MIT EARTH RESOURCES LABORATORY
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Earth Resources Laboratory

An Inversion Approach Towards a Reduction of Fluid Flow Model Complexity

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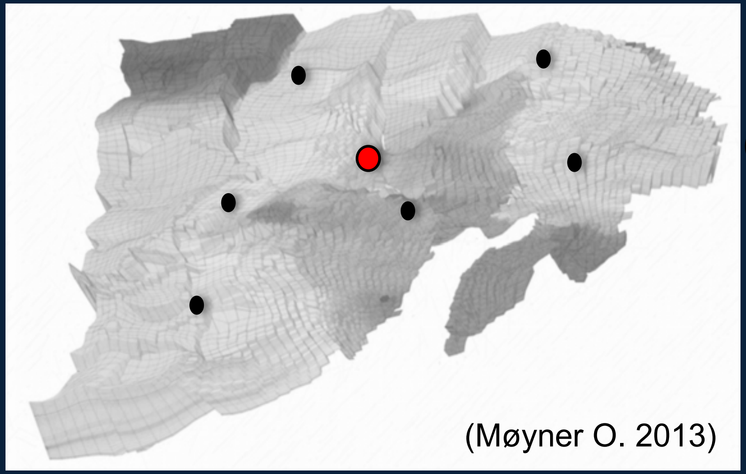
أرامكو السعودية
saudi aramco

Motivation

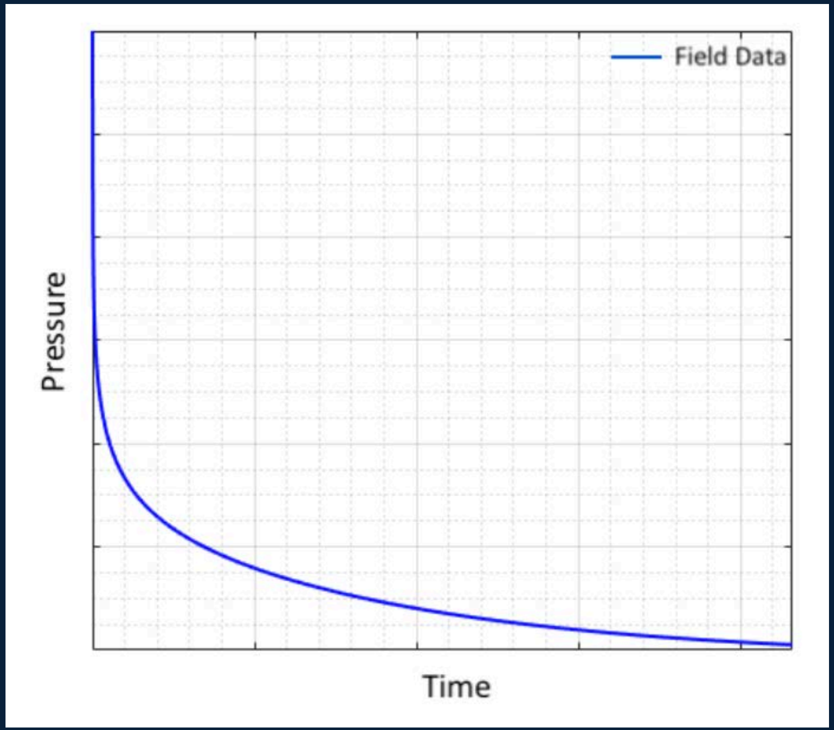


Observation well

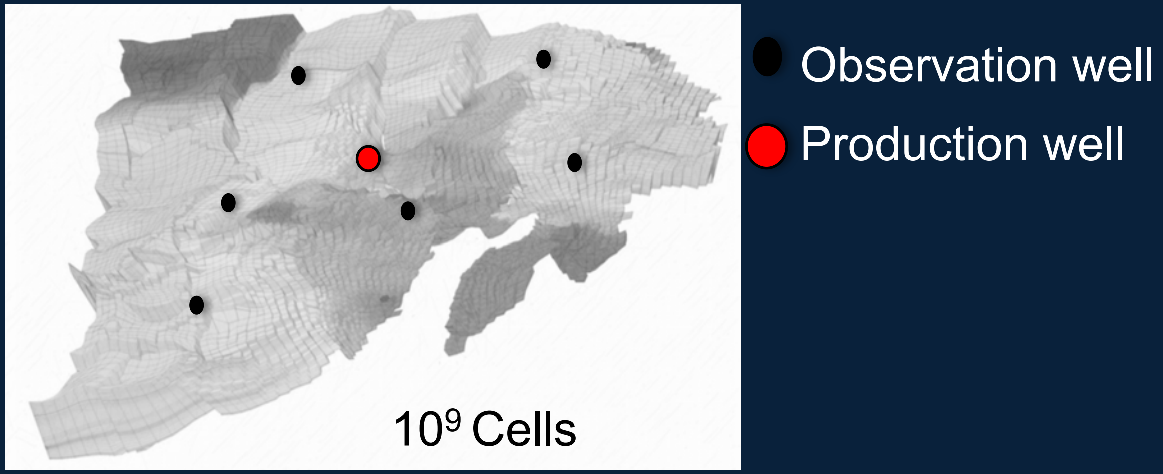
Production well

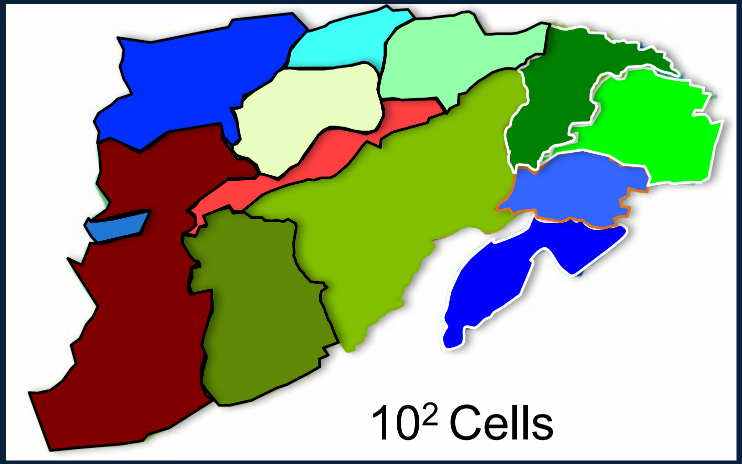
Simulation

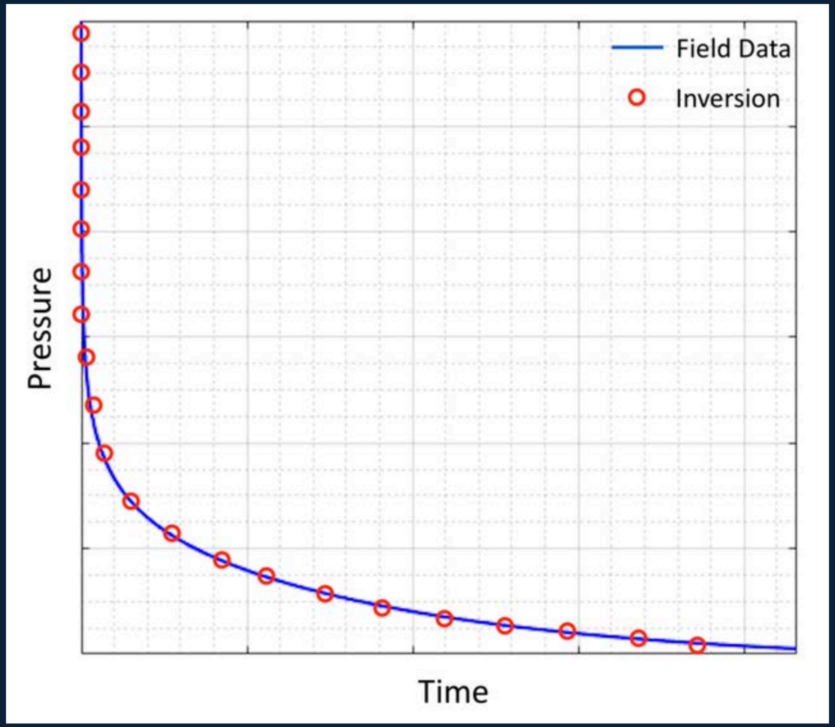
10^9 Cells



Motivation

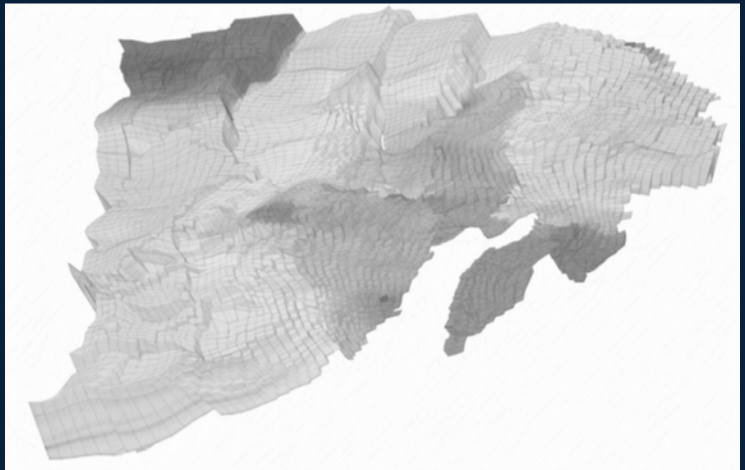

Observation well
Production well
10^9 Cells

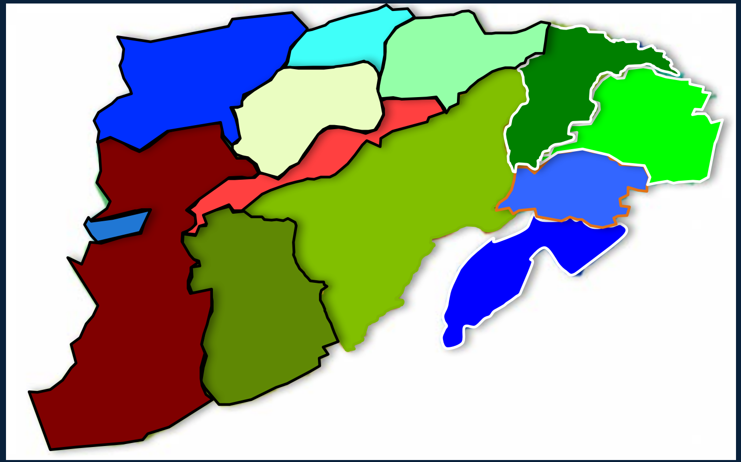

10^2 Cells


Field Data
Inversion
Pressure
Time

Objective

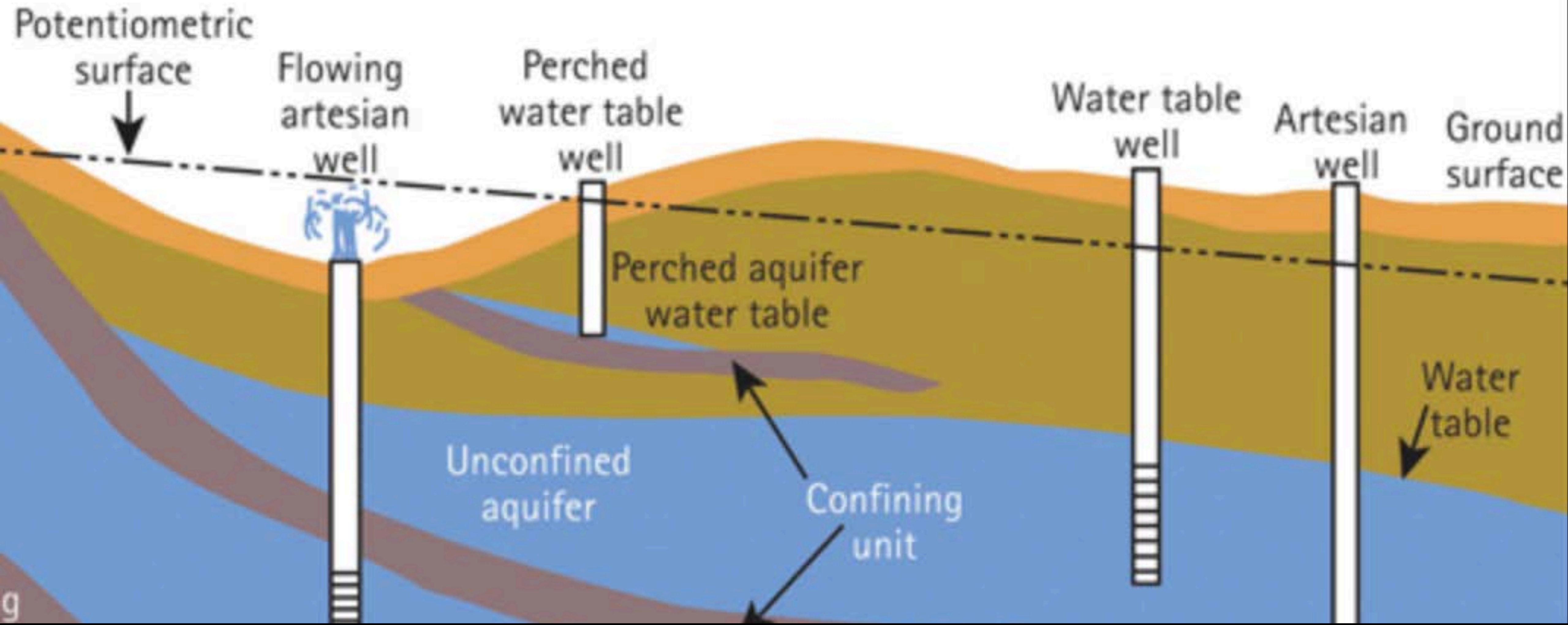
INVERTING FOR THE HYDRAULIC PARAMETERS USING A REDUCED HYDRAULIC CONDUCTIVITY STRUCTURE.





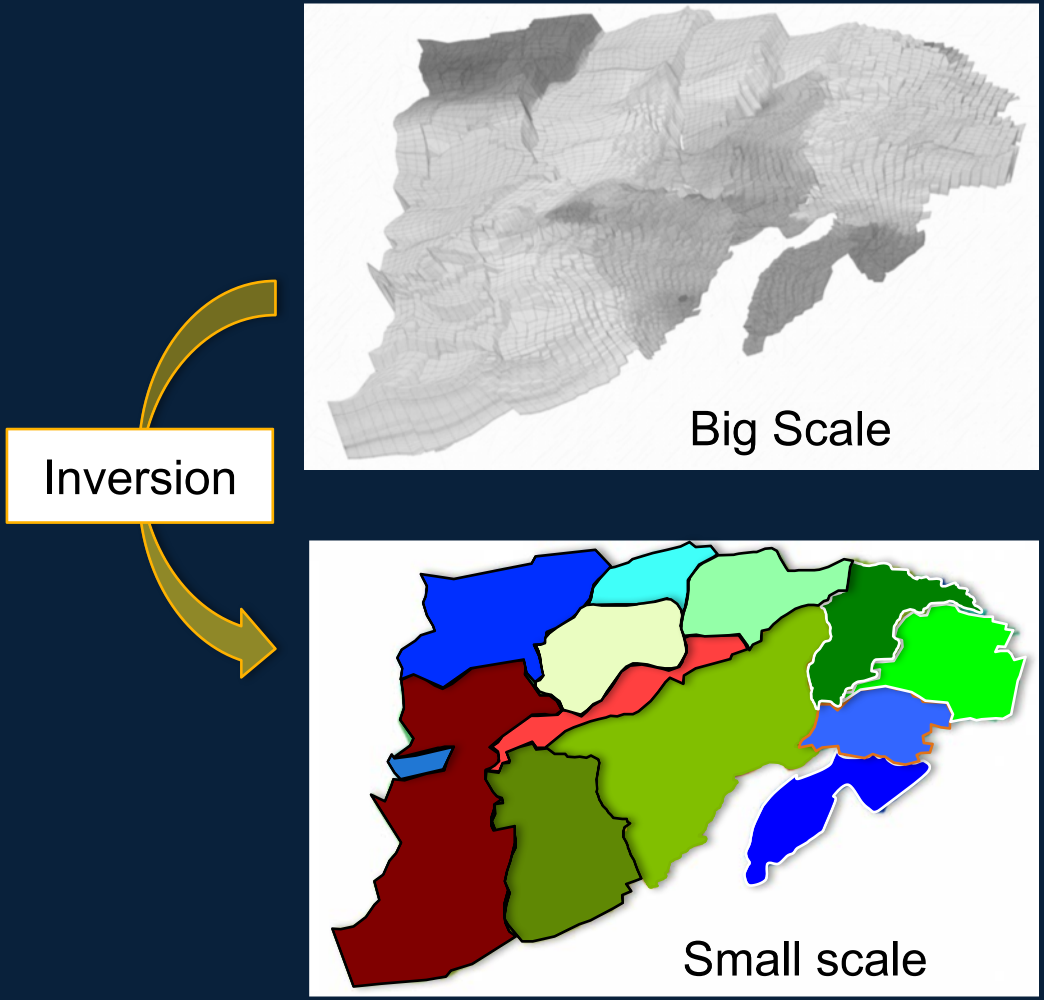
Fluid Flow Equations

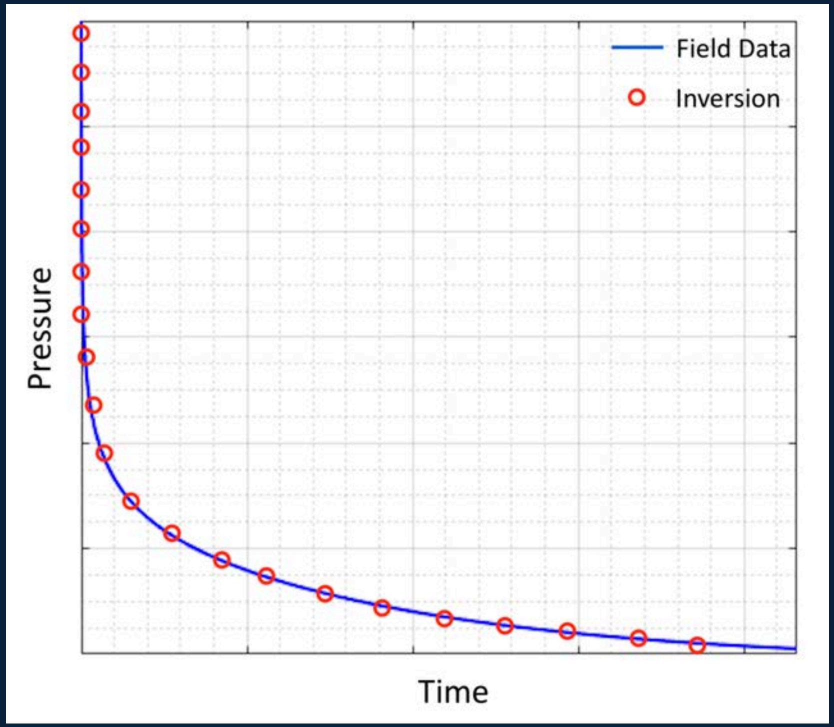
CONFINED AQUIFERS	UNCONFINED AQUIFERS
CONFINED AQUIFERS: IS BOUNDED BY IMPERMEABLE LAYERS FROM THE TOP AND THE BOTTOM.	**UNCONFINED AQUIFERS: THE TOP OF THE AQUIFER IS SUBJECTED TO RECHARGE, AND ITS WATER TABLE ACTS AS THE UPPER BOUNDARY.**
$\mathbf{T}\frac{\partial^2 h}{\partial x^2} + \mathbf{T}\frac{\partial^2 h}{\partial y^2} = S\frac{\partial h}{\partial t}.$	$\frac{\mathbf{K}}{2}\frac{\partial^2 h^2}{\partial^2 x} + \frac{\mathbf{K}}{2}\frac{\partial^2 h^2}{\partial^2 y} = S\frac{\partial h}{\partial t} - R(x, y, t).$



Confined & Unconfined Aquifers

Inversion


Big Scale
Inversion
Small scale


Field Data
Inversion
Pressure
Time

Inversion

OBJECTIVE FUNCTION:

$$min||h_S - h_B||_2$$

h_S: data from small scale

h_B: data from big scale

DAMPED LEAST SQUARE:

$$\delta h_S = (A^T A + \alpha^2 I)^{-1} A^T \delta d.$$

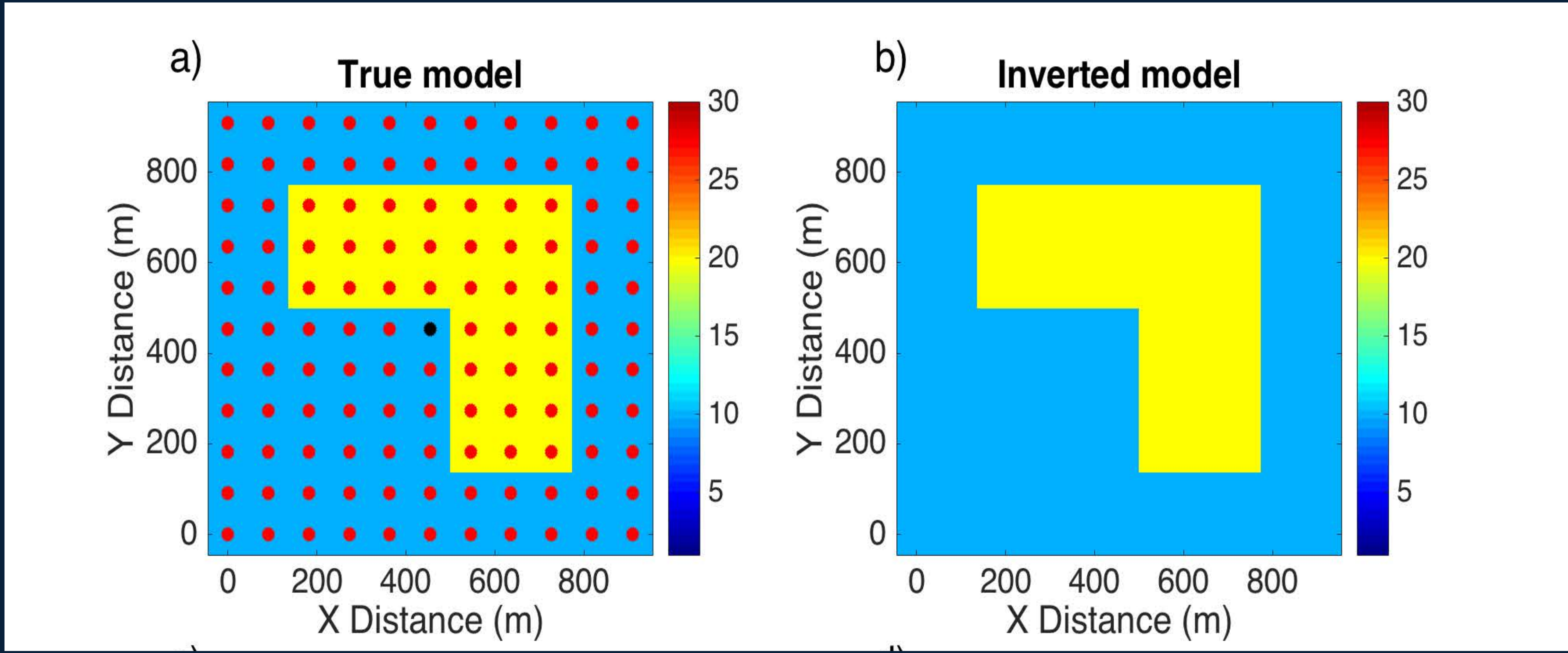
A: Jacobian matrix

I: Identity matrix

α: Damping factor

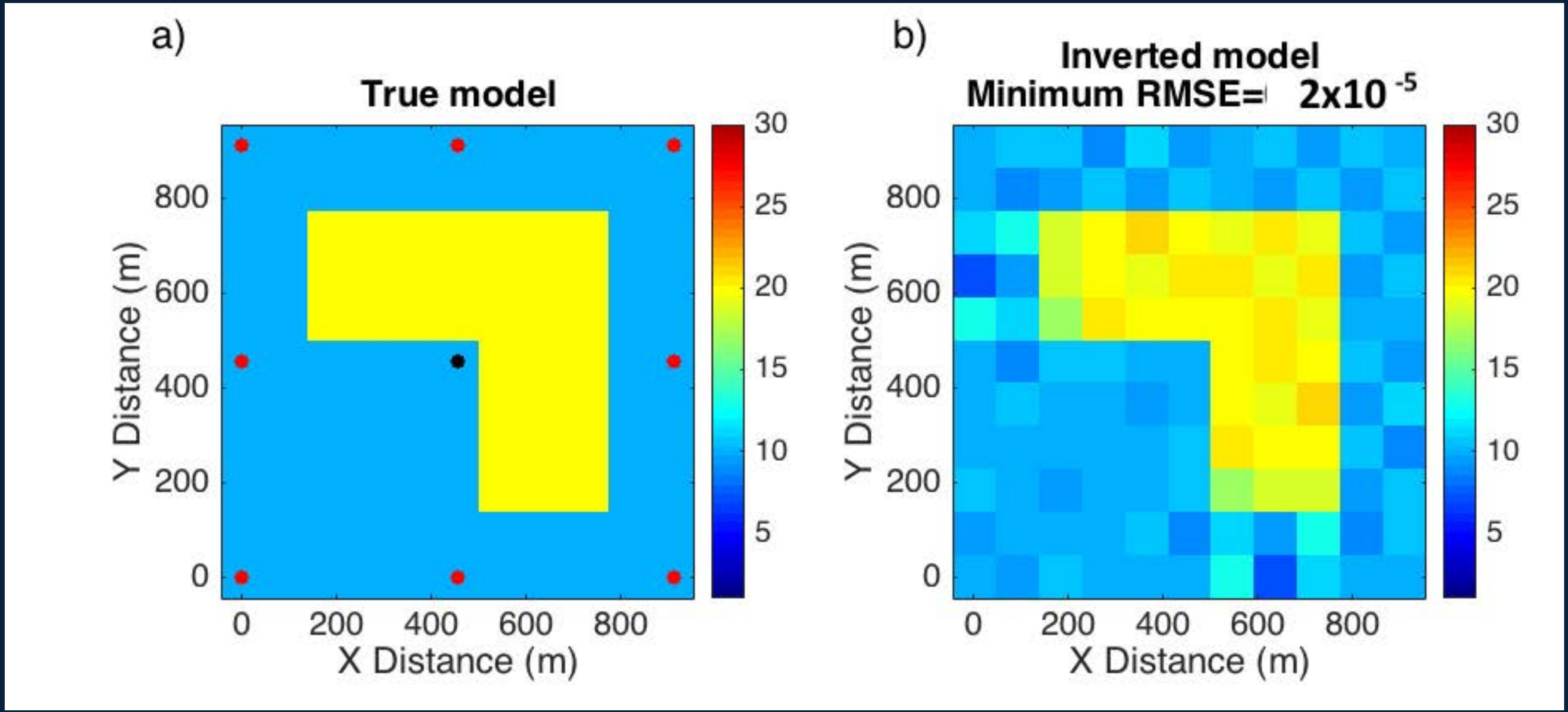
d: data

Case 1 (x,y)



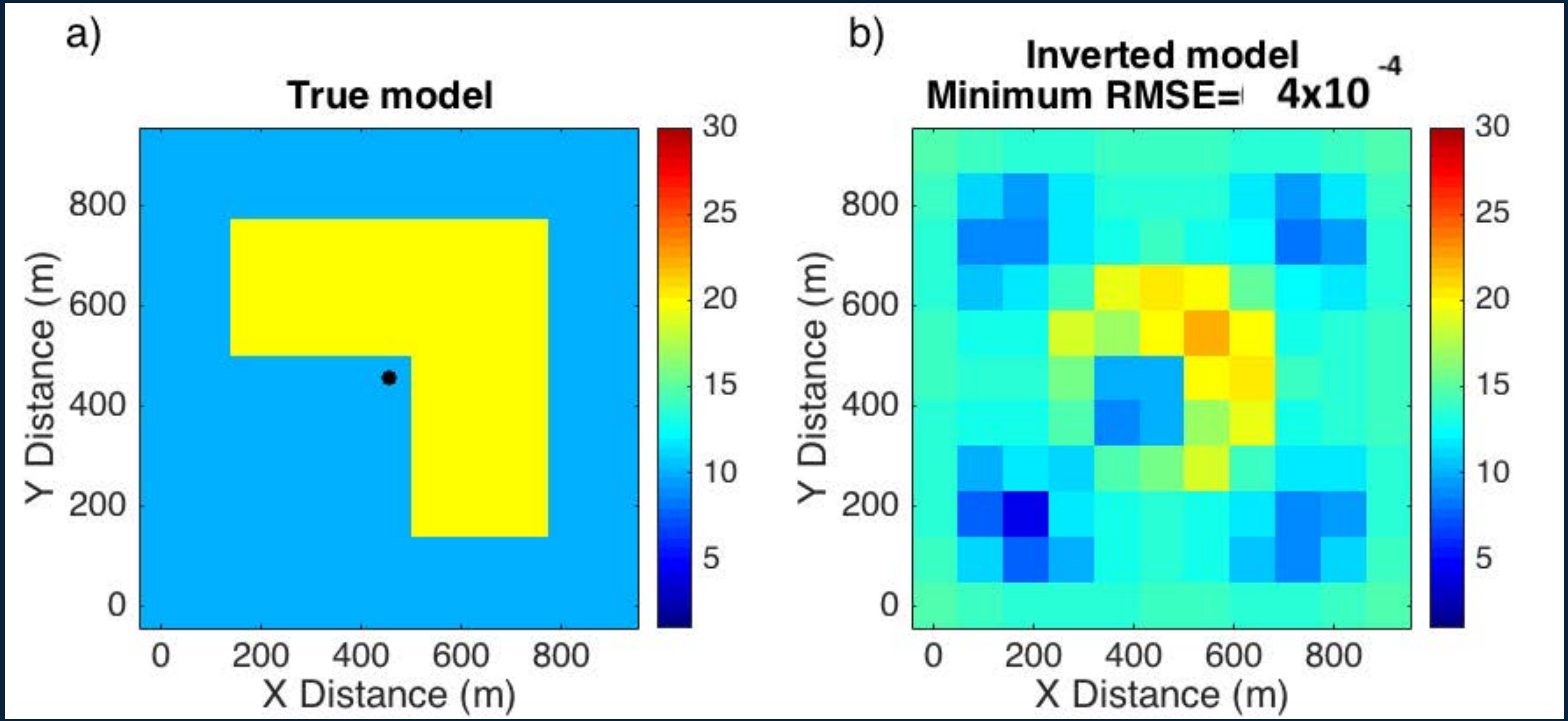
- 1 pumping well
- 1000mx1000m
- 11x11 grid
- 120 observation wells.

Case 1 (Reduced Number of Observation wells)



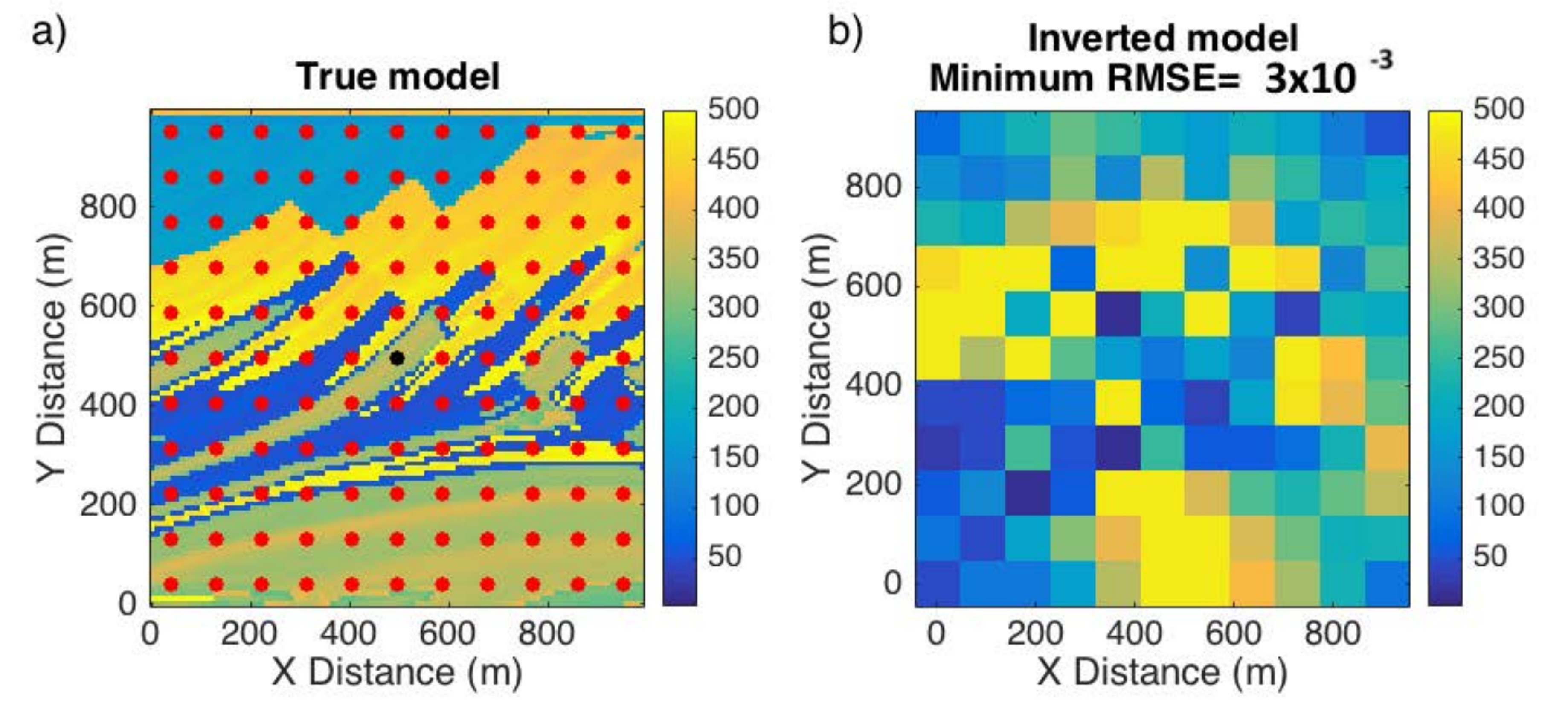
- 1 pumping well
- 1000mx1000m
- 11x11 grid
- 8observation wells.

Case 1 (One Observation well)



- 1 pumping well
- 1000mx1000m
- 11x11 grid
- 1 observation wells.

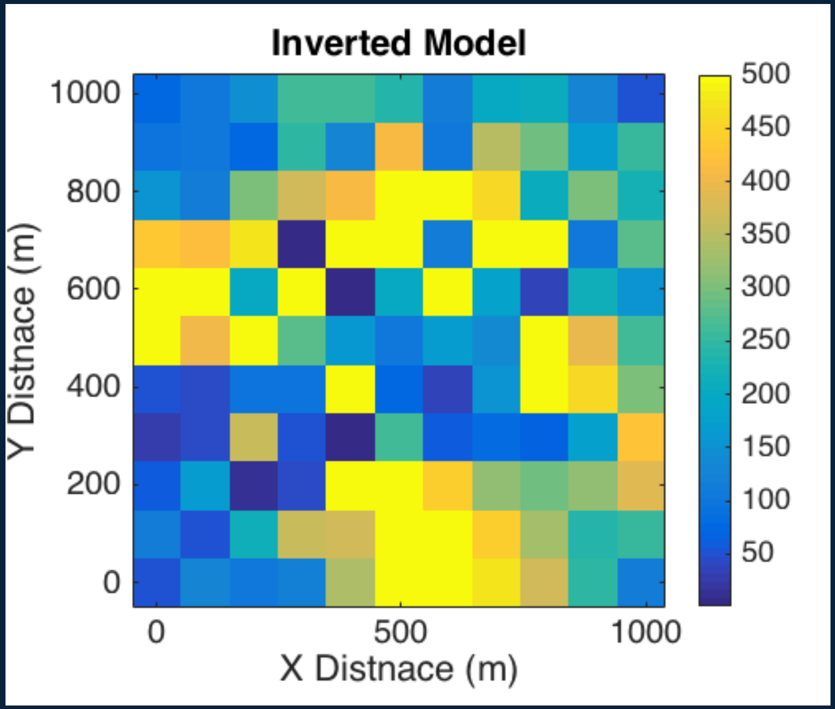
Case 2: Big to Small



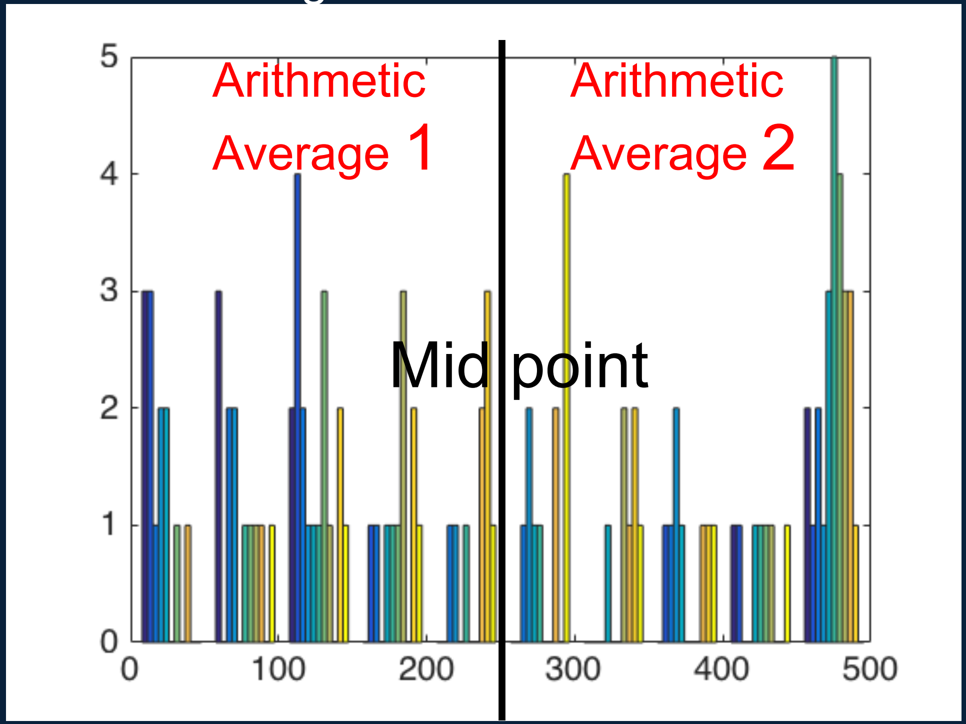
- True model: 99x99 grid
- Inverted model: 11x11 grid
- 1 pumping well
- 120 observation wells

Binary Model (Two Conductivity Values)

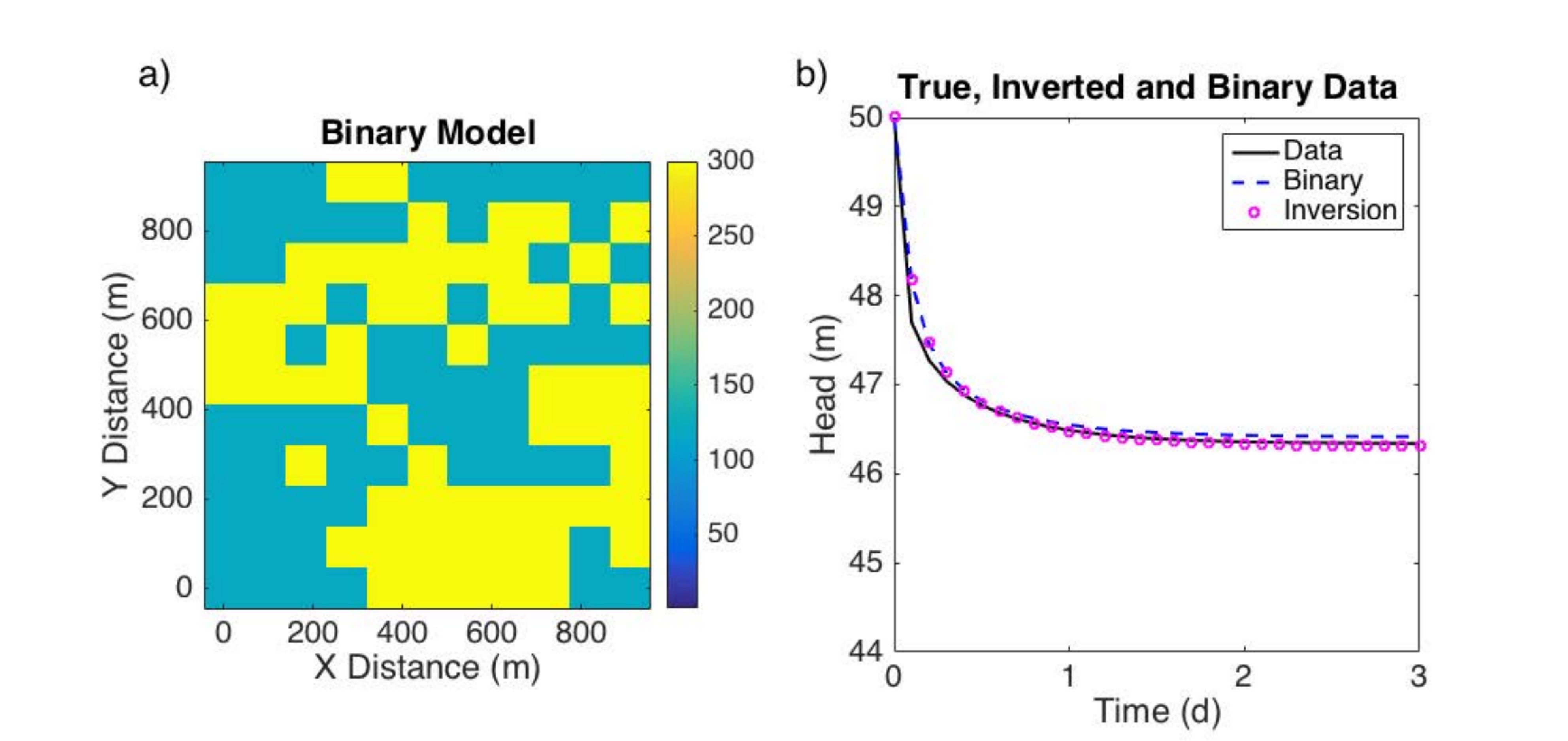
THE BINARY MODEL MATCHES THE INVERTED MODEL IN TERMS OF THE GENERAL STRUCTURE, BUT IT CONTAINS TWO PARAMETERS.



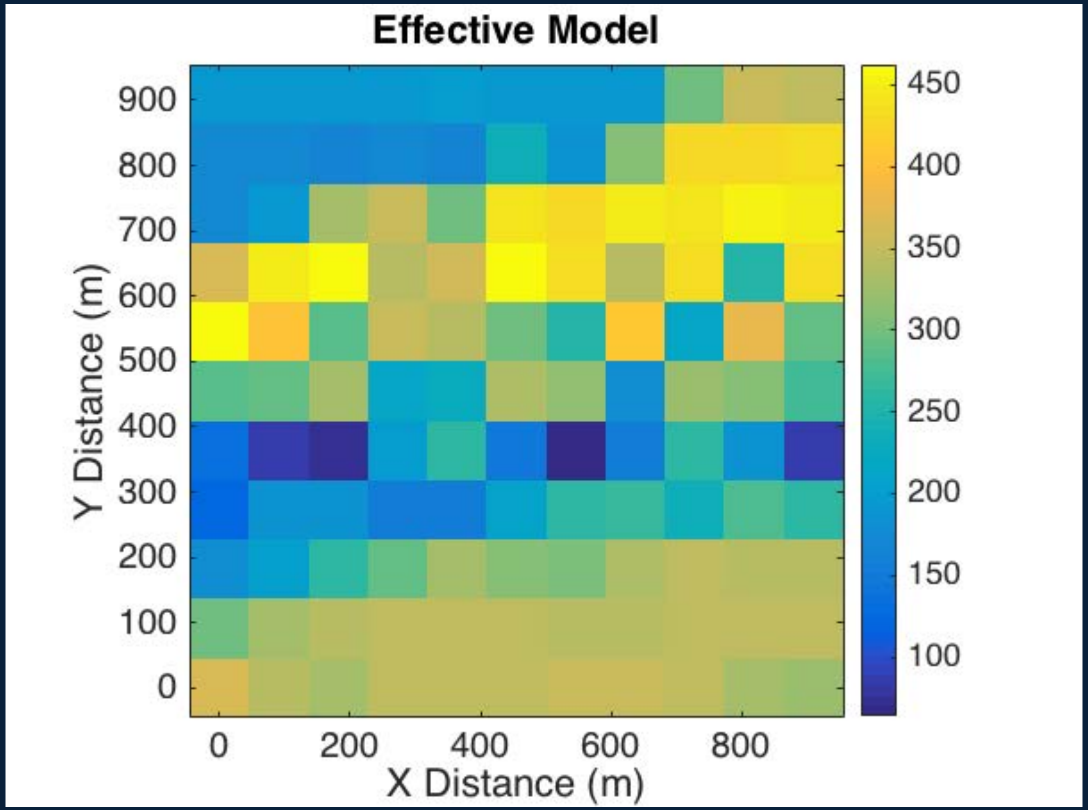
Histogram of the Parameters

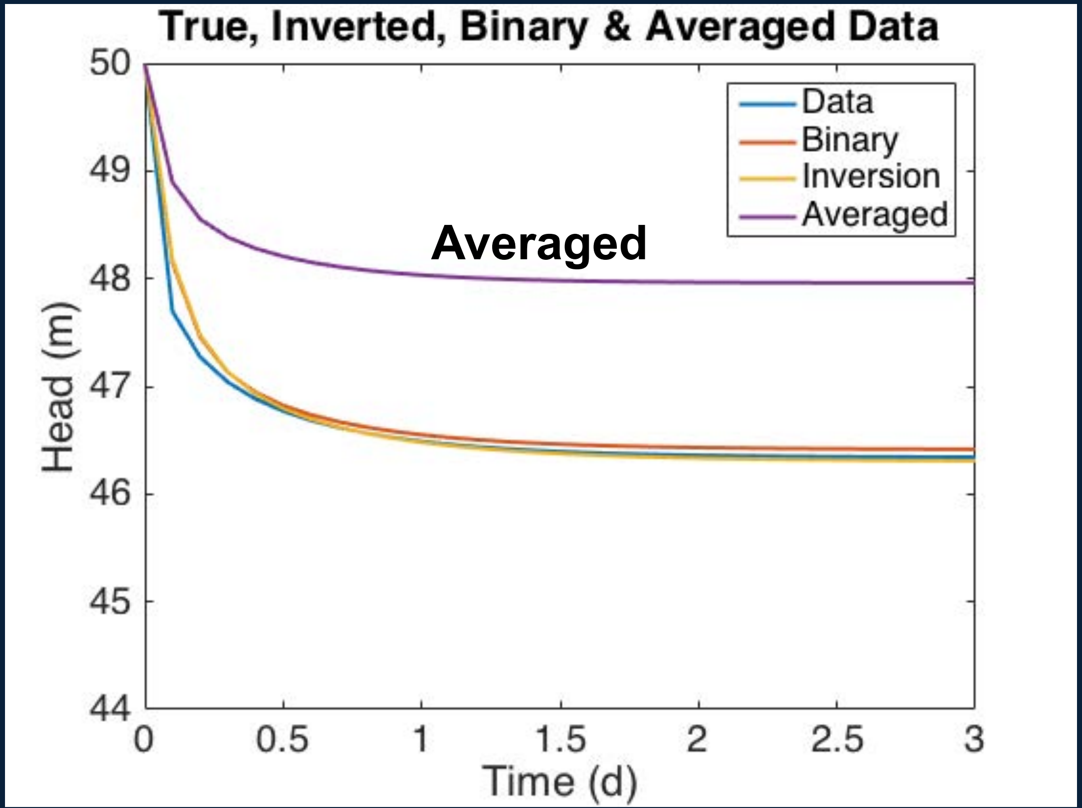


Response of the Binary Model

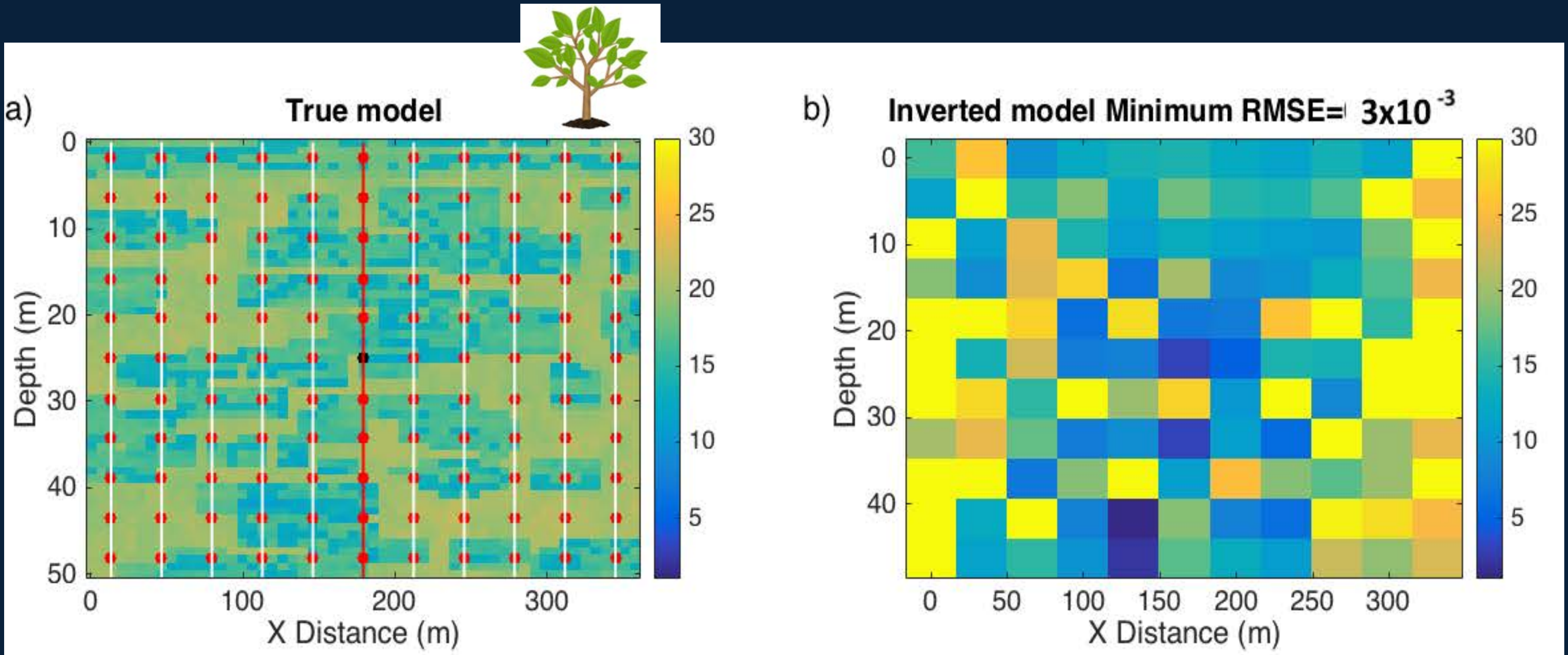


Spatial Average of the 99x99 Model



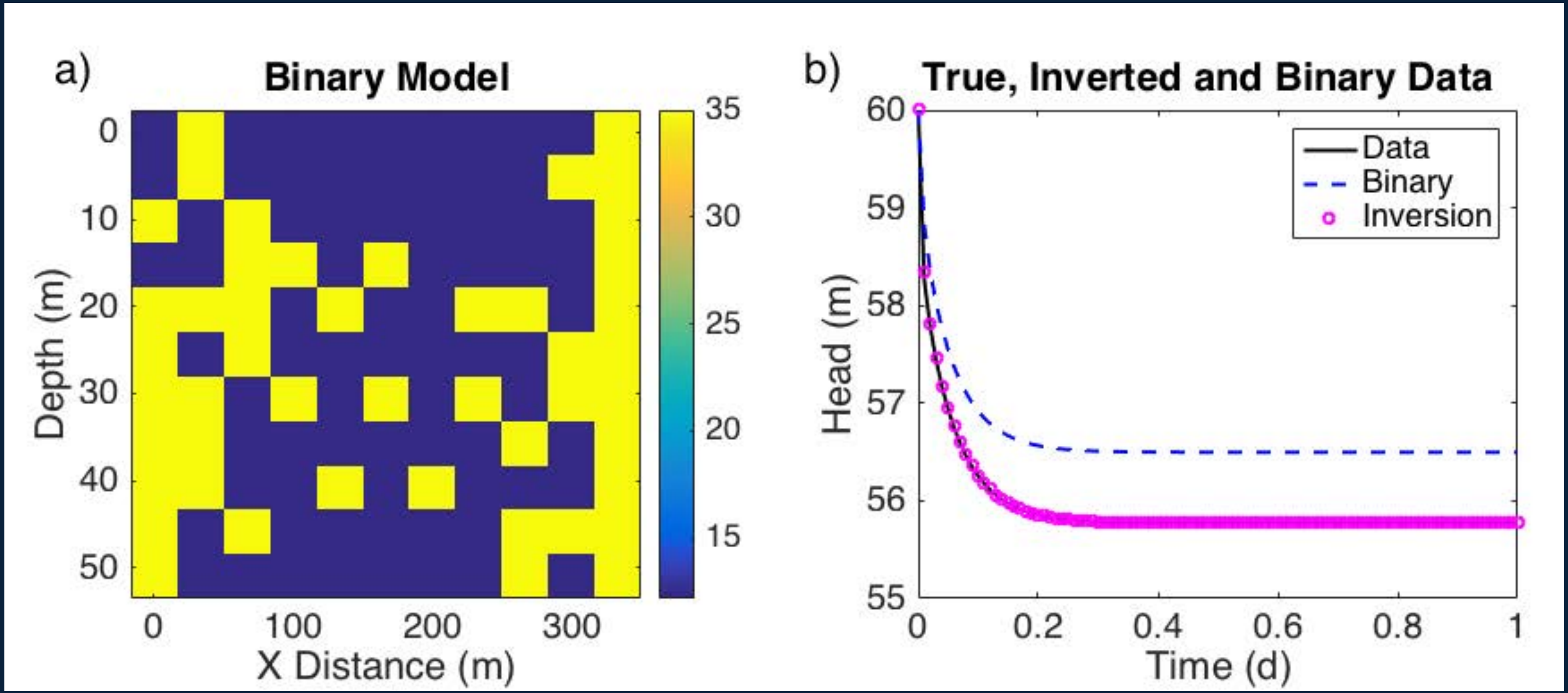


Case 3: Big to Small (x,z)

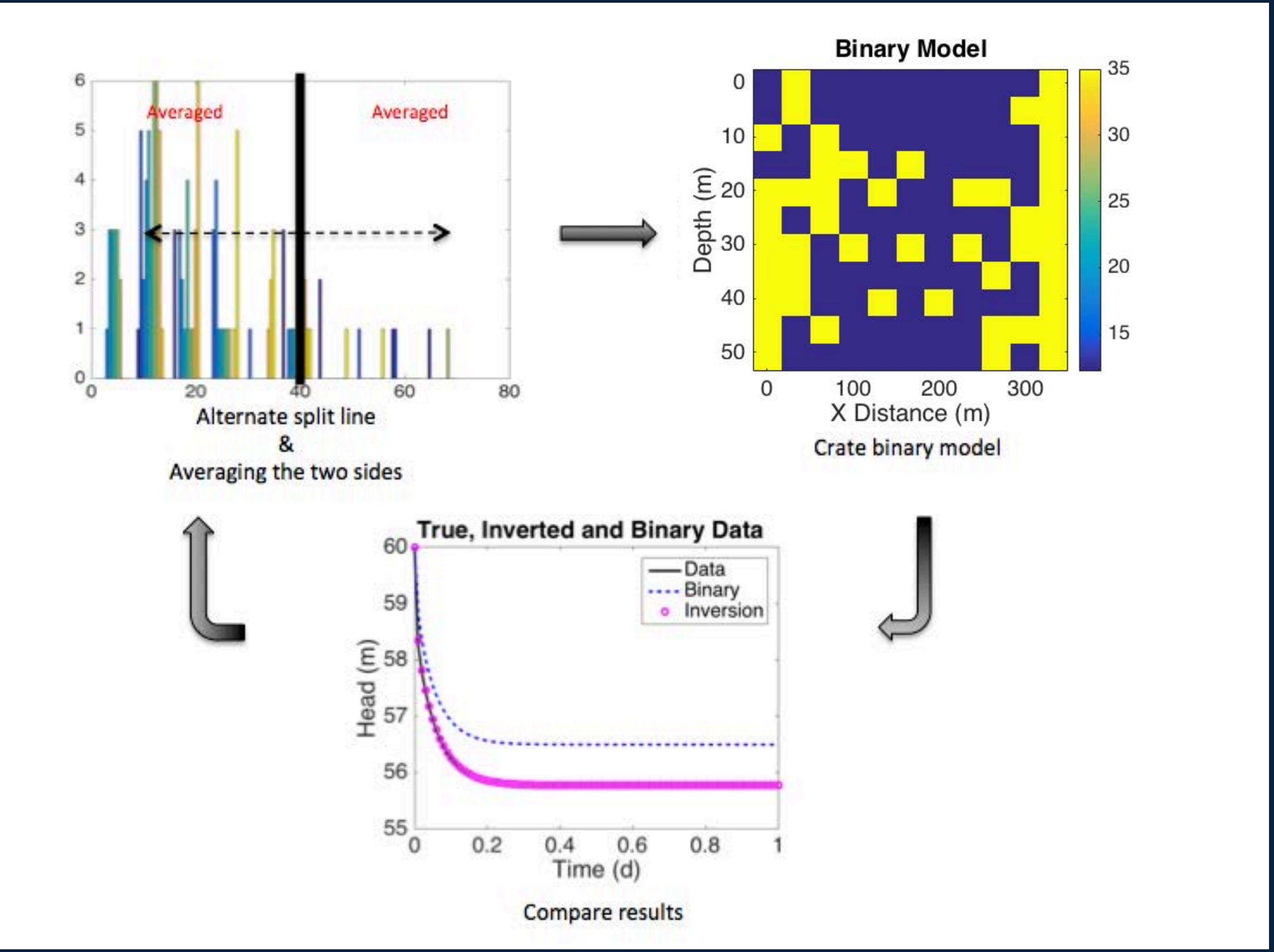


- True model: 55x55 grids
- Inverted model: 11x11 grids
- 1 pumping well
- 11 observation wells (121 data positions)

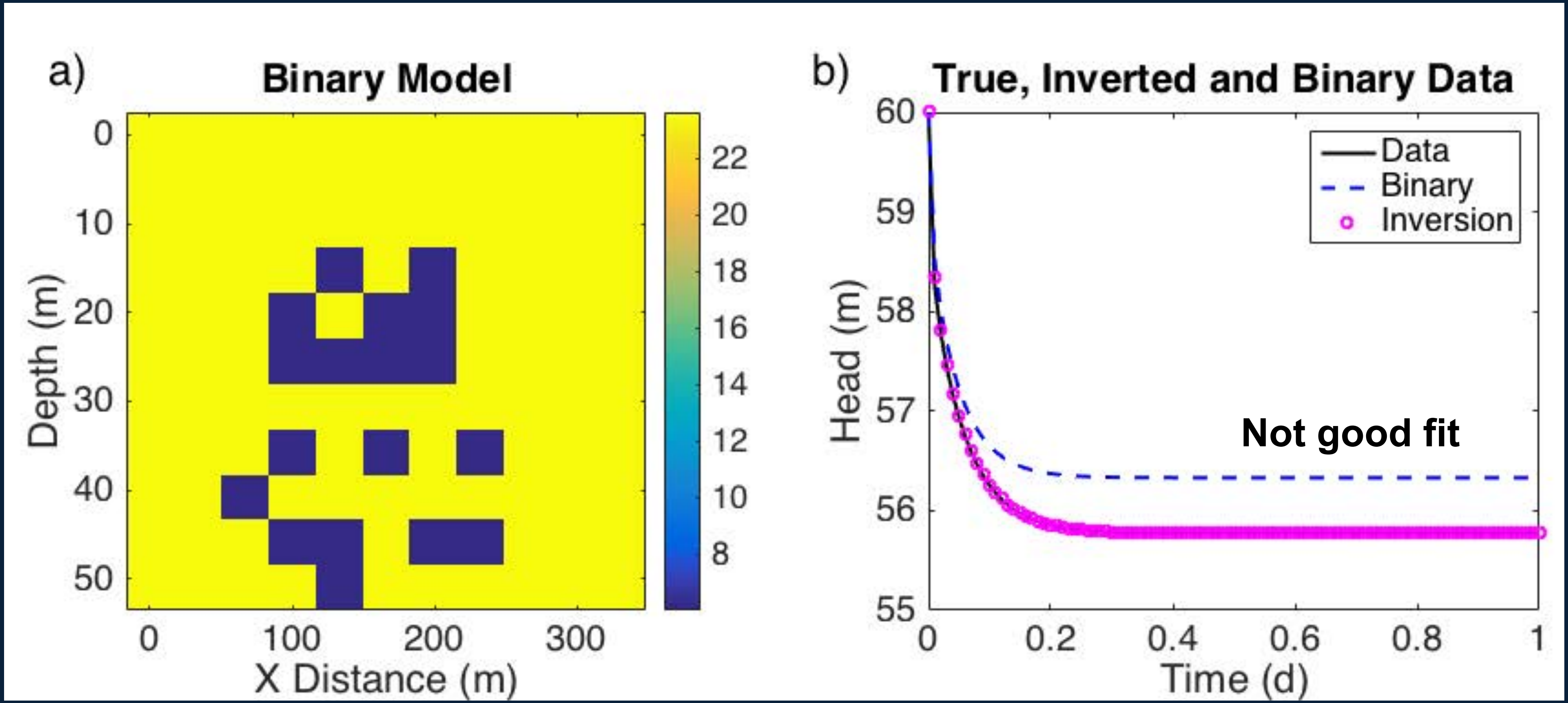
Case 3: (Binary Model)



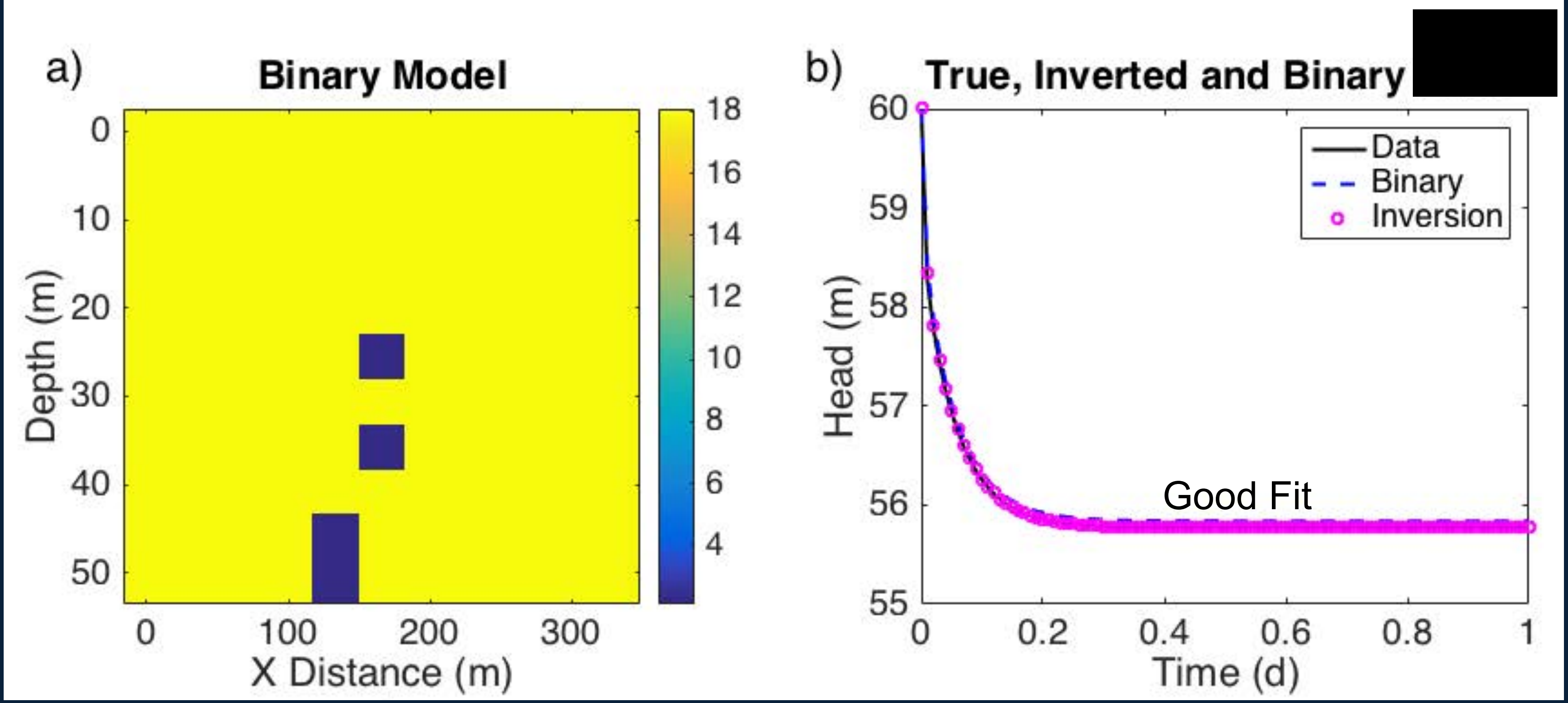
Optimum Binary Model



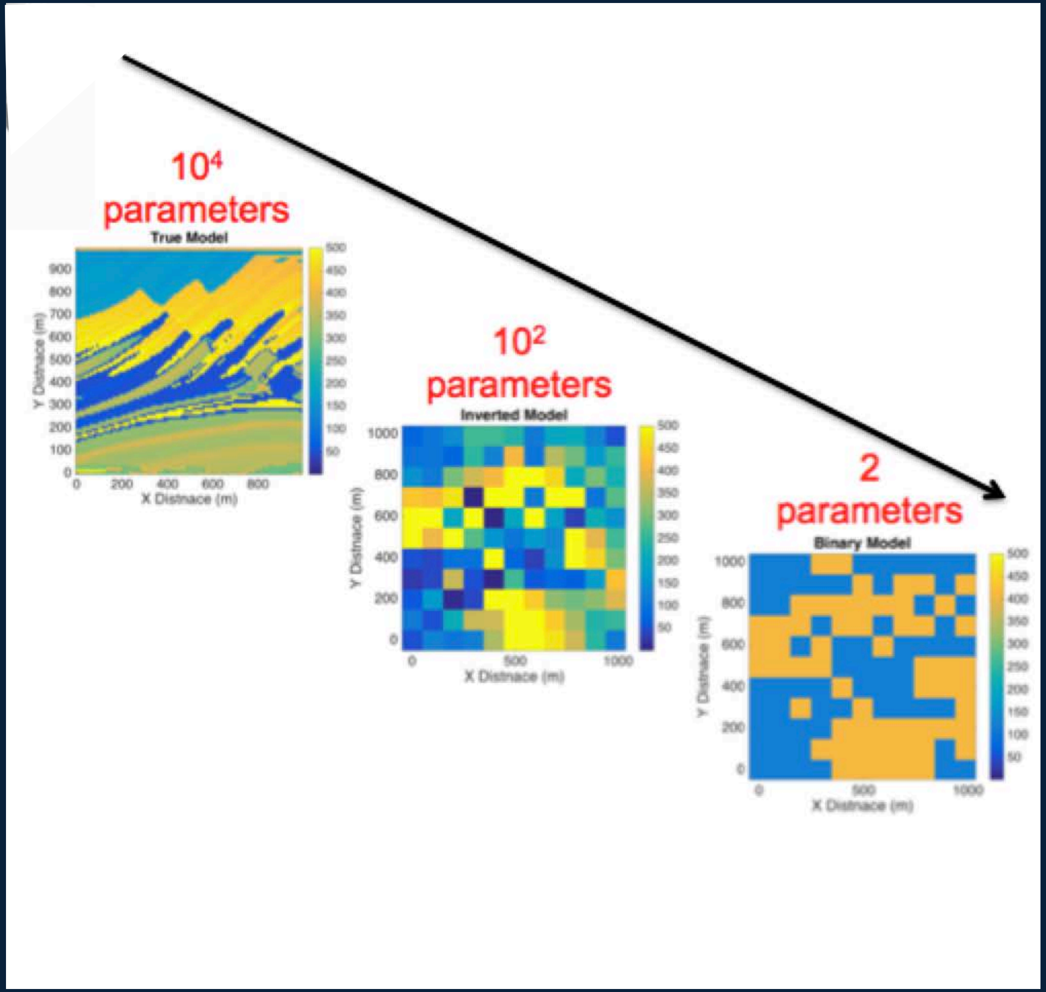
Optimum Binary Model (Arithmetic Averaging)



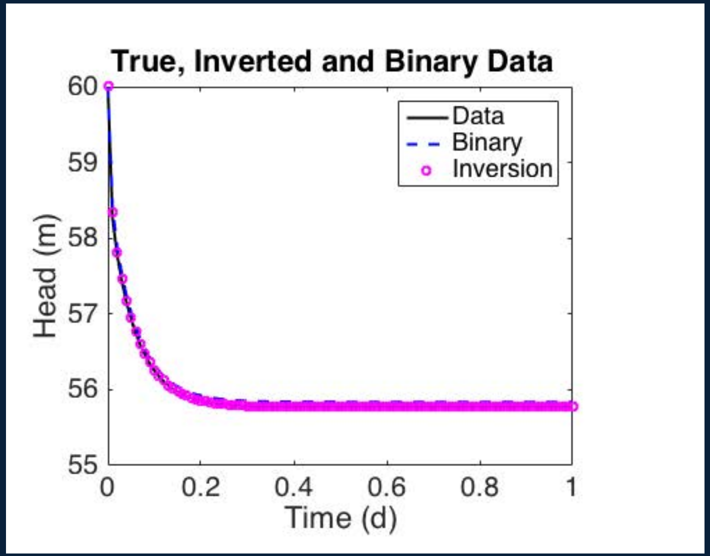
Optimum Binary Model (Geometric Averaging)



Summary

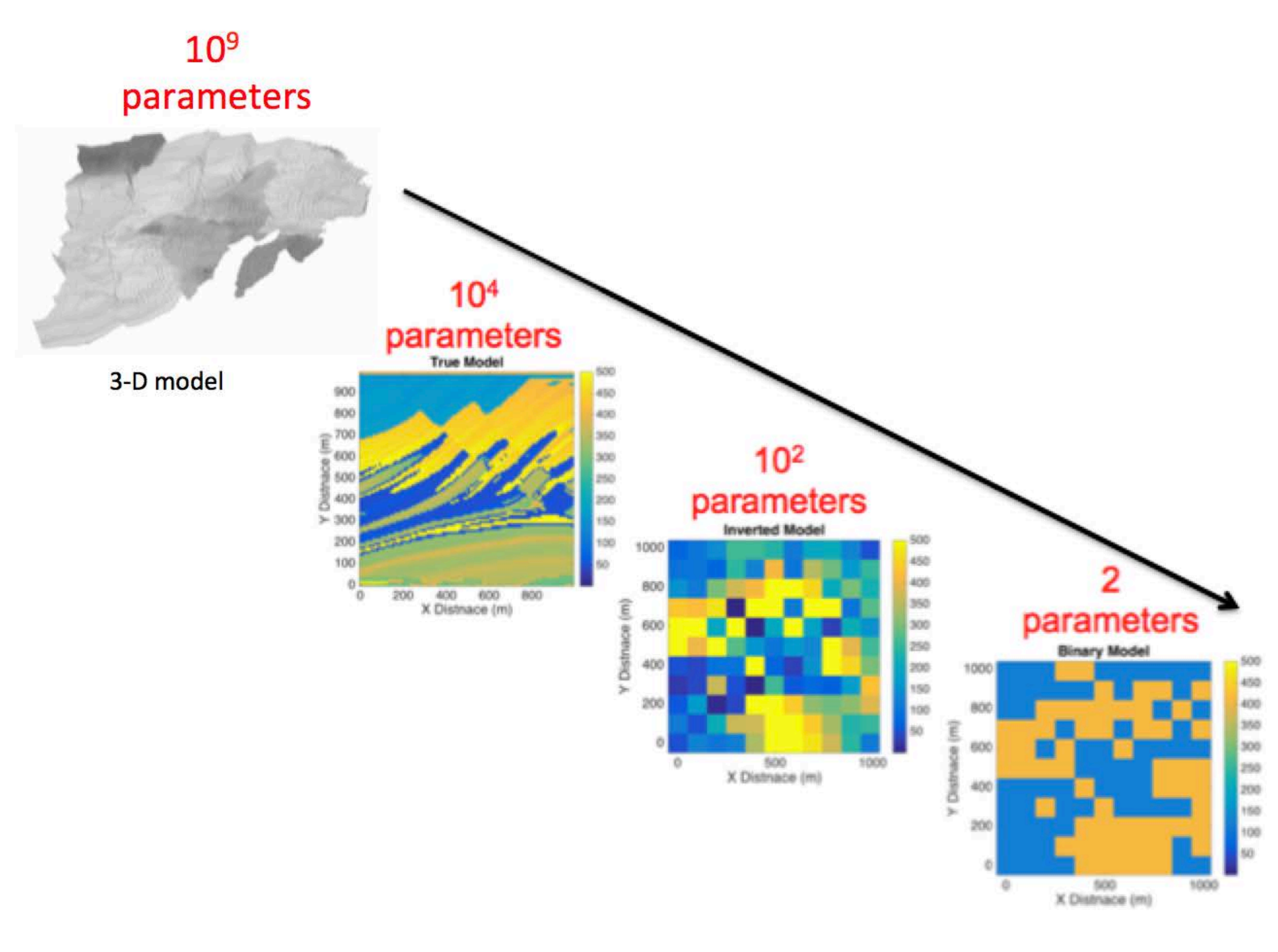


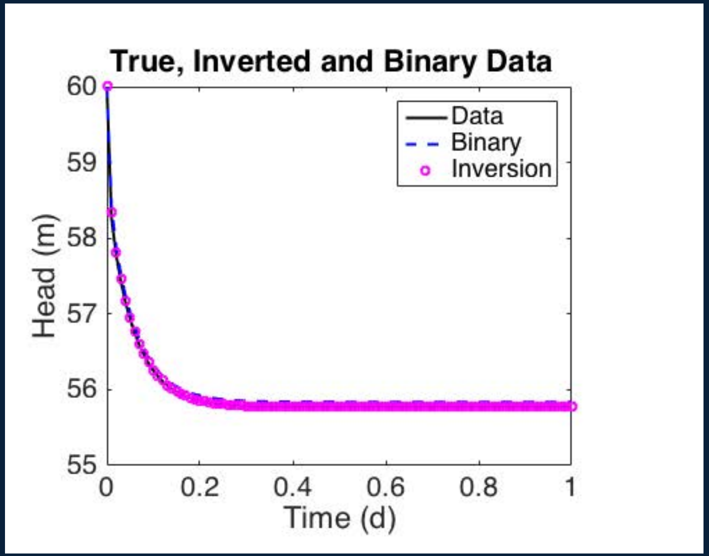
"Perfect Fit"



Summary

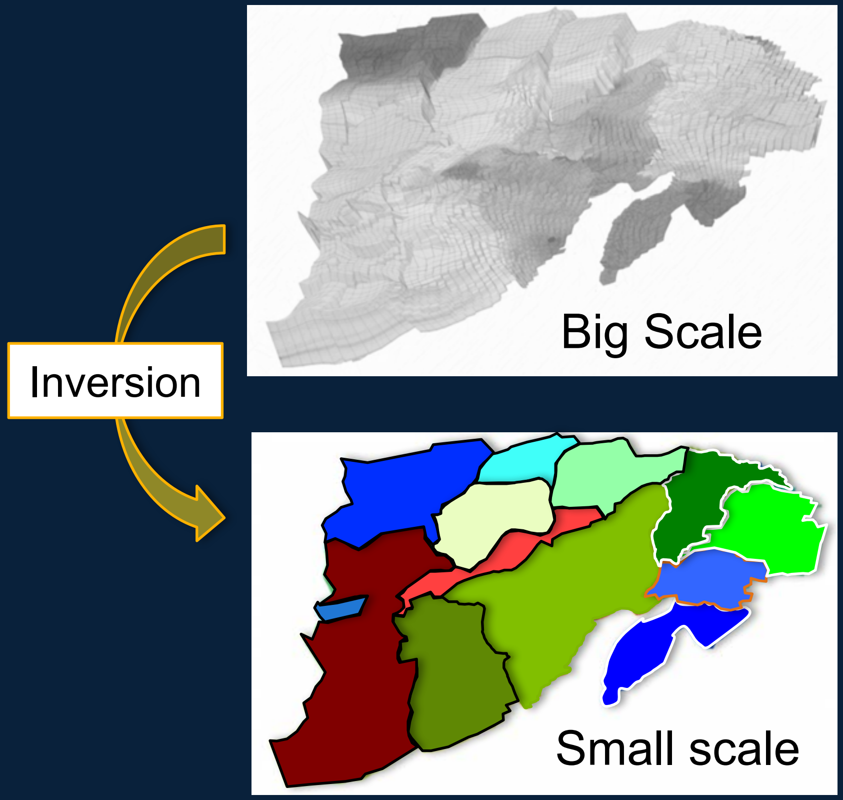
"Perfect Fit"





Conclusions

- A reduced model could fit the production data.
- The model can be reduced to binary model and also fits the production data.
- We had a better success using the geometric mean in creating the optimum binary model.



Thanks