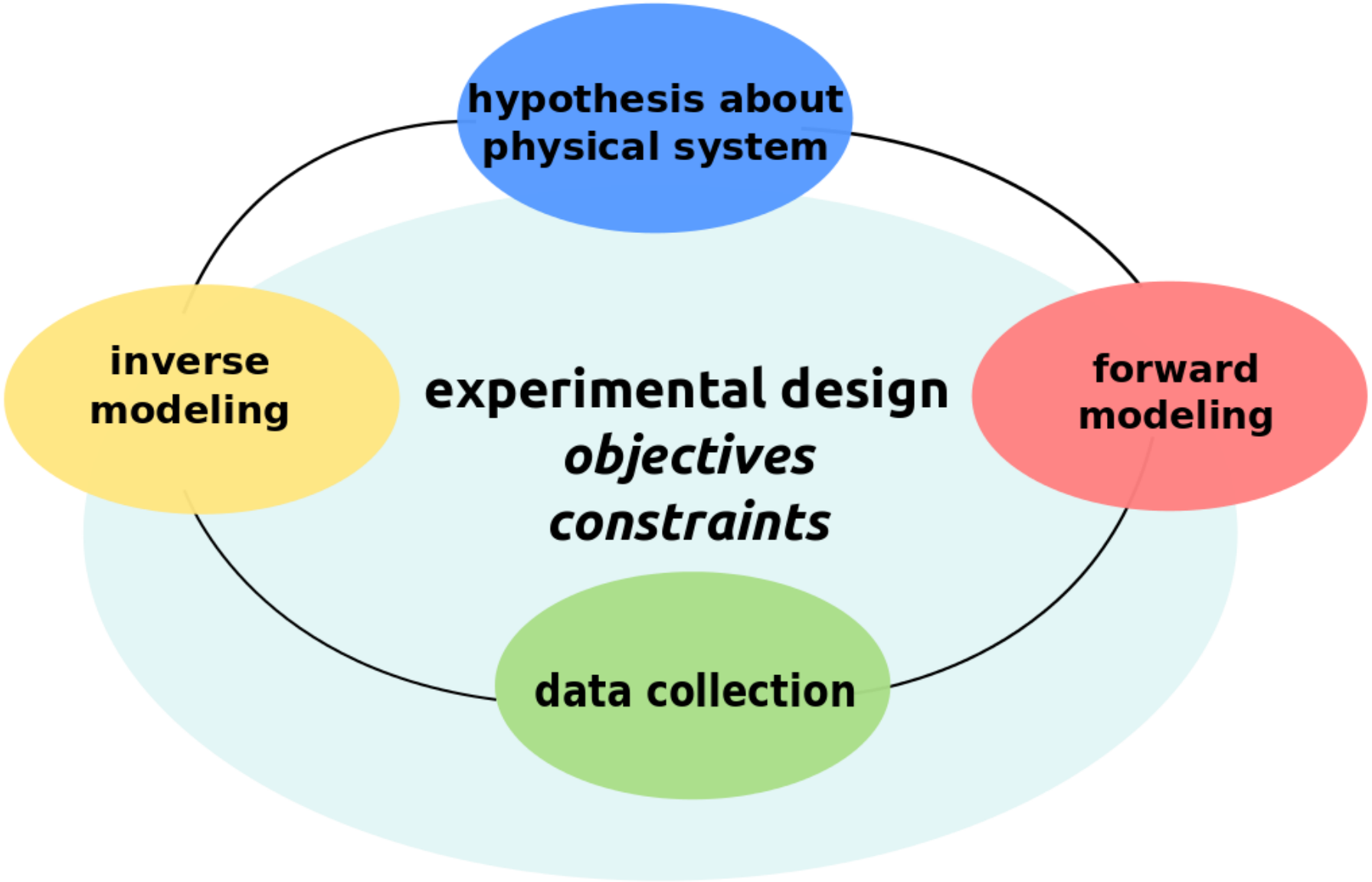
Strategies for joint geophysical survey design

Alexis Shakas[1] and Hansruedi Maurer[2]

1 Institute of Earth Sciences, University of Lausanne, Switzerland

2 Institute of Geophysics, ETH Zurich, Switzerland

Motivation


hypothesis about physical system
inverse modeling
experimental design
objectives
constraints
forward modeling
data collection

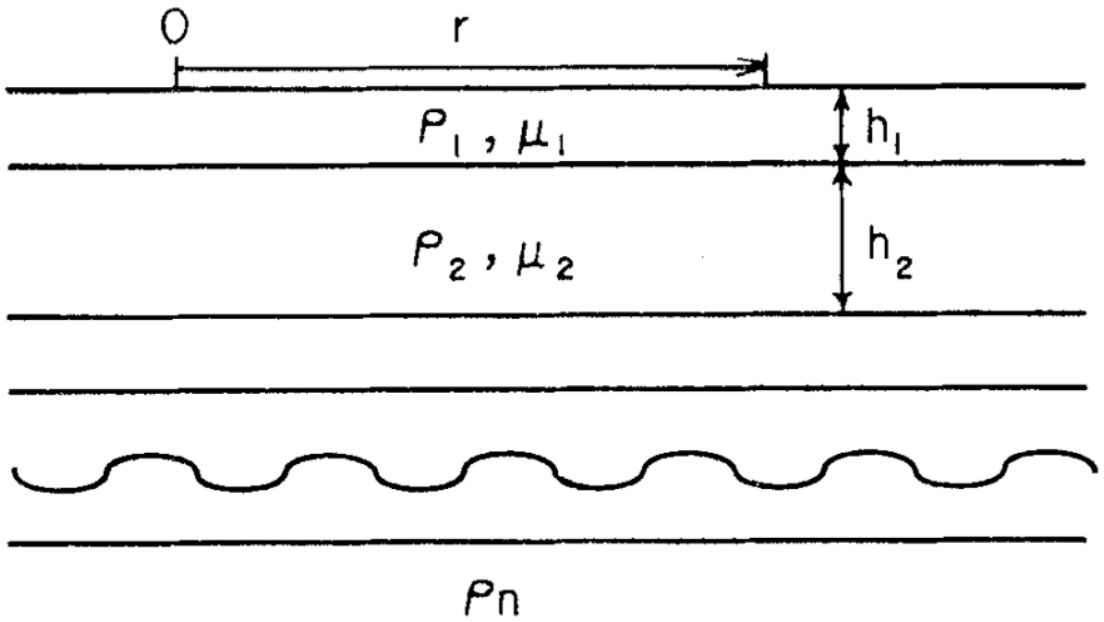
Geophysical Inversion

Iteratively linearized inversion (Greenhalgh et al. 2006)

$$\Delta m_{k+1} = \left[\mathbf{W}_m^{-1}\left(\frac{\partial d}{\partial m}\right)_k^T \mathbf{W}_d \left(\frac{\partial d}{\partial m}\right)_k + \lambda I\right]^{-g} \times \mathbf{W}_m^{-1}\left(\frac{\partial d}{\partial m}\right)_k^T \mathbf{W}_d [d_{obs} - d(m_k)]$$

Joint Inversion of Geophysical Data

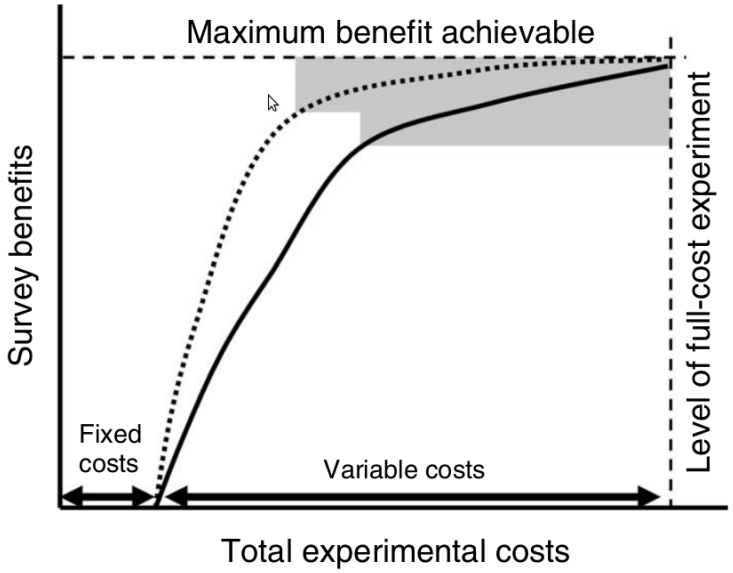
Vozoff and Jupp (1975)



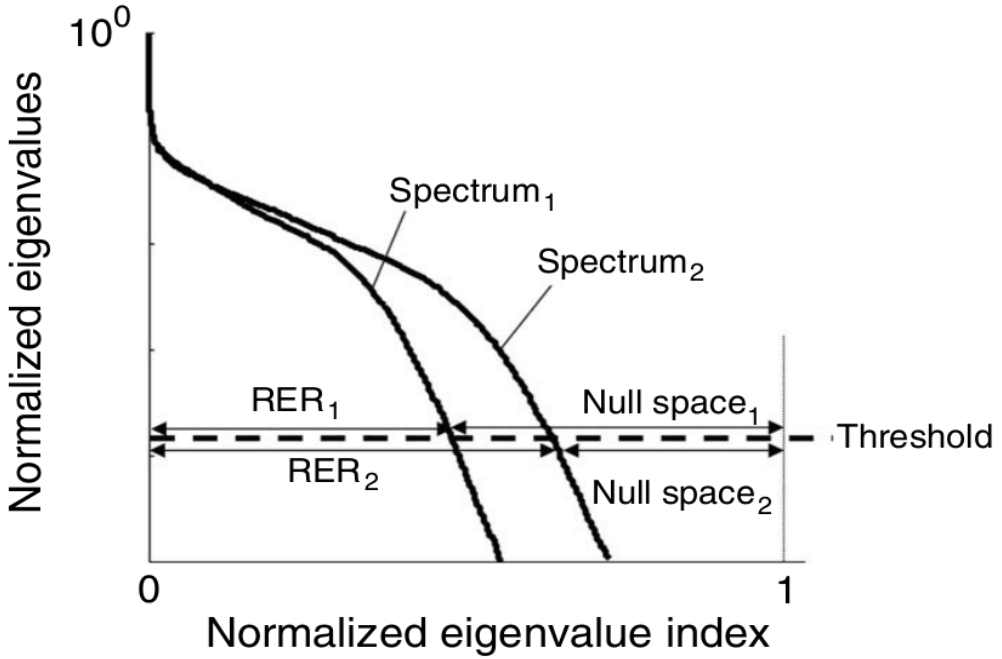
Experimental Design

Model Resolution Matrix (Menke,1989)

$$m_{est} = \mathbf{G}^{-g} d_{obs} = \mathbf{G}^{-g}[\mathbf{G} m_{true}] = [\mathbf{G}^{-g}\mathbf{G}] m_{true} = \mathbf{R} m_{true}$$



(Maurer et al., 2010)



1D Example : Layered Earth model

Survey Objective : To resolve the model parameters

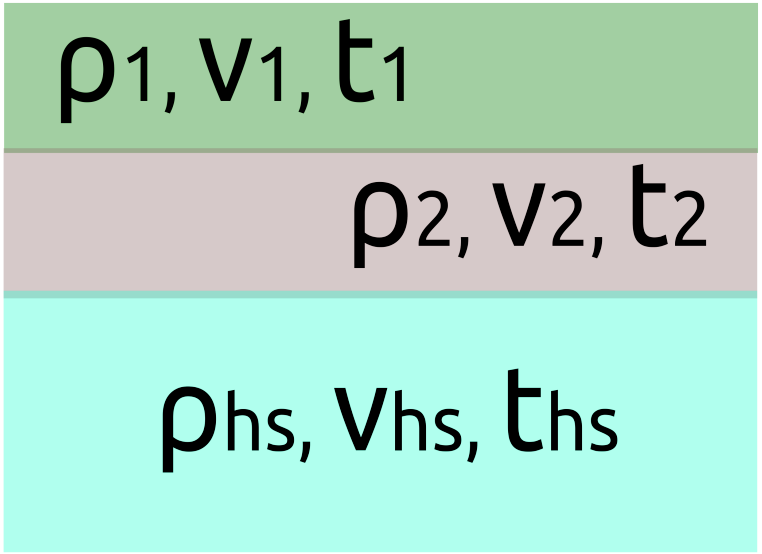
Survey Constraints/Costs

Seismic Refraction Tomography

- 100 geophones, 2 *m* spacing

Electrical Resistivity Tomography

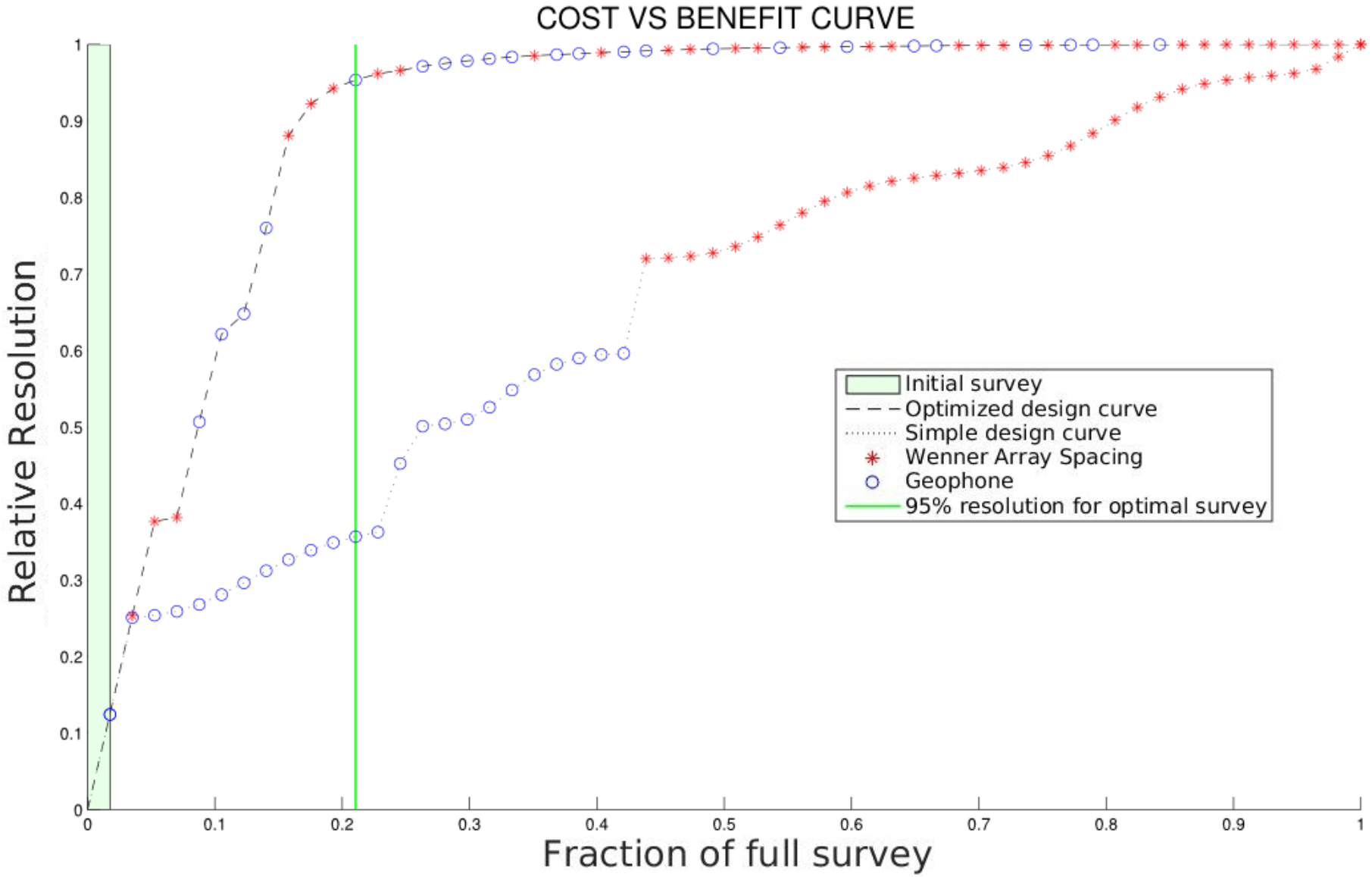
- 100 electrodes, 2 *m* spacing



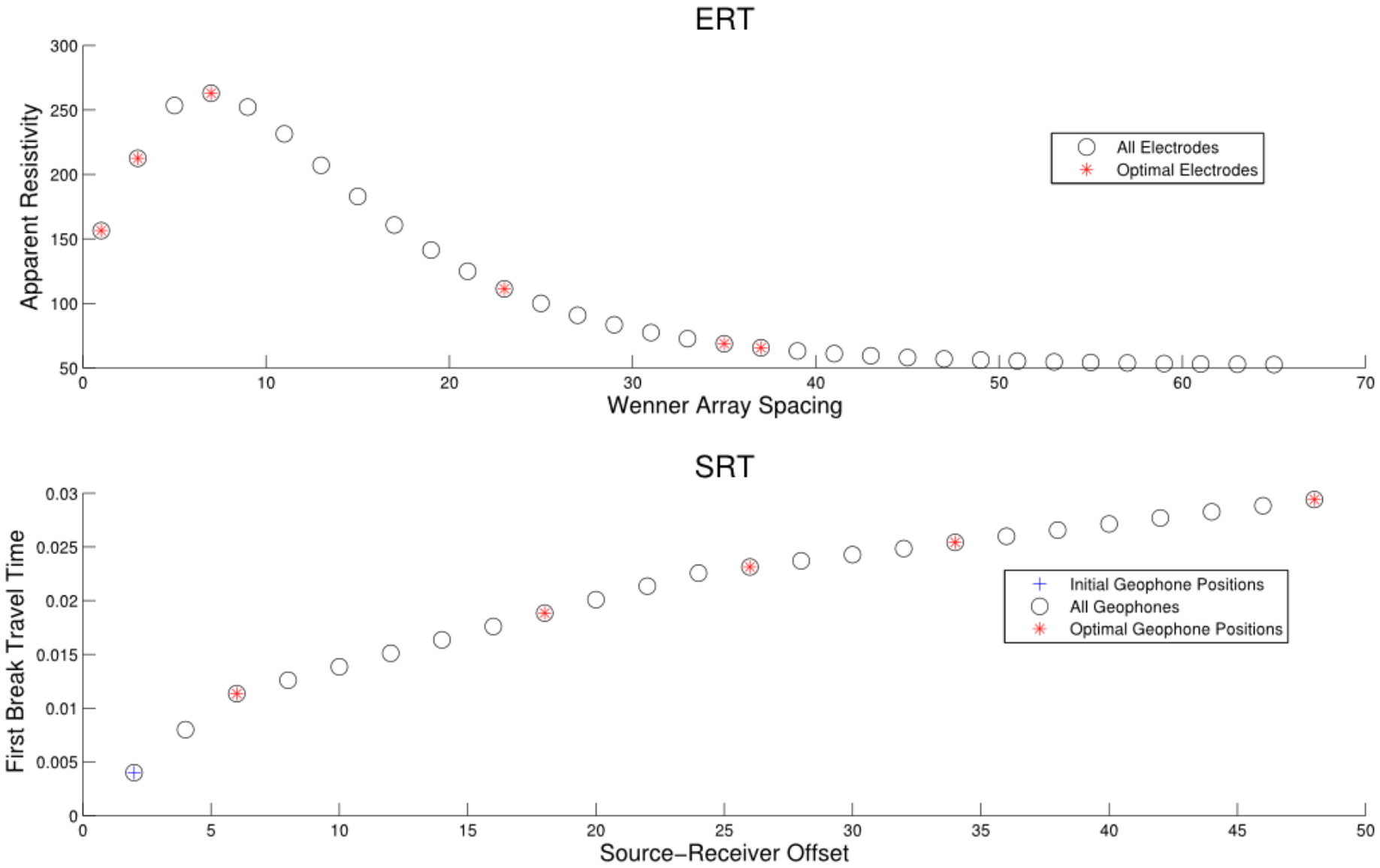
Forward Modeling
ERT : analytic solutions through digital filters
SRT : analytic solutions through ray-tracing

Joint Inversion through common layer thicknesses !

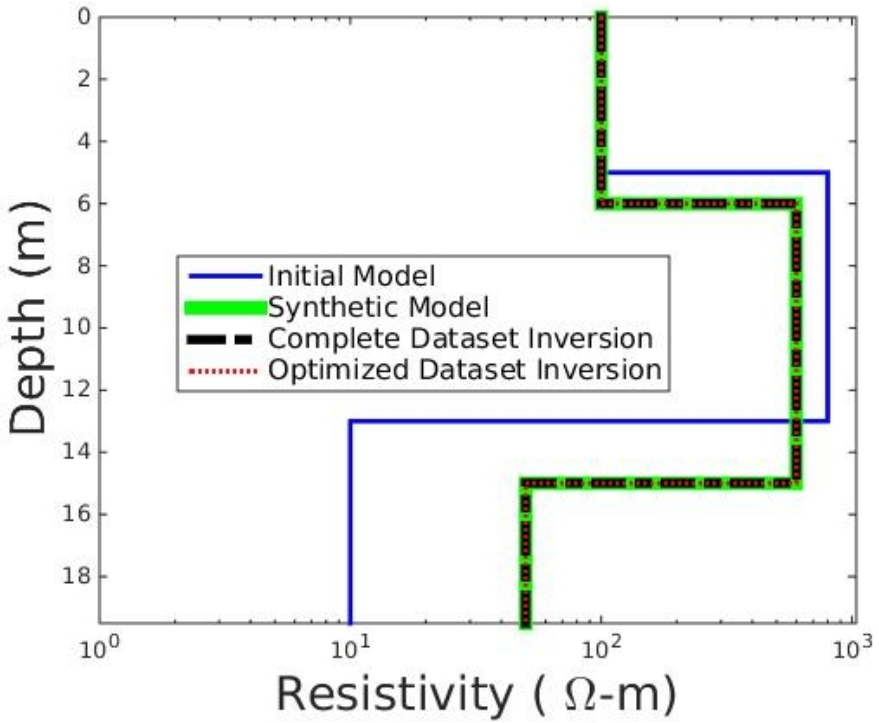
1D Example : Experimental Design

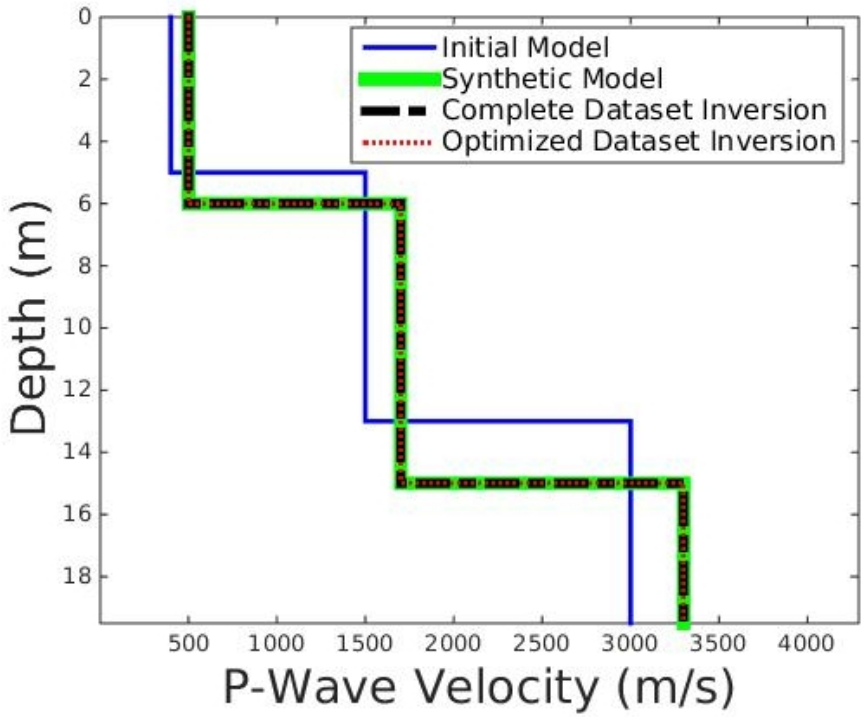


1D Example : Optimal Data



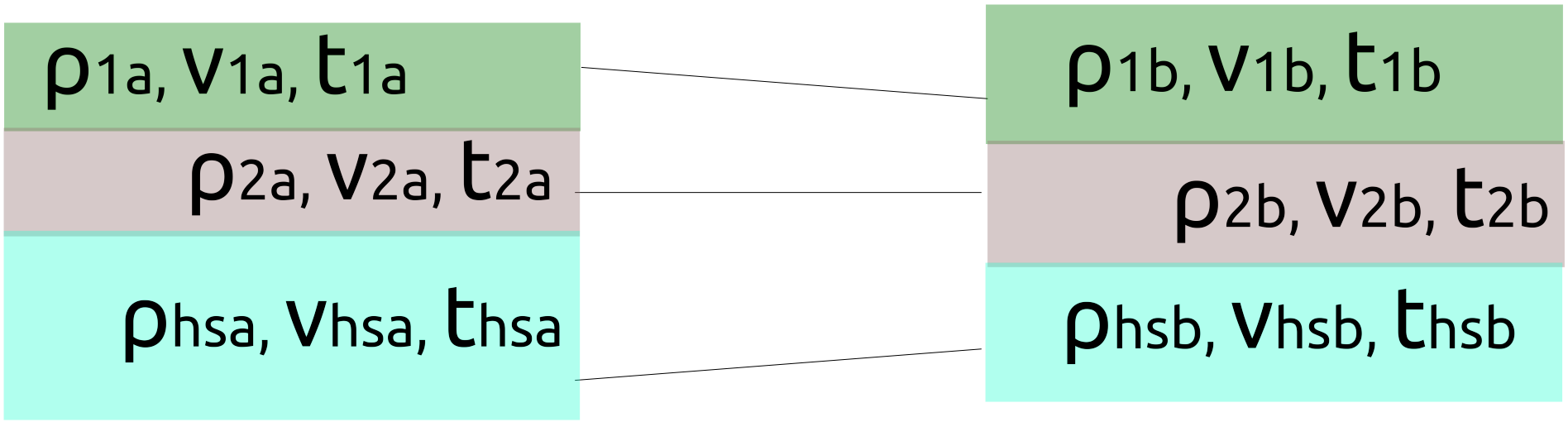
1D Example : Joint Inversion





2D Example: Lateral Constraints

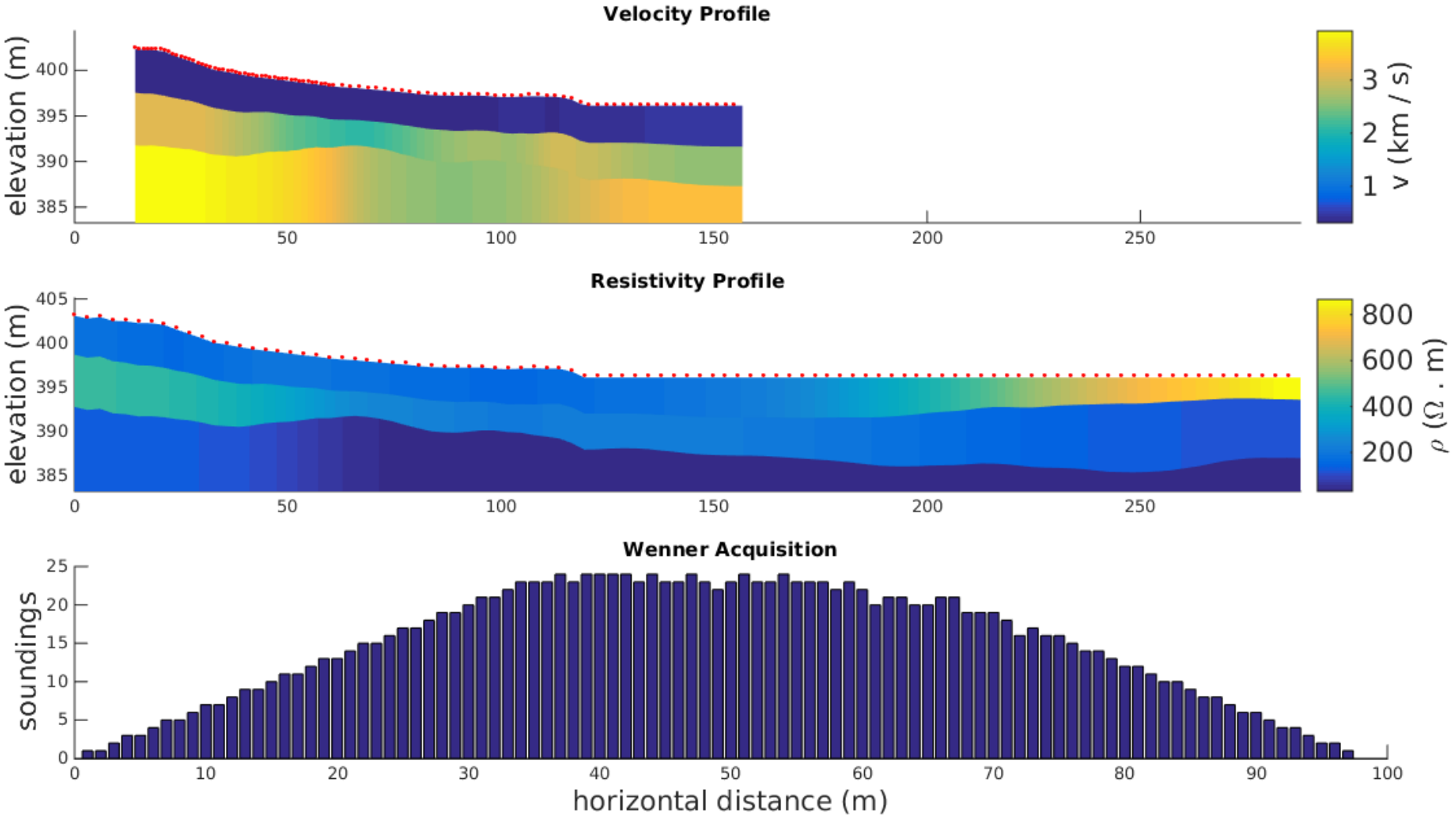
Layered and laterally constrained 2D inversion of resistivity data, Auken and Christiansen (2004)



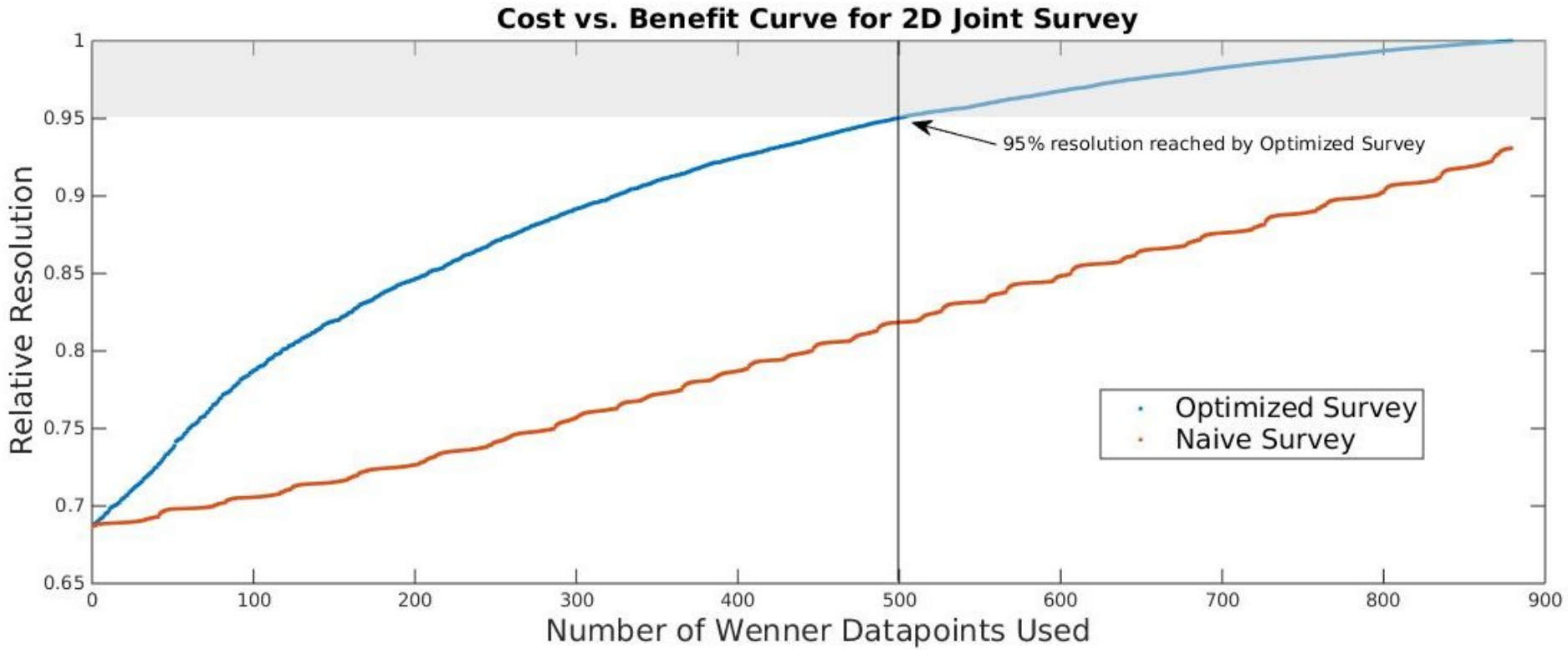
Data from Doetsch et al. (2006)

- 150 electrodes, 2 m spacing (2335 datapoints)
- 96 geophones, 2 m spacing, 67 shots (3950 datapoints)

2D Full Joint Inversion

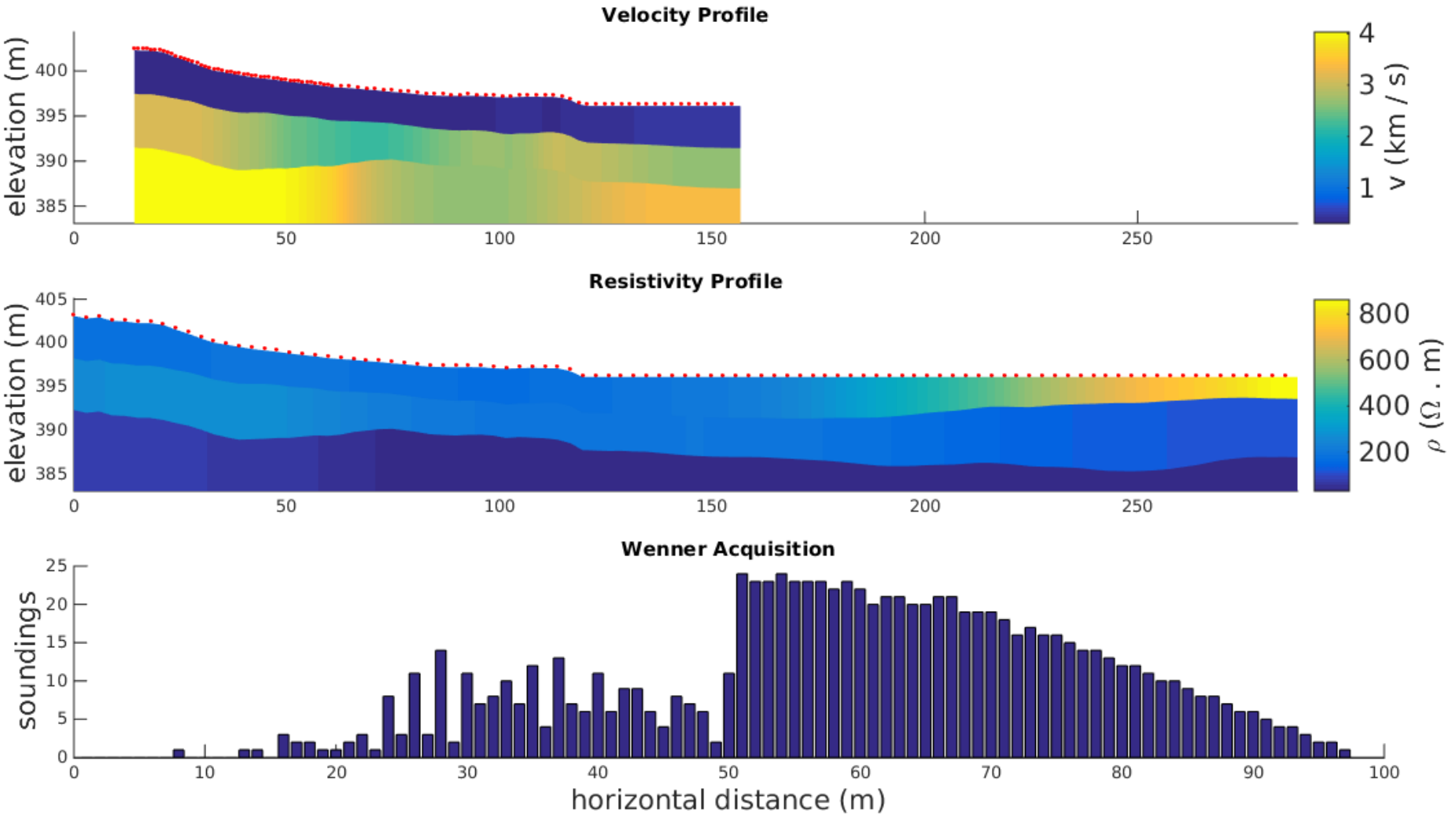


2D Joined Experimental Design

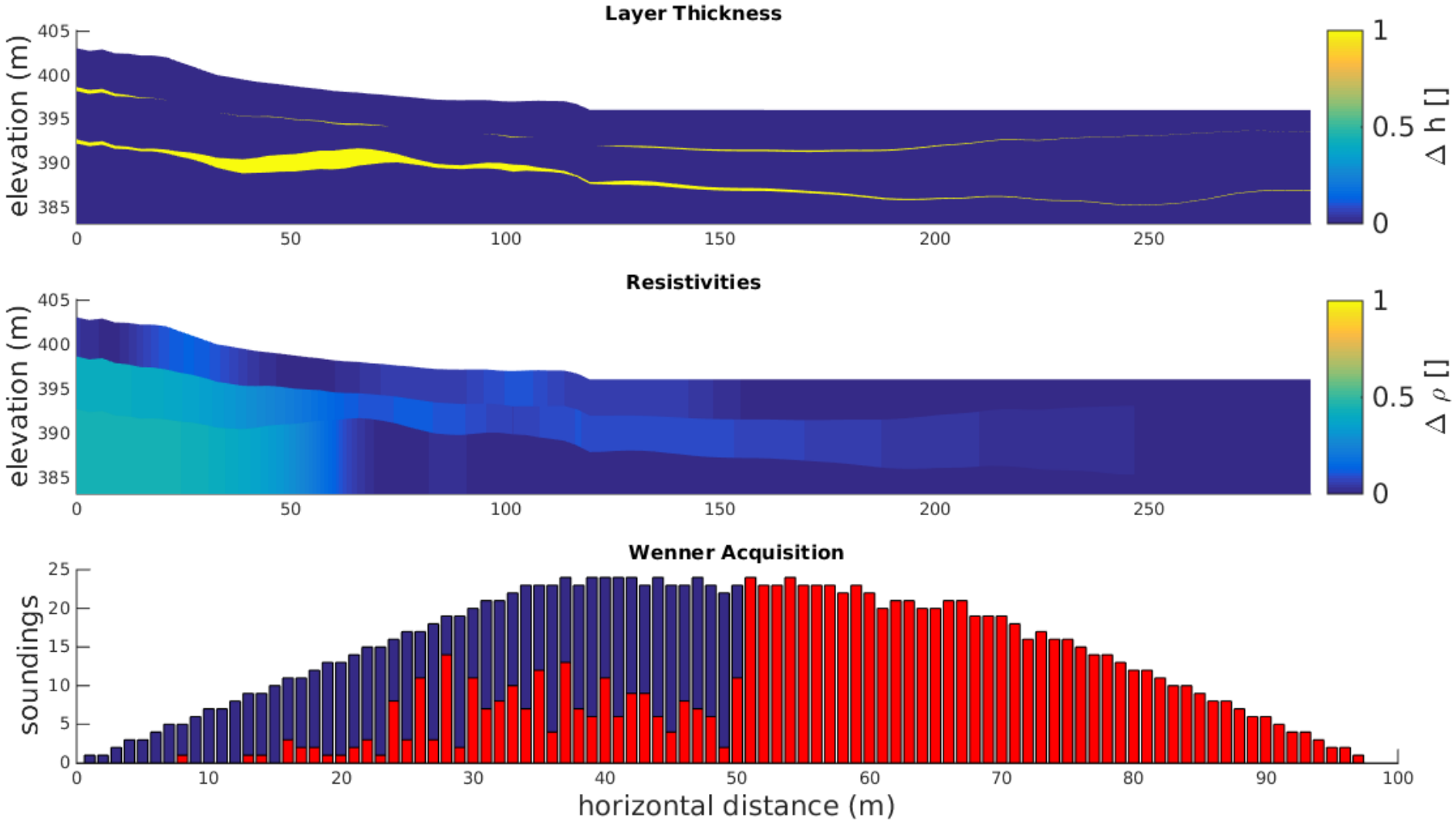


Optimized Survey : 500 datapoints
Complete Survey : 2335 datapoints

2D Optimized Joint Inversion



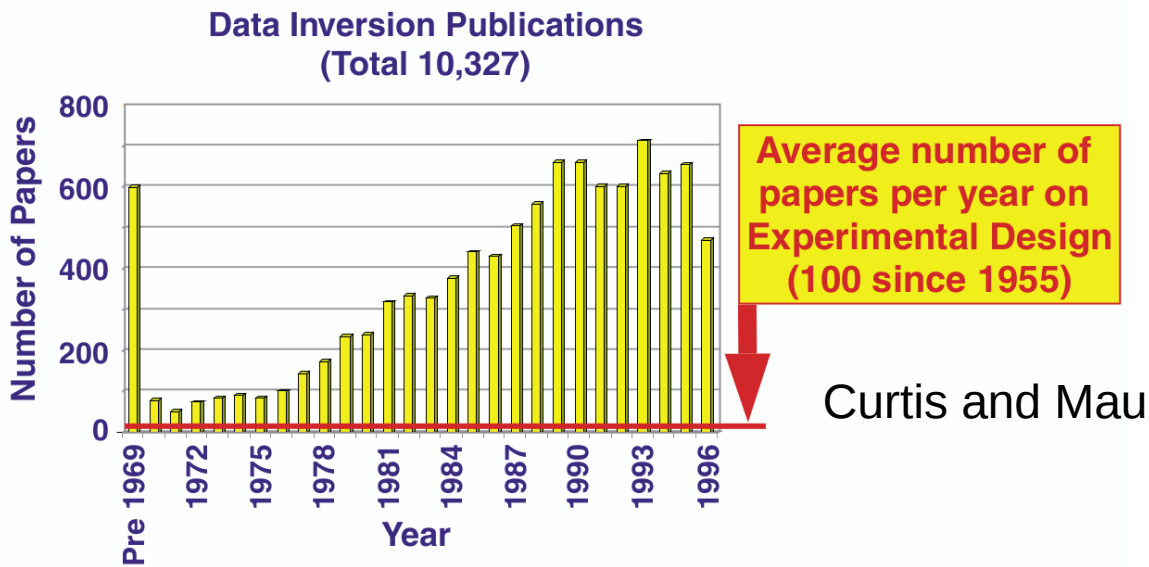
Differences in Joint Inversion



Conclusions

Experimental Design can reduce the cost of geophysical surveys

Separate geophysical methods can be combined in experimental design through structural constraints



Curtis and Maurer (2000)

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