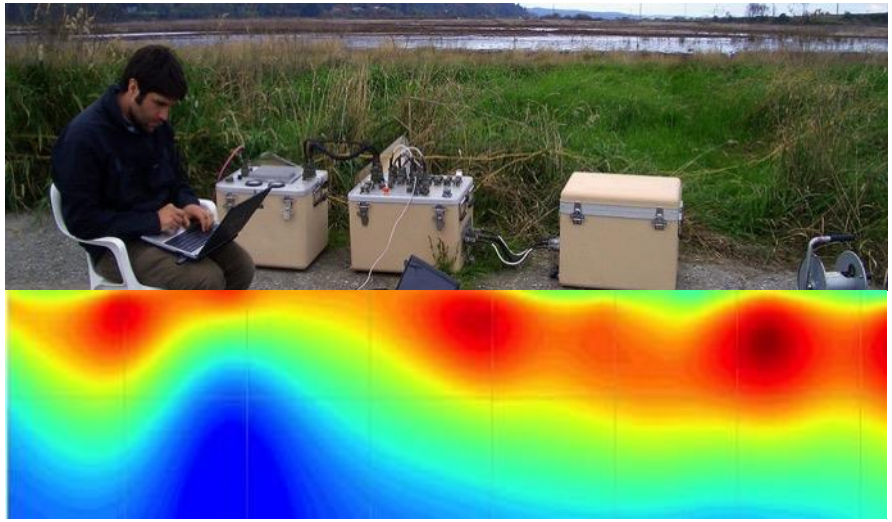
EOSC 350 : Environmental, Geotechnical and Exploration Geophysics I

EM Inversion

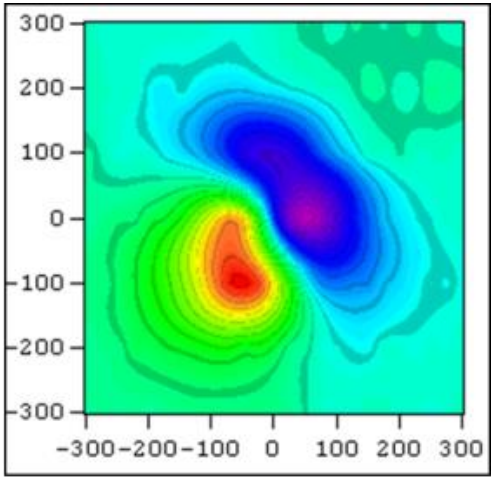


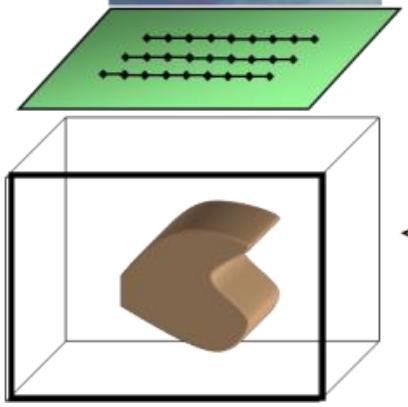
September – December, 2017

Workflow

Field survey

Data



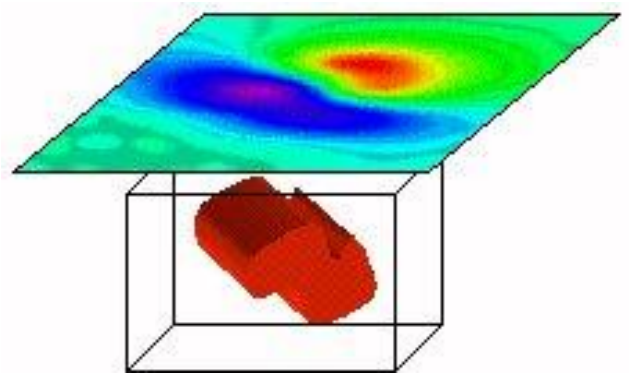


Interpretation

Simulation and inversion

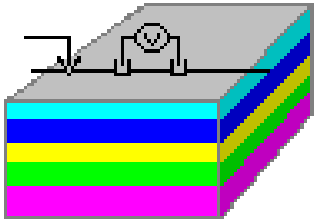
Geophysical Inversions

Data Acquisition

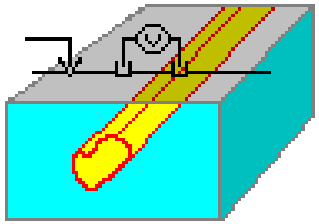


Inversion

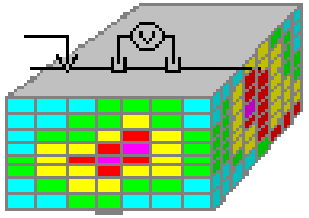
1D Model



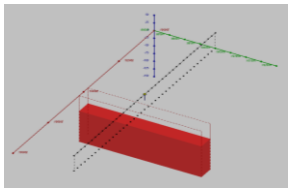
2D Model



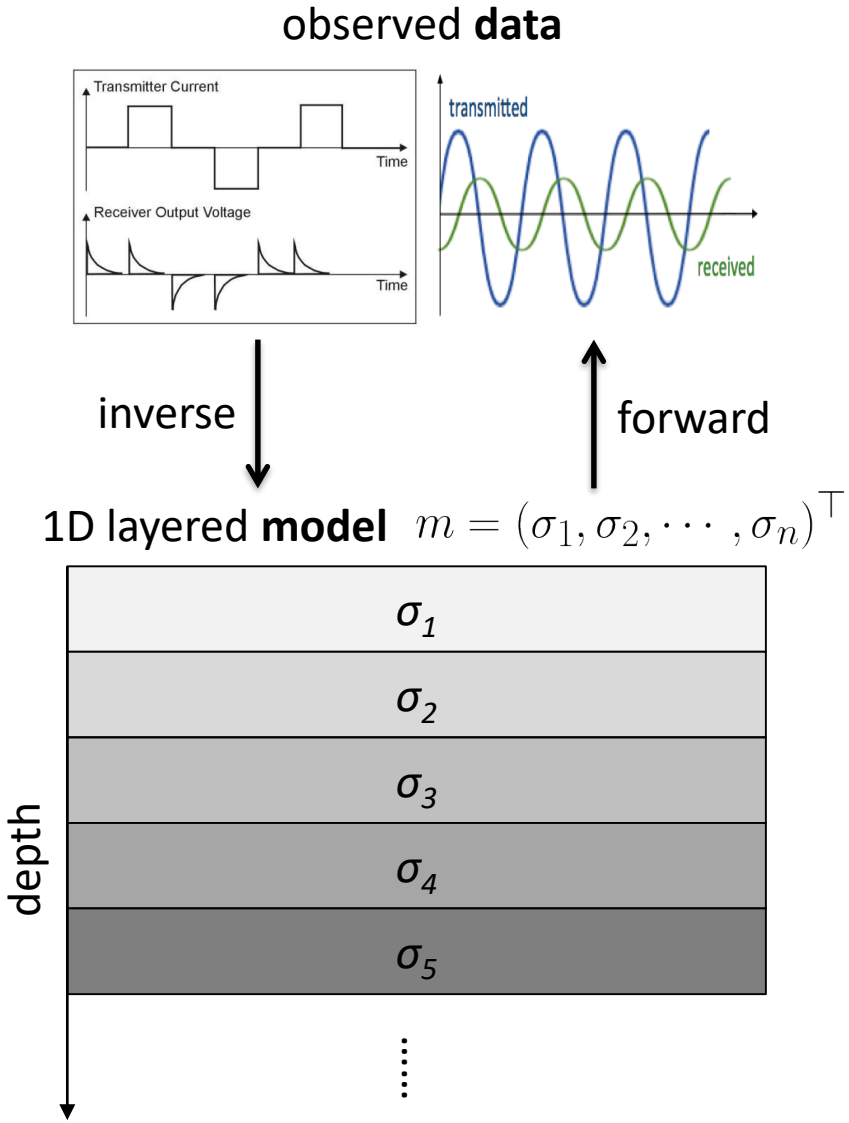
3D Model



Parametric Model



Forward and Inversion



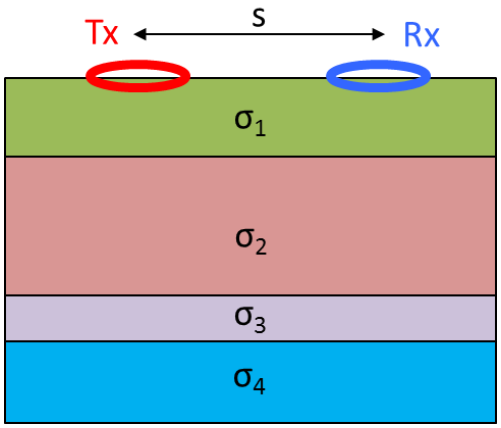
Forward $\mathrm{d} = \mathrm{F}(\mathrm{m}) + \varepsilon$

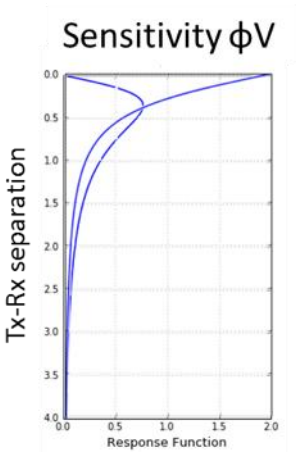
Inverse $\mathrm{m}^* = \mathrm{F}^{-1}(\mathrm{d})$

- m: model vector
- F: forward operator (e.g. Maxwell's equation, Poisson's equation)
- ε: noise
- m*: inferred model

Question: What problems can you expect in the process of recovering the true model by fitting the field data?

Non-uniqueness





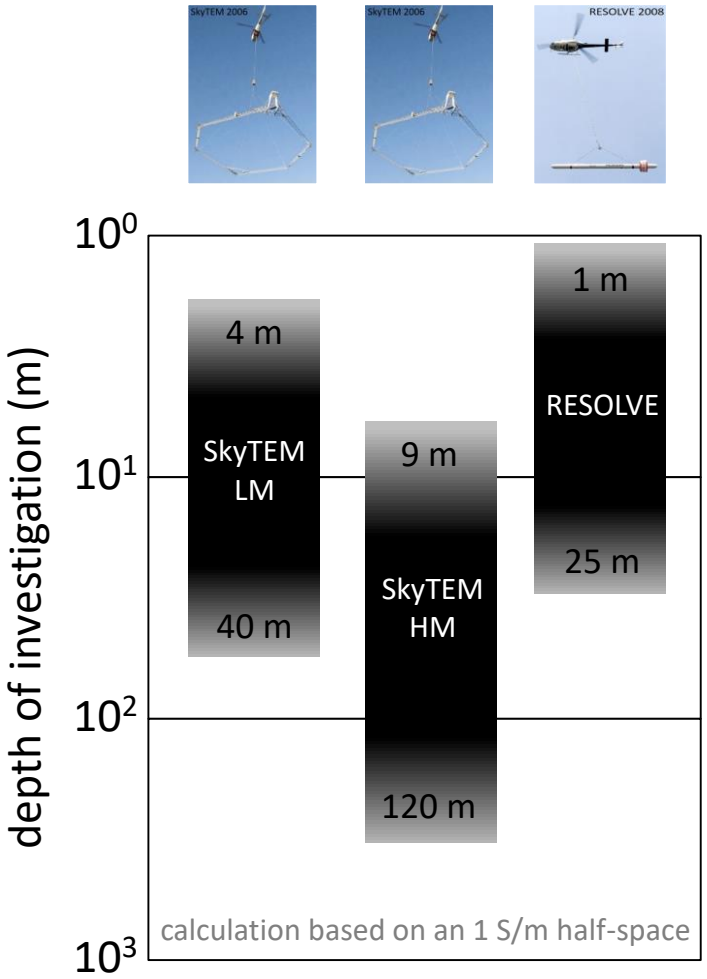
- The data will not change if σ_4 changes
- An infinite number of feasible models
- Regularized inversion
  - fit the data
  - model as simple as possible

Objective functional

$$\phi = \phi_d + \beta\phi_m$$

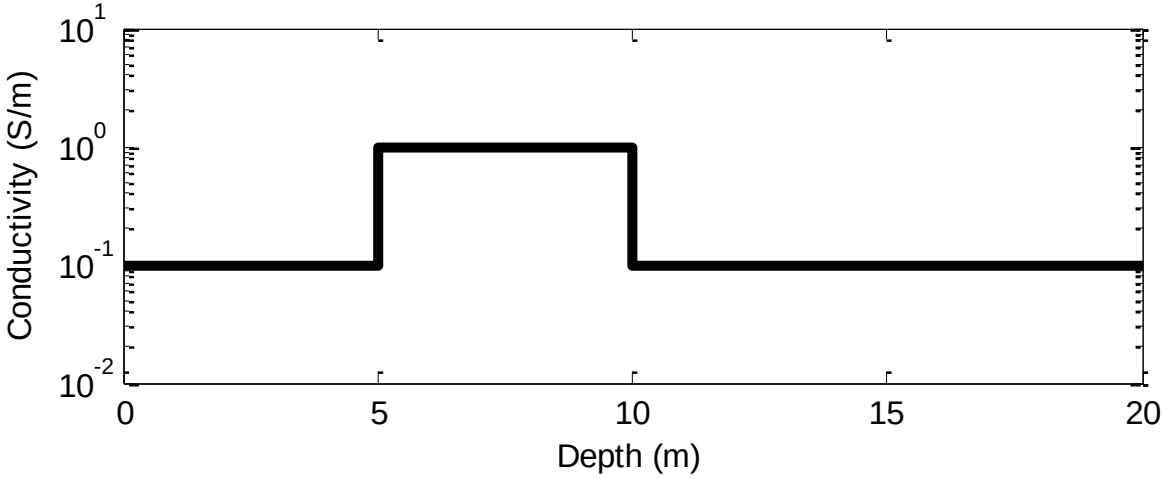
$$\phi_d = \sum_{i=1}^{N} \left(\frac{F_i[m] - d_i}{\epsilon_i} \right)^2$$

$$\phi_m = \alpha_s \|\mathbf{W}_s(m - m^{\text{ref}})\|^2 + \alpha_z \|\mathbf{W}_z(m - m^{\text{ref}})\|^2$$

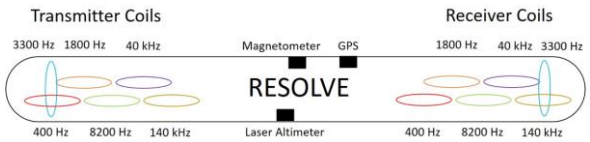


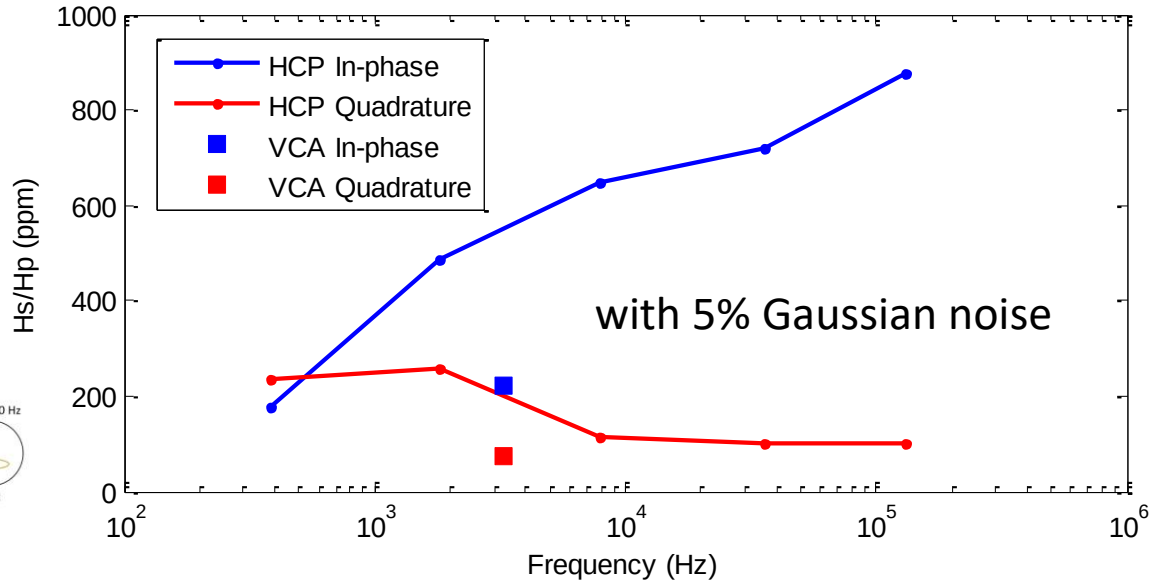
1D Forward Modeling

1D conductivity model

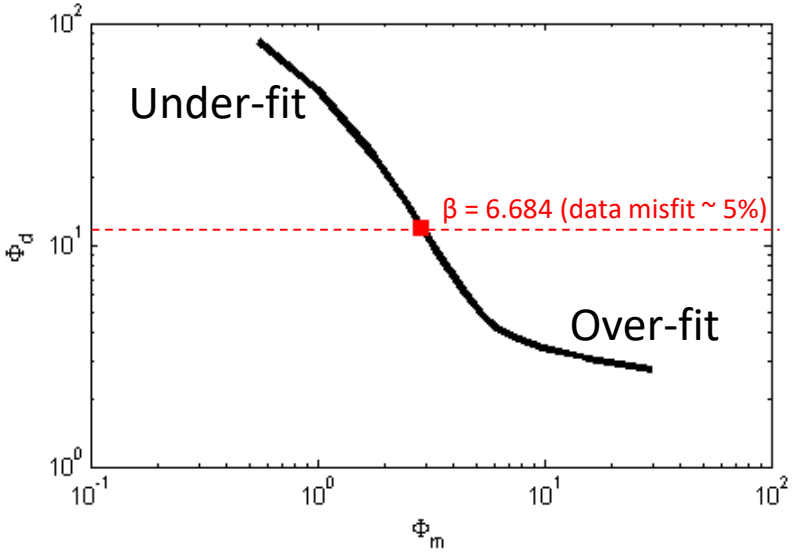


FEM responses (RESOLVE)

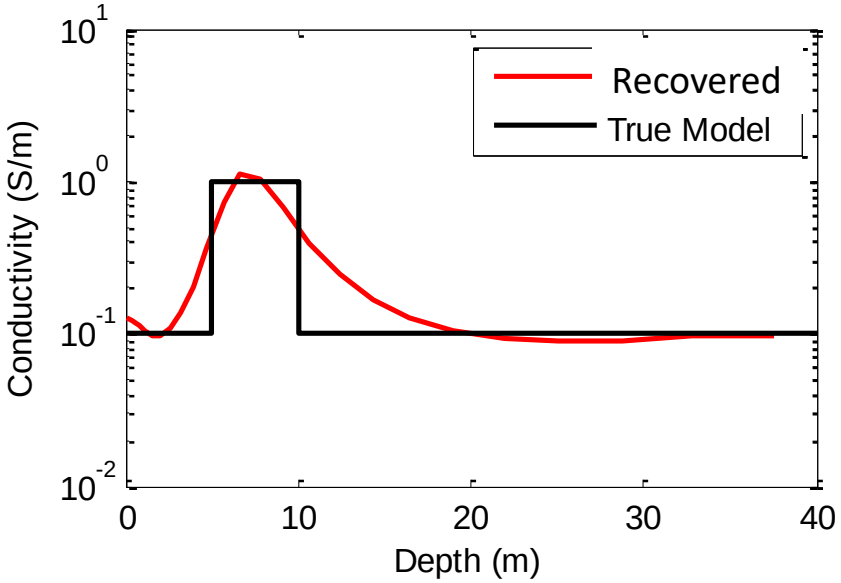


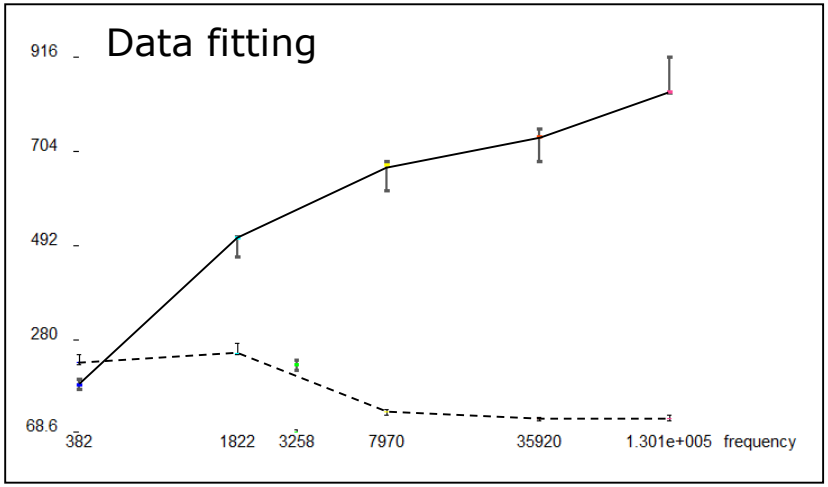


Minimize $\phi = \phi_d + \beta\phi_m$

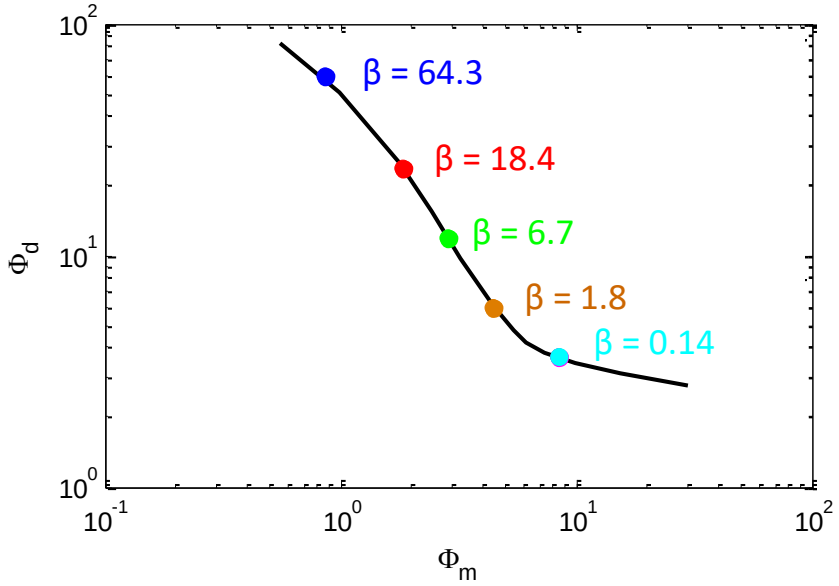


- Regularization (trade-off) parameter β controls relative importance of data fitting and simplicity of model
- Under-fit: Did not squeeze all the information out of the data
- Over-fit: Converting noise to model structures





Minimize $\phi = \phi_d + \beta\phi_m$



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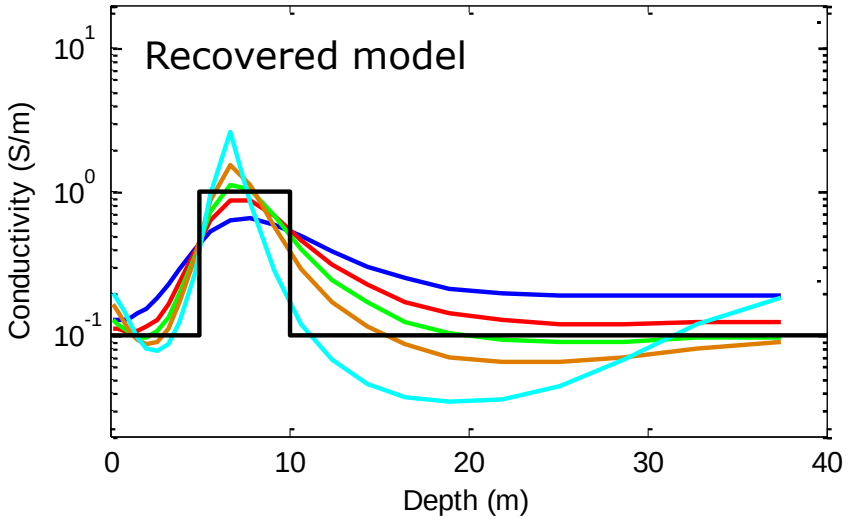
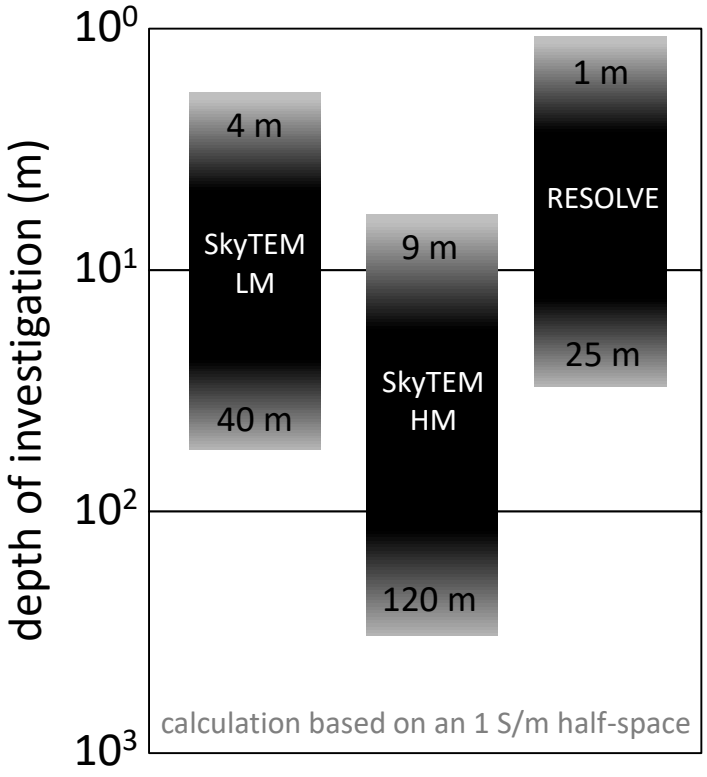
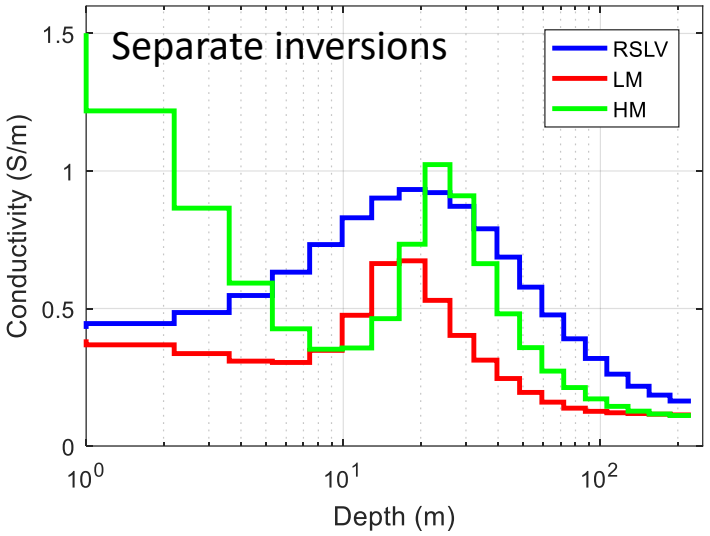
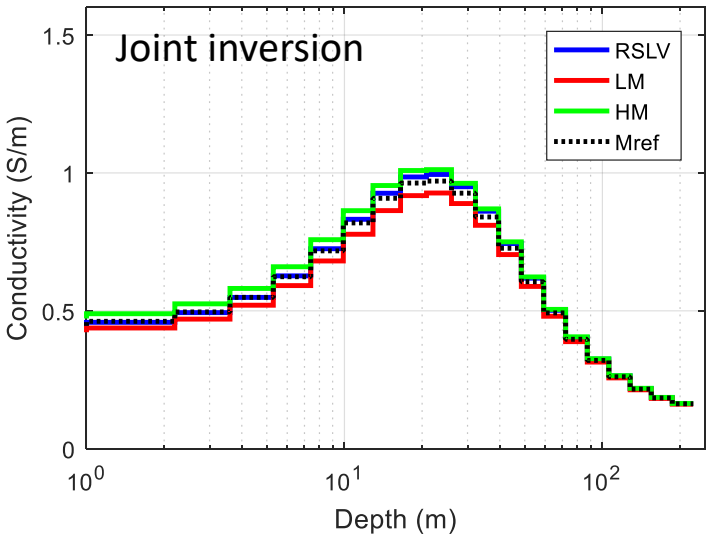


In practice, the noise is non-Gaussian and not exactly unknown. So geologic or other a prior information is critical in choosing an appropriate inversion model.

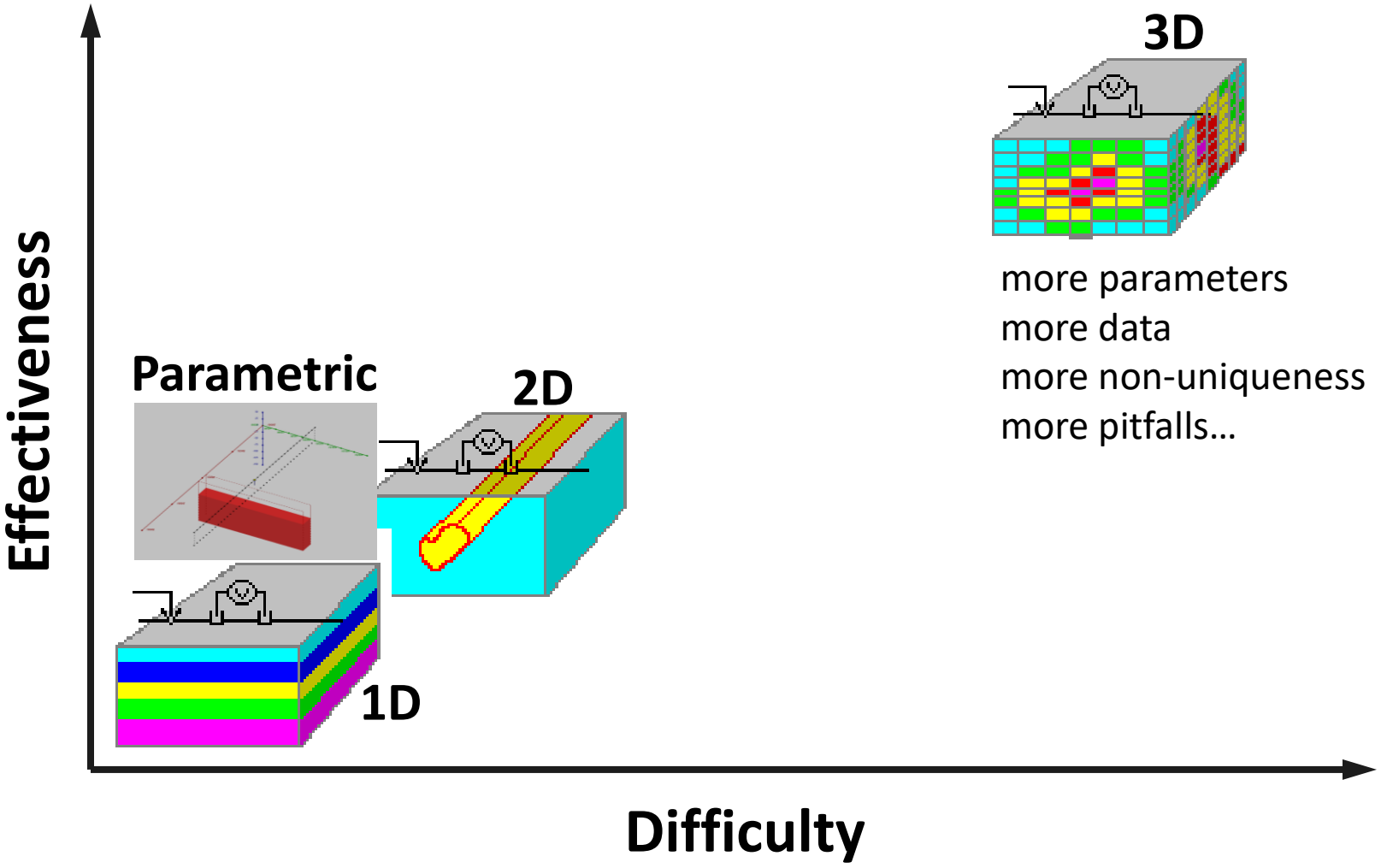
Joint Inversion



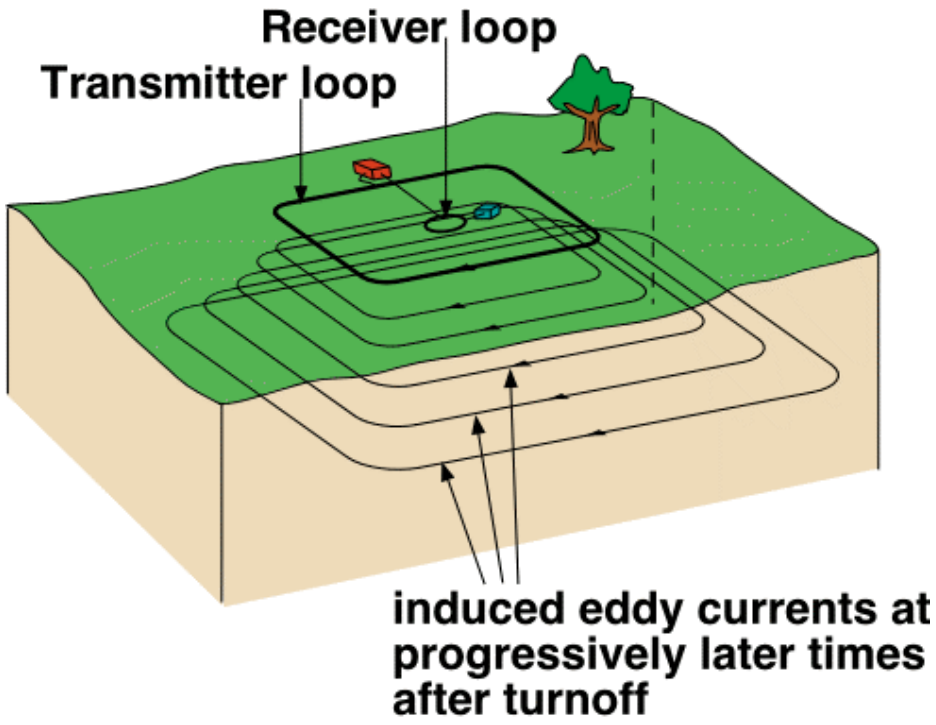




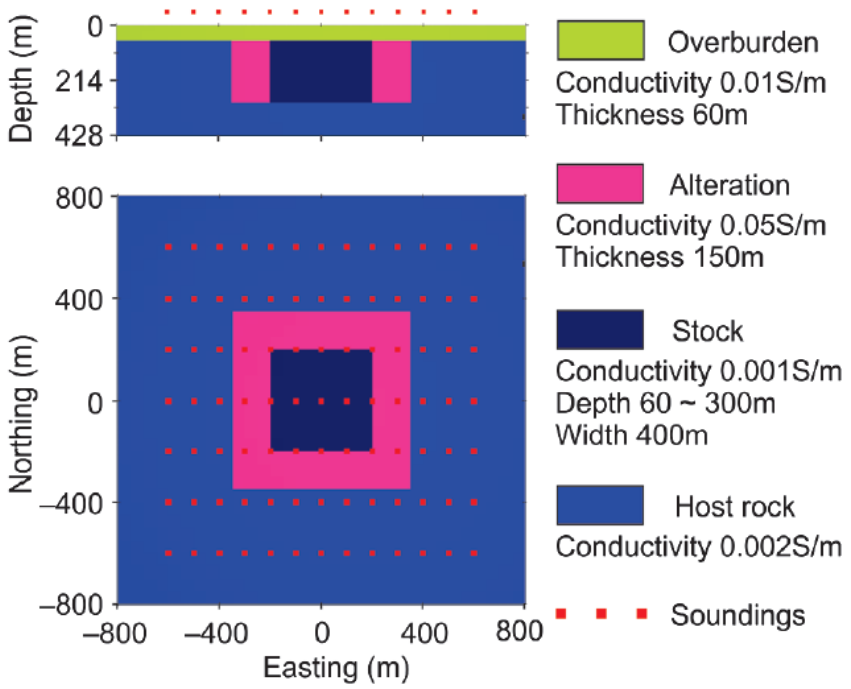
3D Inversion



Concentric Tx-Rx Time-domain EM

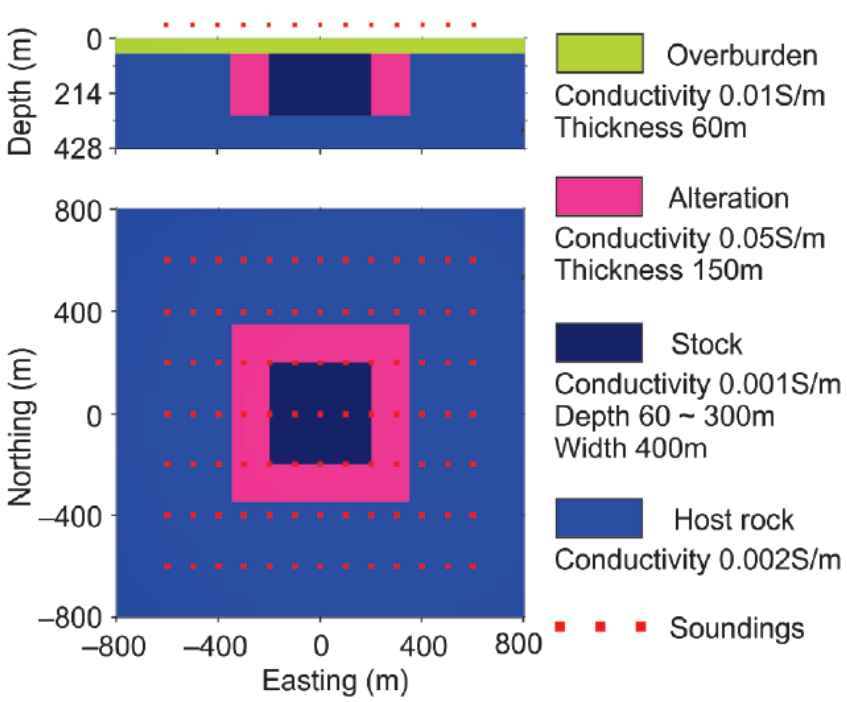


Simplified porphyry model

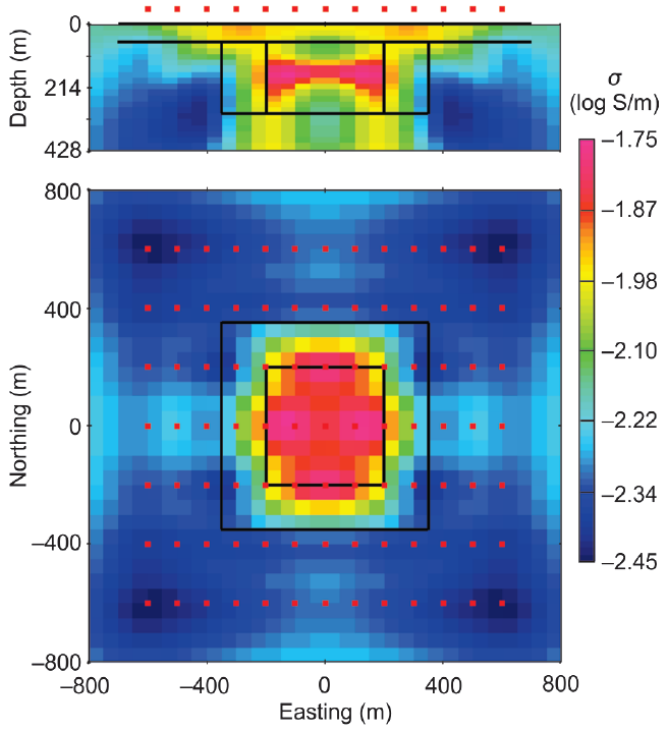


1D TEM Inversion

Simplified porphyry model

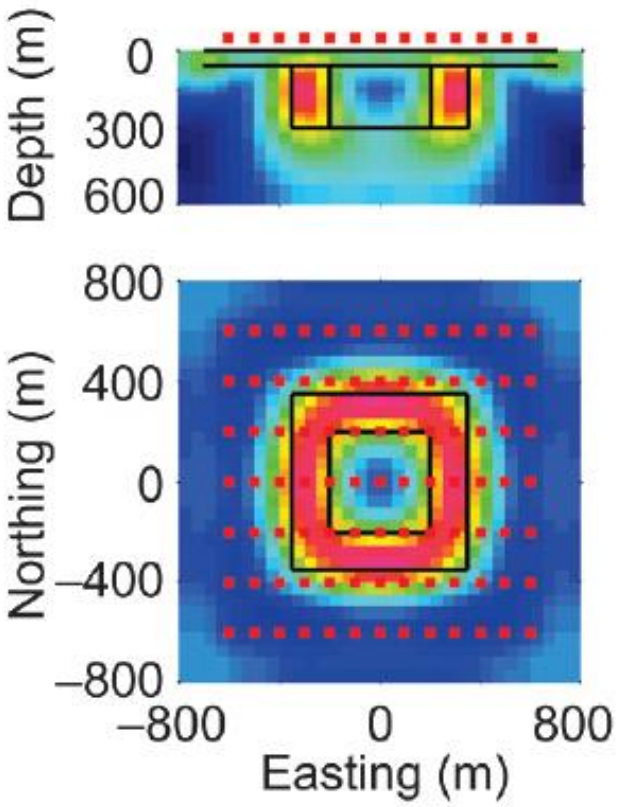


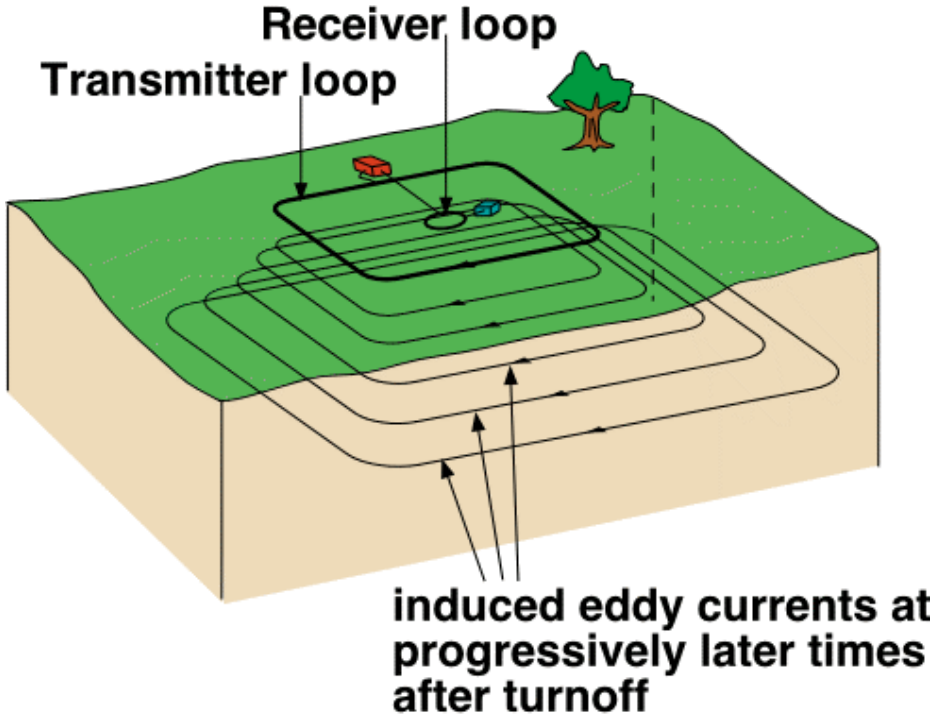
Stitched 1D layered inversion



3D TEM Inversion

3D voxel inversion





- High sensitivity in high induced currents
- Need to model the 3D current distribution
- 3D inversion: key in complex geology

Summary

- Concepts about inversion
  - 1D, 2D, 3D, parametric
  - Data and model, forward and inverse
  - Non-uniqueness
  - Regularized inversion: trade-off between data misfit and model complexity
  - Joint inversion
  - 3D inversion
- How do you work with geophysicists?
  - Check the validity of model dimensionality
  - Ask about uncertainty and alternative models