[\frac{i\omega\mu}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial H_y}{\partial z}\right]-i\omega\mu_y H_y+\frac{\partial}{\partial x}\left[\frac{ik_y}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial E_y}{\partial z}\right]-\frac{\partial}{\partial z}\left[\frac{ik_y}{k_y^2-\omega^2\mu\varepsilon}\frac{\partial E_y}{\partial x}\right]=-\frac{\partial}{\partial z}\left[\frac{i\omega\mu_z}{k_y^2-\omega^2\mu\varepsilon}J_{sx}\right]$$

Challenges in using FEM

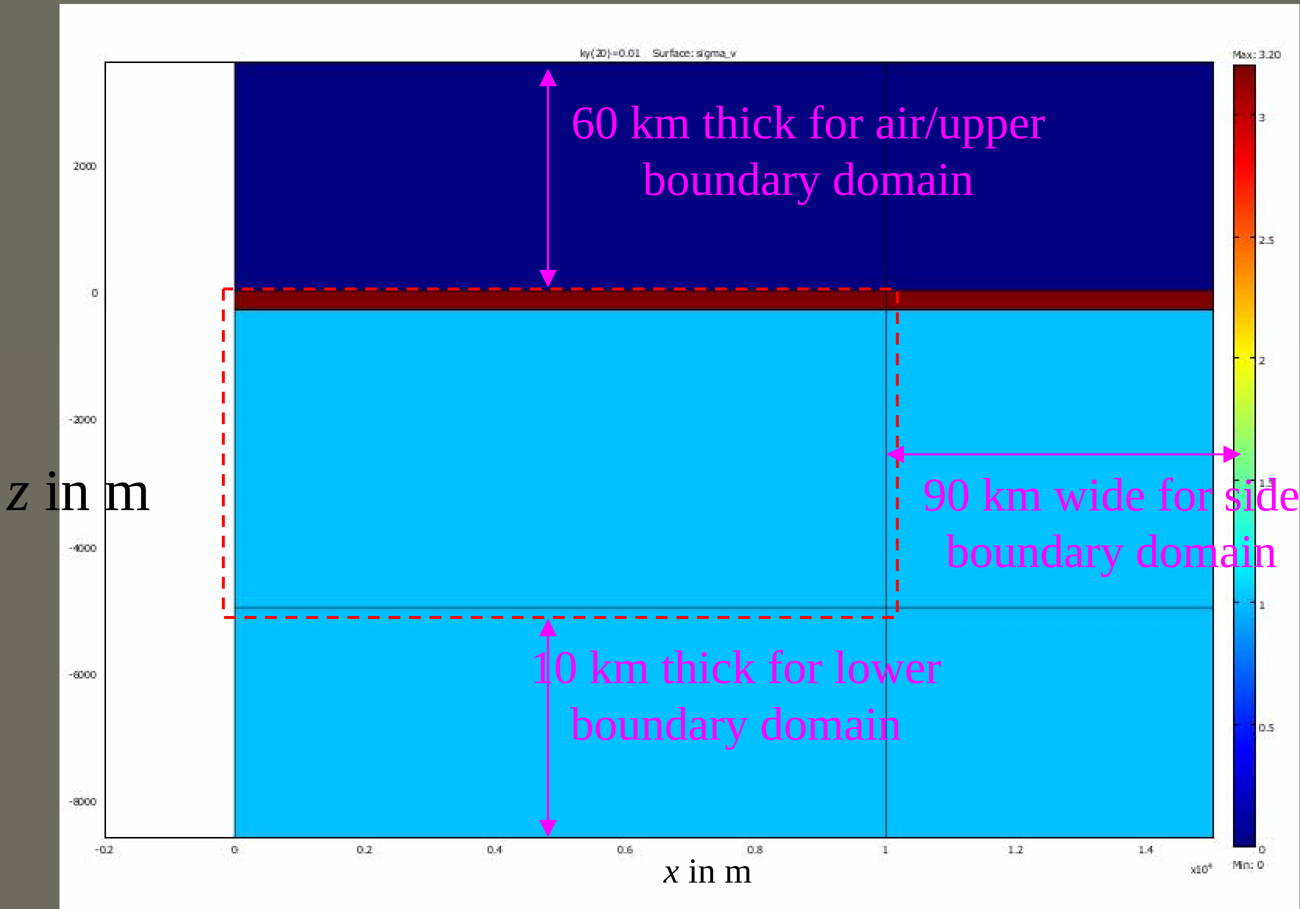
- Source singularity: general in FE application; but near-field is not of the major interest.
- Absorbing boundary conditions/domains: general in FE application; even more crucial in CSEM.
- Discretization relating to skin-depth, not wavelength: at least 4 quadratic elements per skin-depth.
- AVO curves are in logarithmic scale of range of 10 order.

Simple absorbing boundary domain, proposed

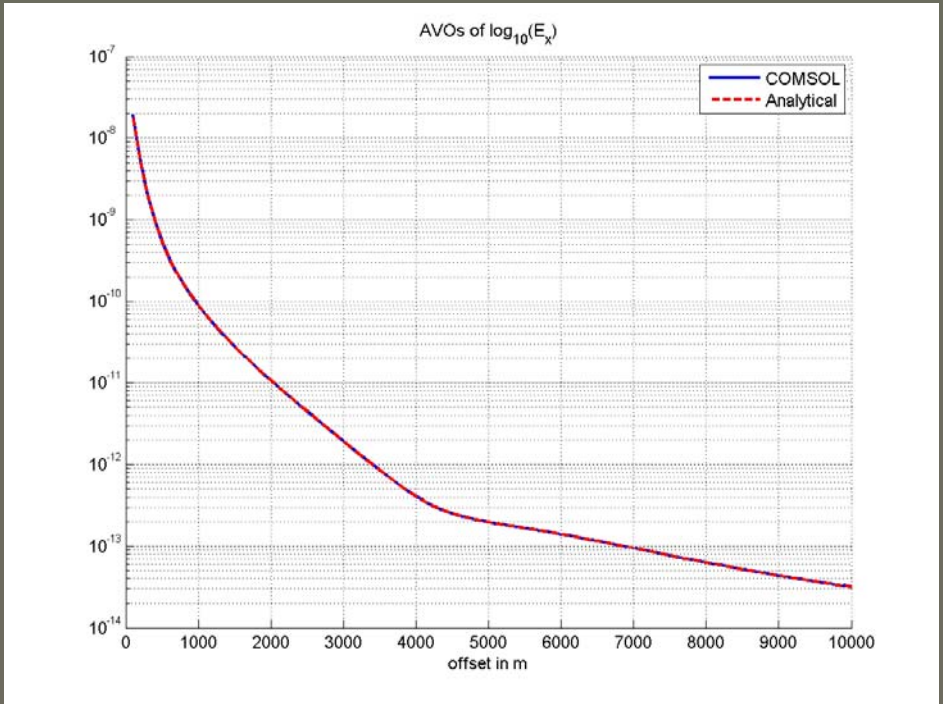
- 100 x (skin-depth): left and right boundary domains are important!!!
- 20 elements/layers, exponentially increasing

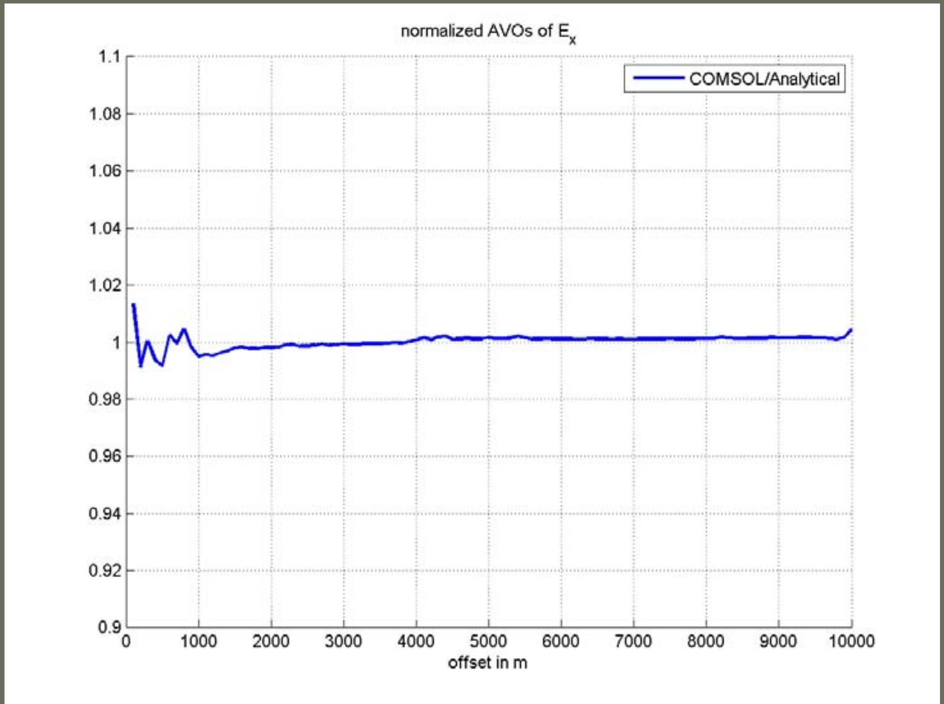


Numerical example: simplest model, to see only the artificial reflection



Numerical example: results, less than 1% error!





Other absorbing boundary conditions/domains, remarks

- We have also experienced some other advanced boundary conditions or domains such as perfectly matched layer (PML) [ref. 1,6], boundary integral equation method (BIEM) [ref. 8], consistent transmitting boundary condition (CTBC) [ref. 5], impedance boundary condition, etc.
- Each of these domains and conditions has its own advantages and disadvantages.
- PML technique seems a most attractive. However, when applying it to the CSEM FE modeling, it is not trivial to determine the optimal PML parameters for the discrete numerical modeling.
- Currently, we are extending this study and evaluate the simple boundary domain in comparison with the other advanced boundary domains or conditions.

Conclusion and Future work (for COMSOL 2009)

- Simple absorbing boundary domain proposed works quite well, and it is quite robust.

- Nevertheless, meshing in COMSOL might be difficult due to big aspect ratio.

- We need to improve the performance and will present in COMSOL conference in 2009!

Acknowledgements

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