Smooth 3D inversion of the MT data for comparison: finite-difference modeling and least-squares inversion

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Outline of talk:

1. **Method**
2. **Dataset-1**
3. **Dataset-2 (secret dataset)**

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1. Method

Inversion Scheme

Sasaki (1999, 2004)

- **Forward:** 3D staggered-grid finite difference
- **Inversion:** linearized least-squares
- Smoothness regularization
- Static shifts treated as unknowns
- Optimization by Bayesian criterion

$$U = \left\| \mathbf{W}\left[\mathbf{d} - F\left(\mathbf{m}\right) - \mathbf{G}\mathbf{s}\right] \right\|^2 + \alpha^2 \left(\left\| \mathbf{C}\mathbf{m} \right\|^2 + \beta^2 \left\| \mathbf{s} \right\|^2 \right)$$

$$\mathbf{Z} = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix}$$

***d*:** apparent resistivity and phase of off-diagonal components
***W*:** 1% error floor
G: assume Gaussian static shifts

To save computation time

- **Frechet derivative**

$$A_{ij} = \frac{\partial F_i(\mathbf{m})}{\partial m_j}$$

Approximate in homogeneous medium at first two iterations. Then, full Jacobian at two iterations, and otherwise Broyden update.

- **Regularization**

α, β : optimum value searched by ABIC minimization at each iteration; one of them alternately fixed. Five trial values at each iteration.

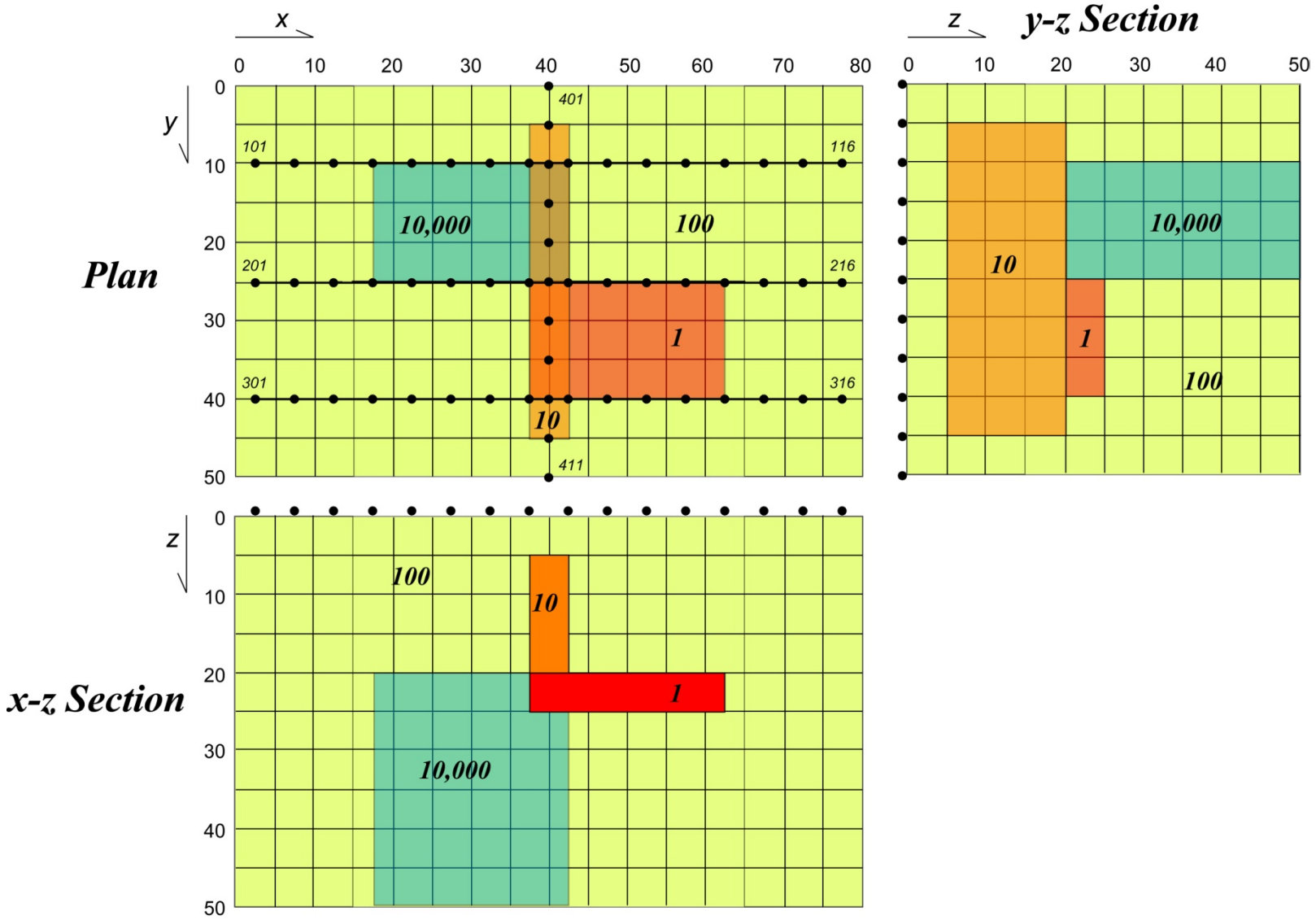
Computing Facility

- **HP Alpha Station ES47**
  - **4 GB (usually use less than 1 GB)**
  - **Single CPU**

- **Computation time**
  - **A few days**

Dataset-1

Model-1



Parameters

FDM cell size

- Surface cell: 2.5km x 2.5km x 0.25km
- 55 x 43 x 39 cells
- Numerical error (100 ohm-m) < 1.5%

Data

- 59 stations
- 17 periods (0.18 – 1800 sec)
- ρxy, ϕxy, ρyx, ϕyx (ρ in log)
- 3% Gaussian noise added

Block

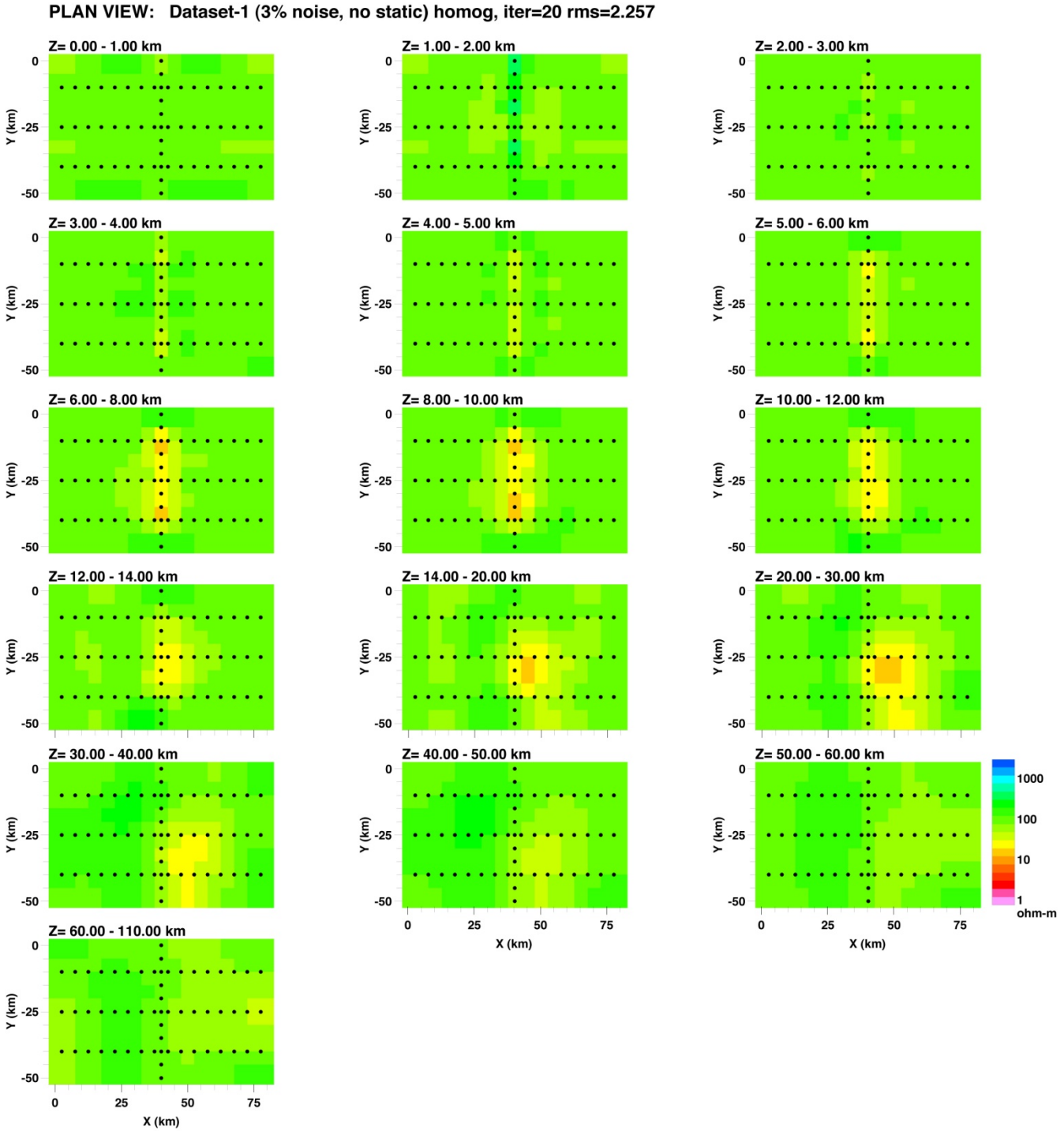
- 15 x 10 x 16 blocks

Inversion

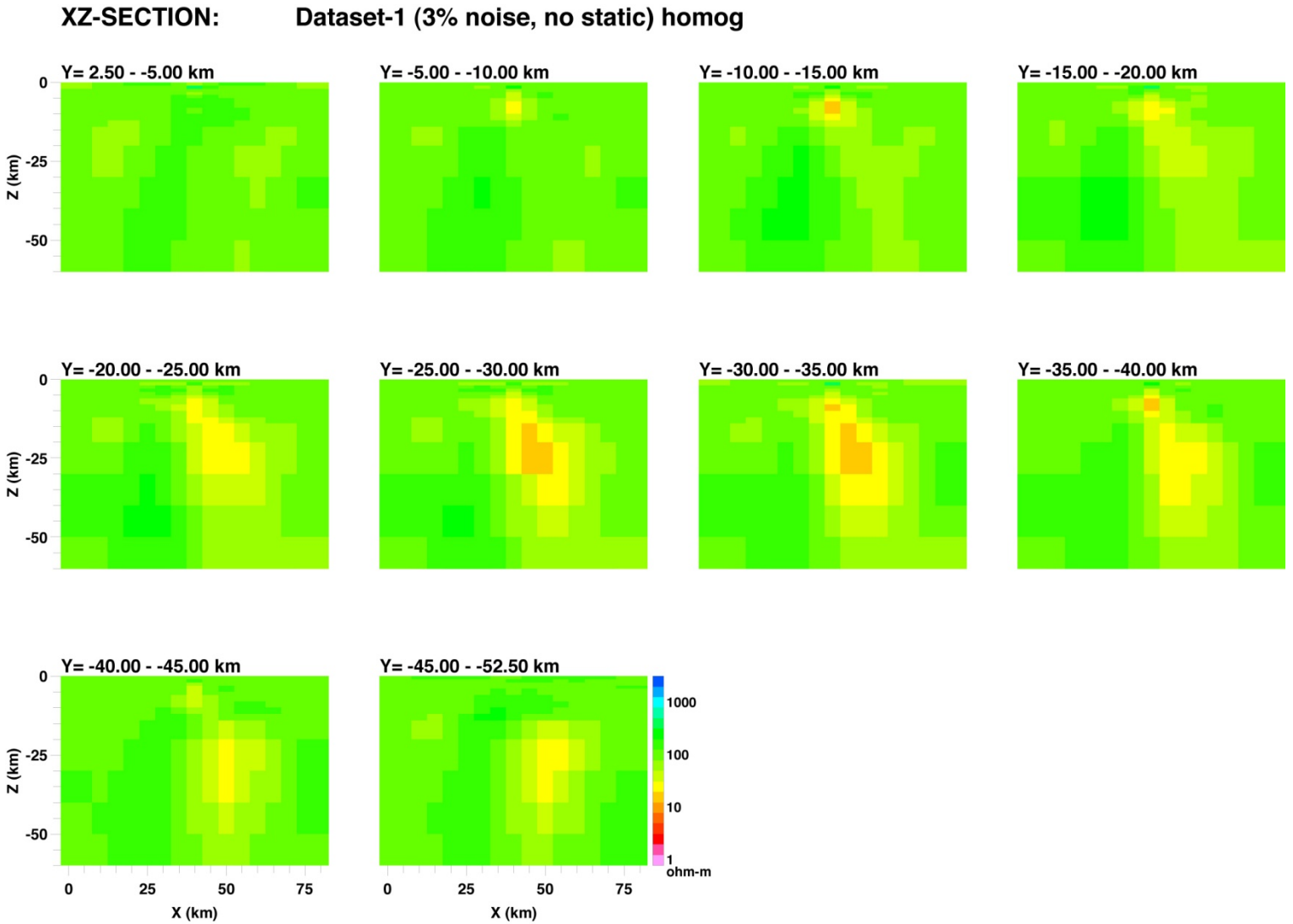
- Initial model: 84.4 ohm-m homog.
- Static shift not-considered
- Homogeneous Jacobian
- 1% noise floor

Iteration=20
rms misfit = 2.257

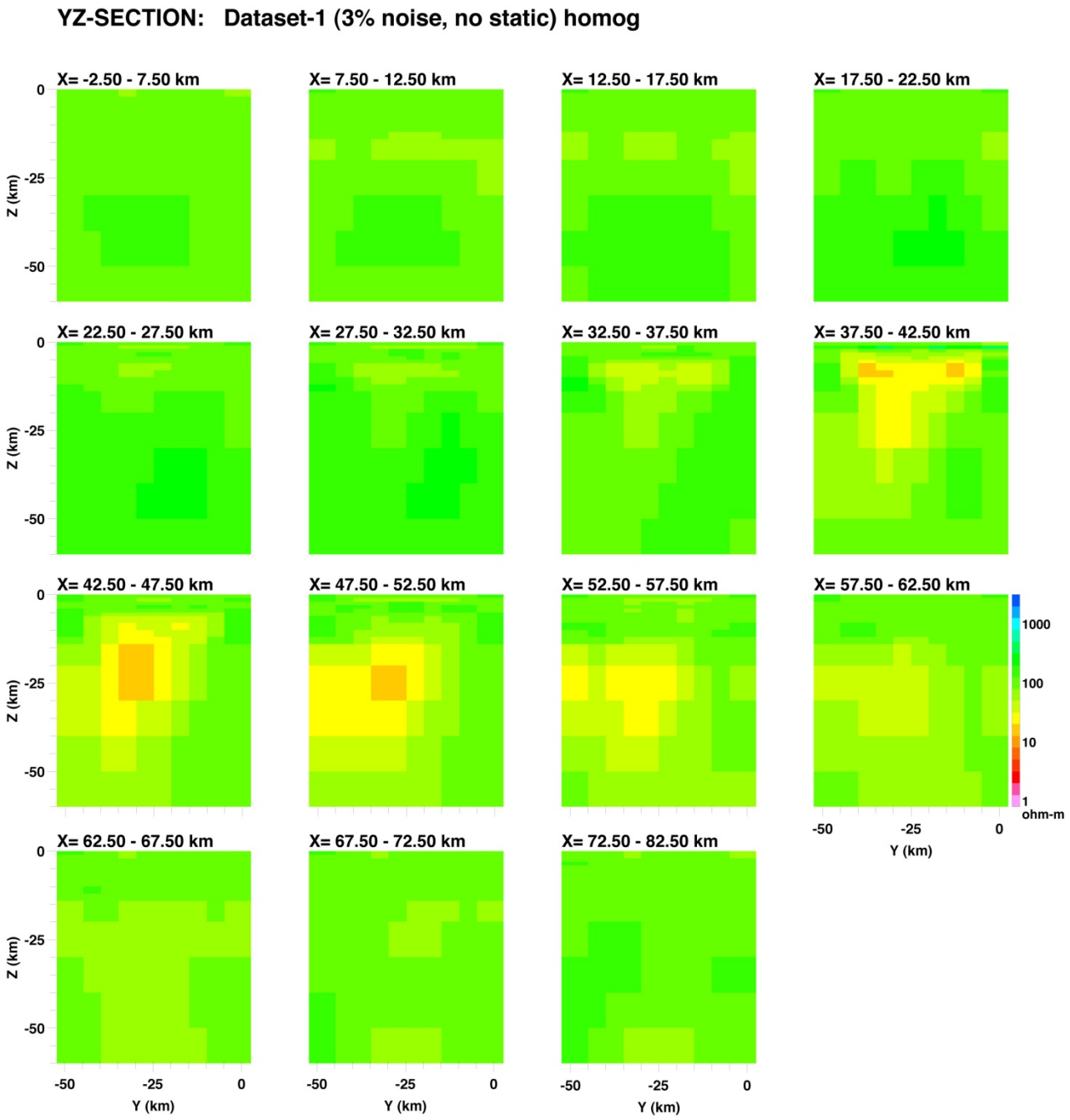
Dataset-1, inversion, depth-slice



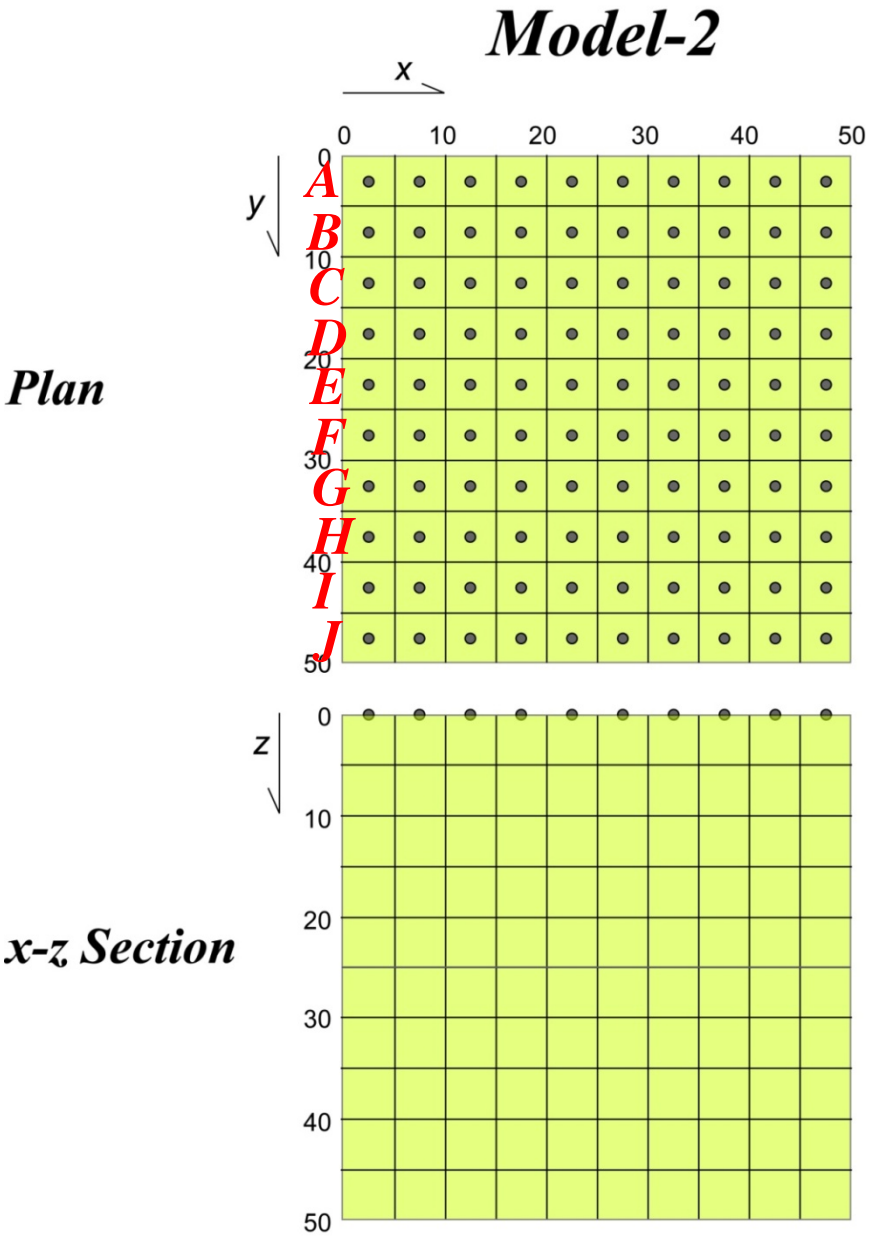
Dataset-1, inversion, xz-slice



Dataset-1, inversion, yz-slice



Dataset-2 (Marion secret dataset)



FDM cell size

- Surface cell (center):
  2.5km x 2.5km x 0.25km
- 43 x 43 x 39 cells
- Numerical error (100 ohm-m)
  < 1.5%

Data

- 100 stations
- 15 periods (0.56 – 1800 sec)
- ρxy, ϕxy, ρyx, ϕyx (ρ in log)

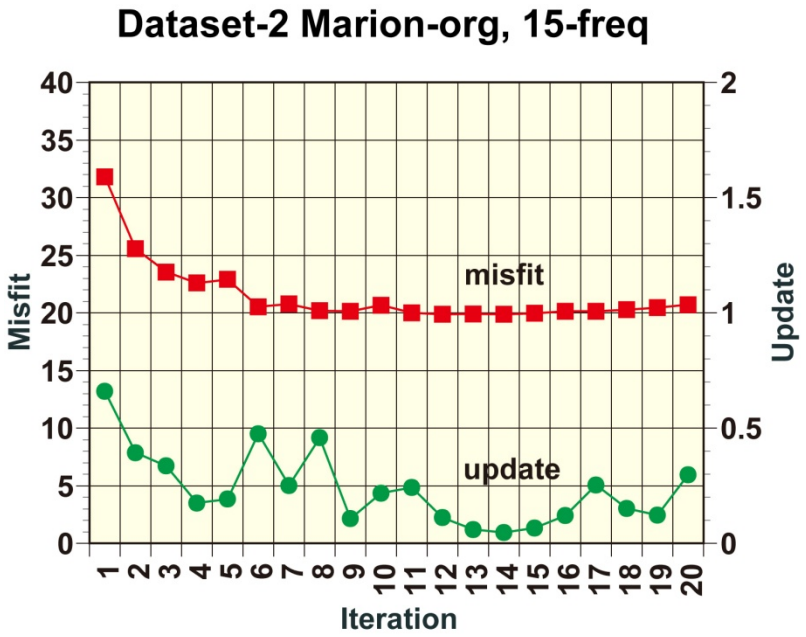
Block

- 10 x 10 x 16 blocks

Inversion

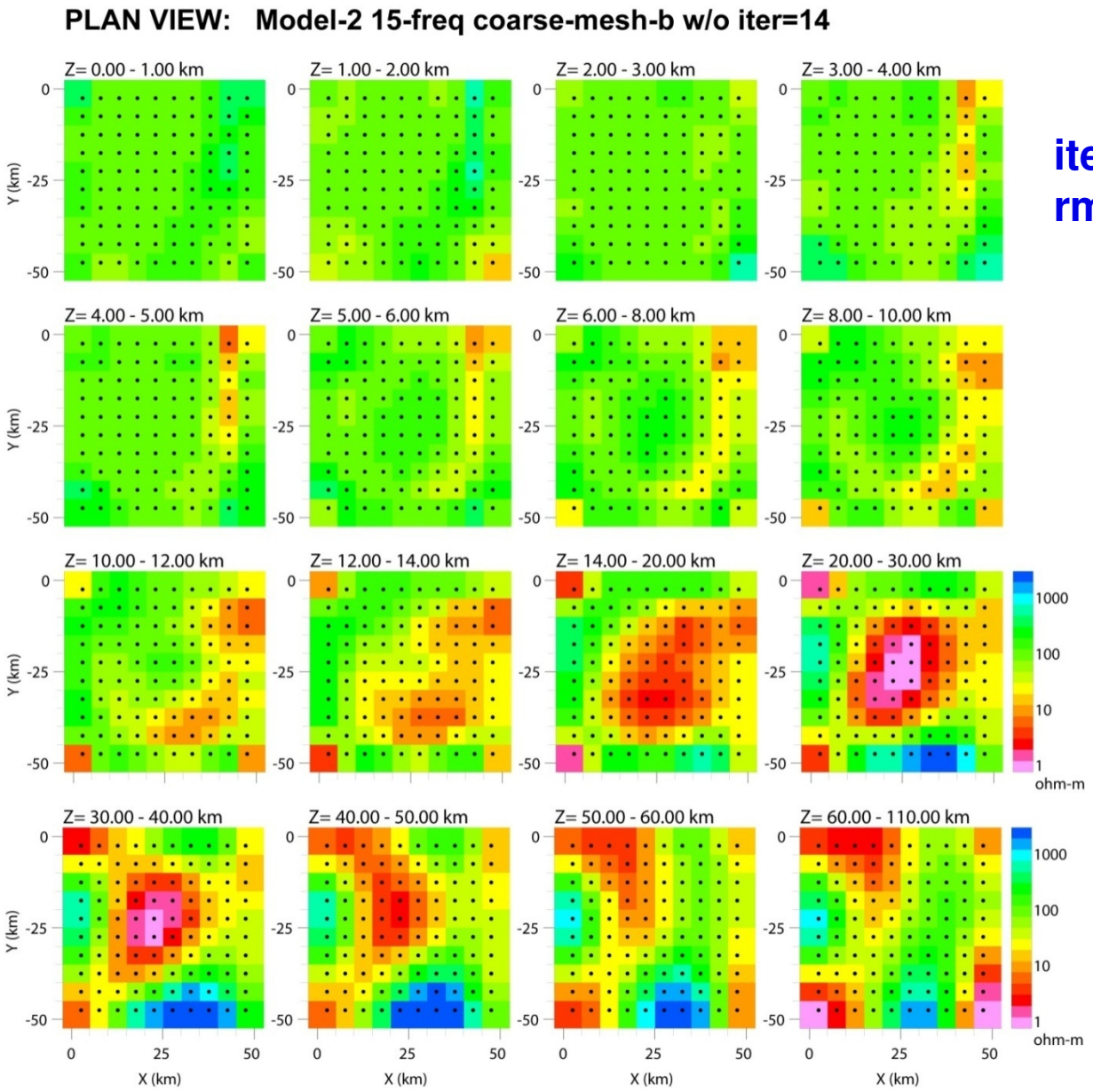
- Initial model: 63.1 ohm-m homog.
- Static shift not-considered
- 1% noise assumption

Dataset-2, Marion-data, inversion



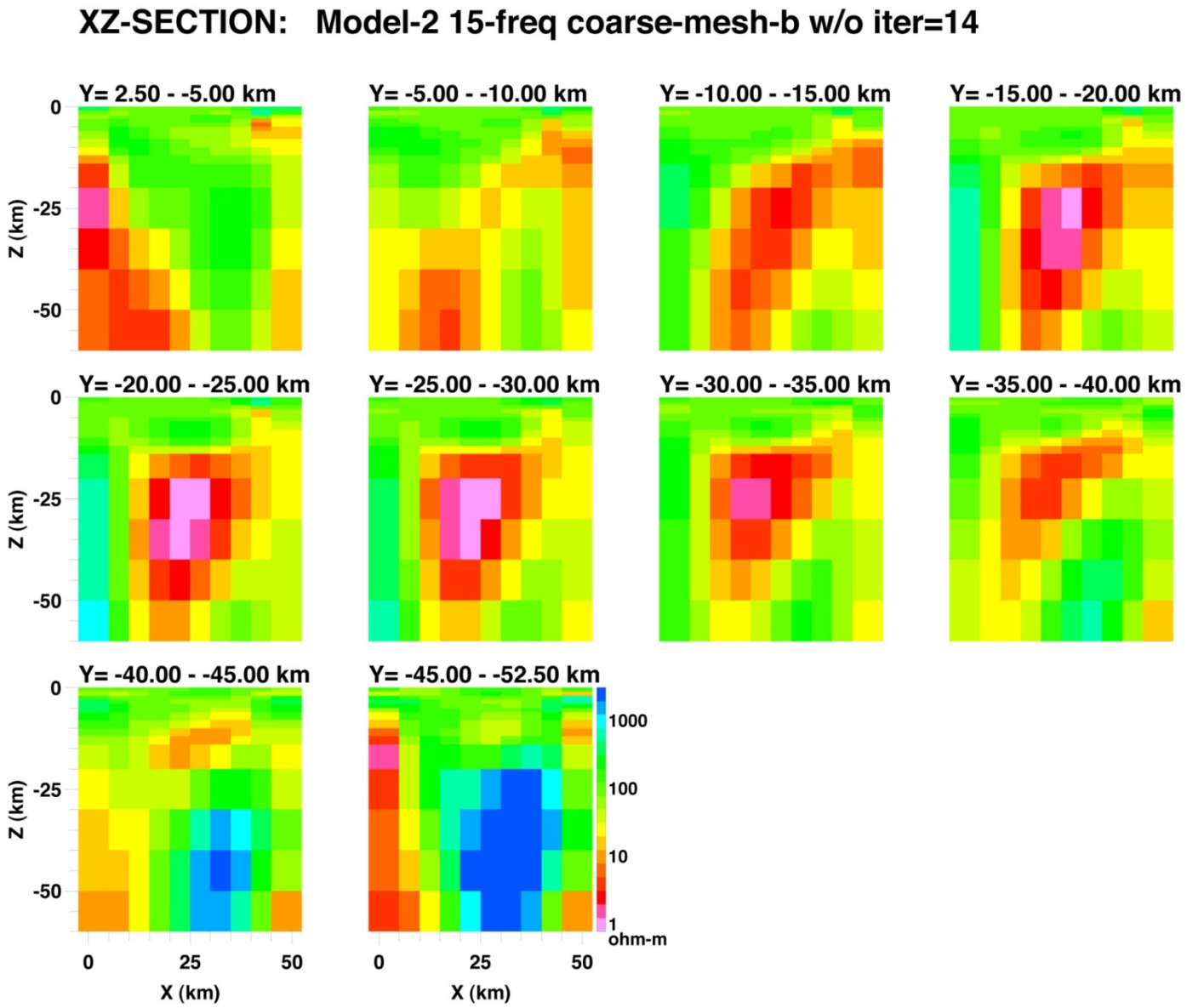
Iteration = 14
rms = 19.88

Dataset-2, Marion-data, depth slice

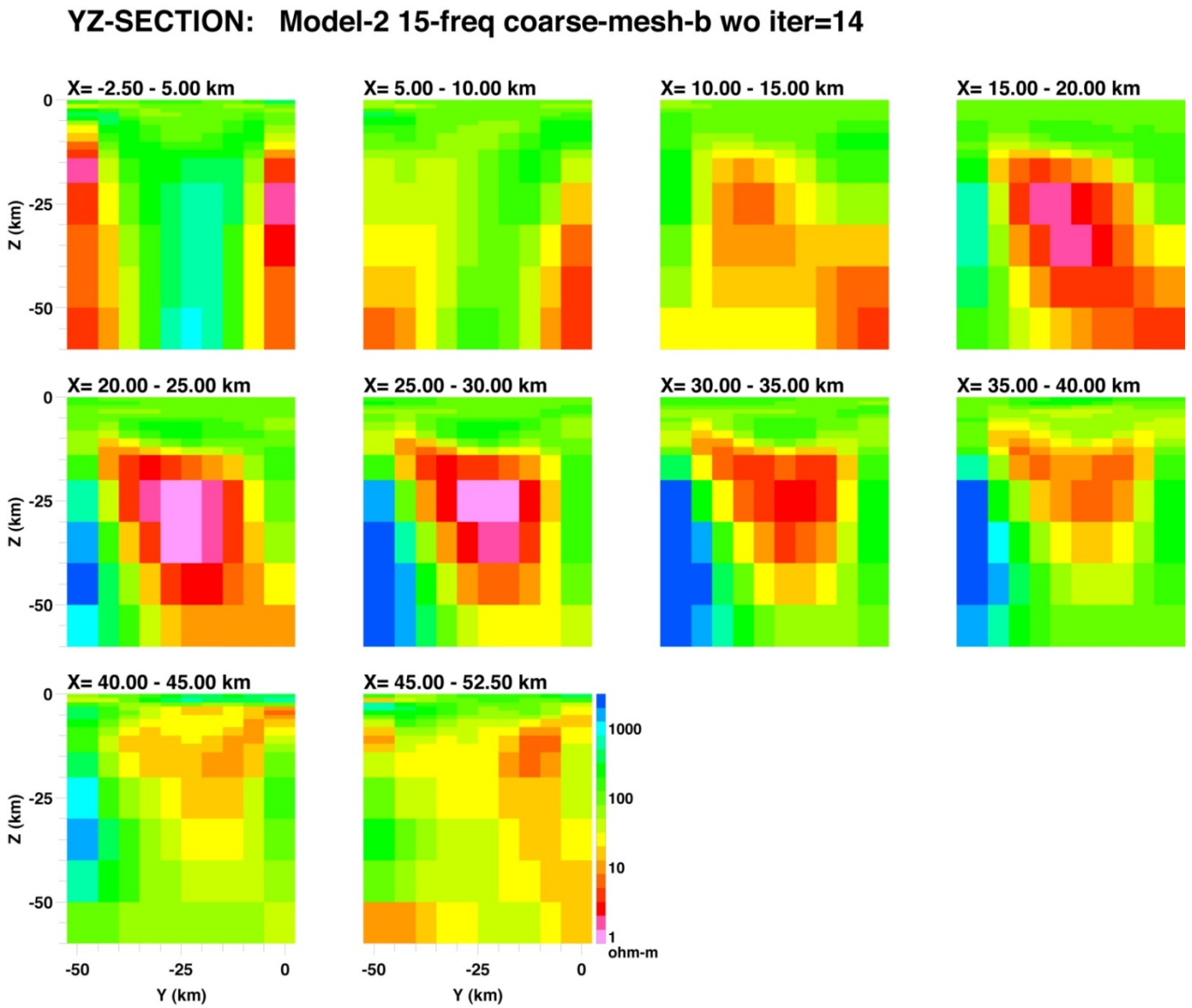


iteration = 14
rms =19.88

Dataset-2, Marion-data, xz-section



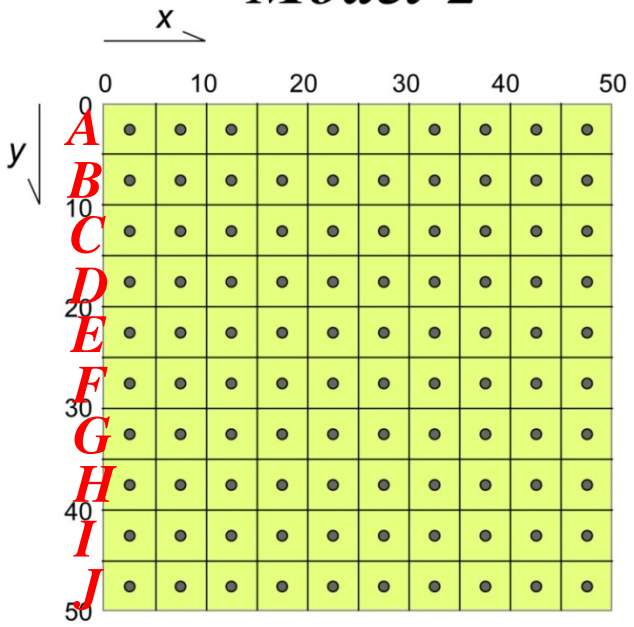
Dataset-2, Marion-data, yz-section



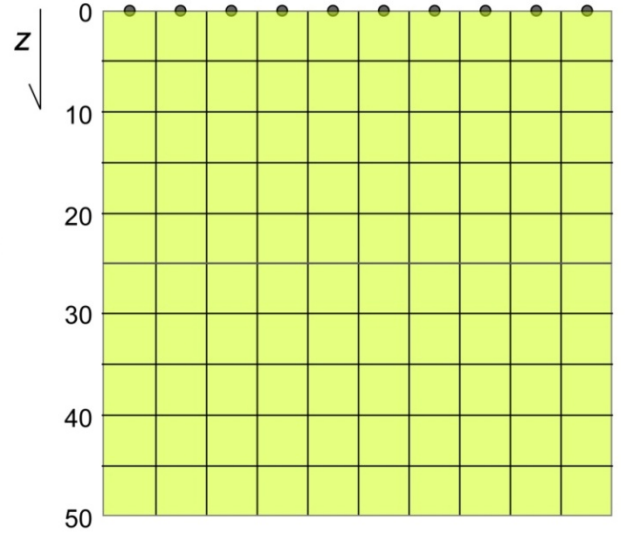
Dataset-2 (xy/yx components swapped)

Model-2

Plan



x-z Section



original

ρxy, ϕxy

ρyx, ϕyx

swapped

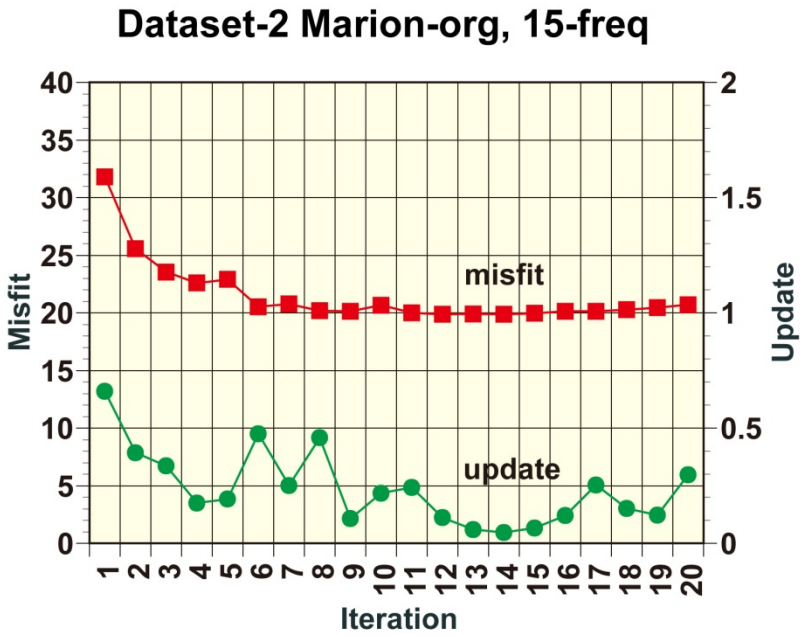
ρyx, ϕyx

ρxy, ϕxy

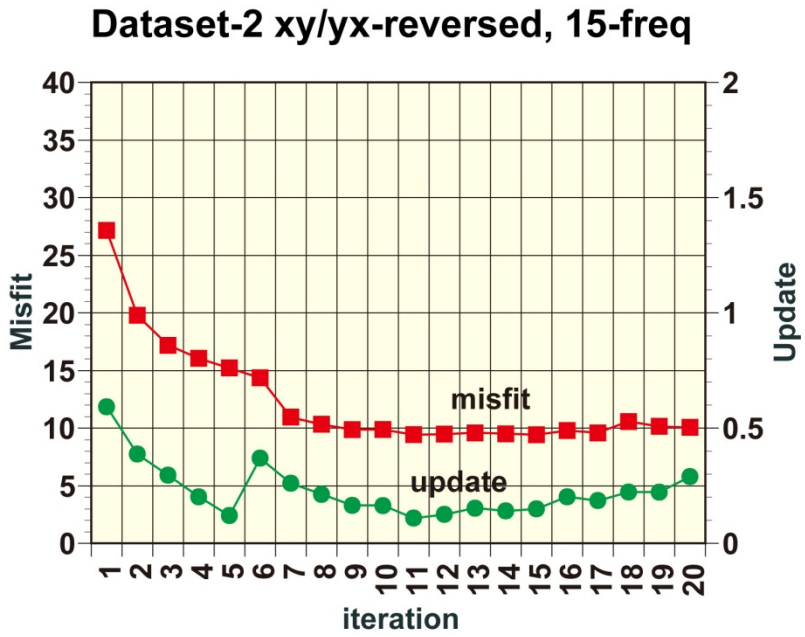
- **15 periods (0.56 – 1800 sec)**
- **17 periods (0.56 – 5600 sec)**

Dataset-2, xy/yx-reversed, inversion

Original

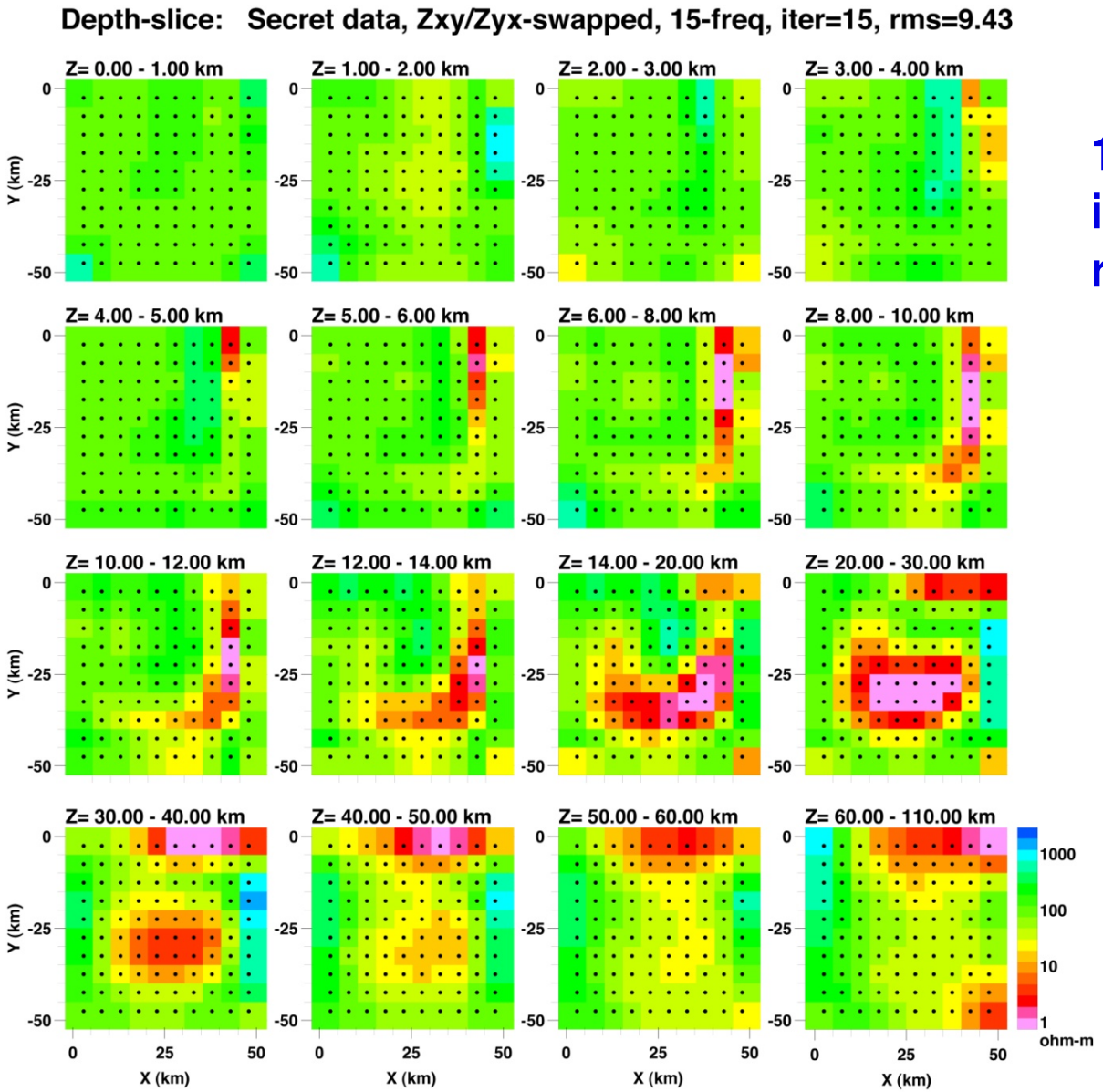


Swapped



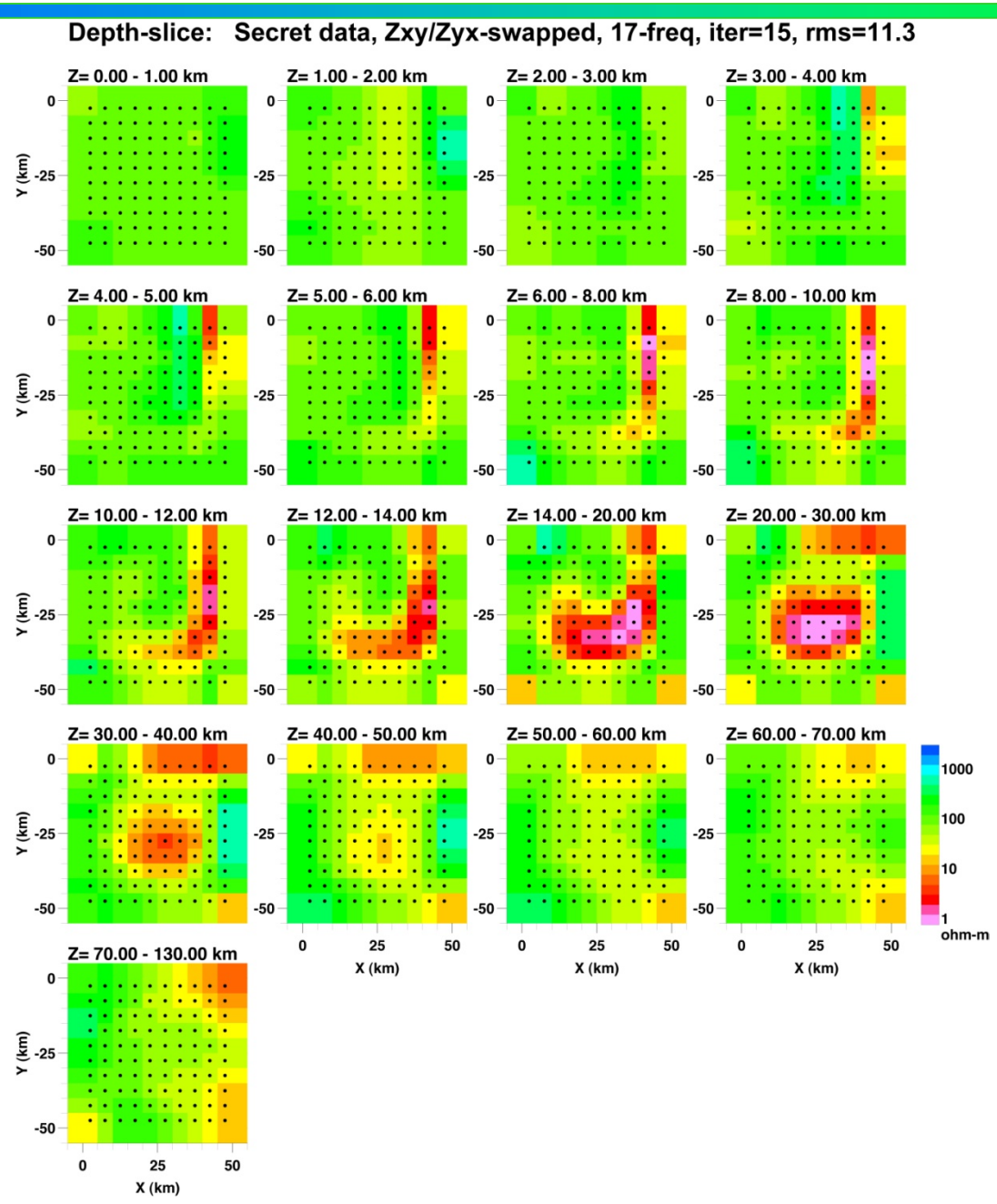
Iteration = 15
rms = 9.43

Dataset-2, Zxy/Zyx swapped, depth slice, 15 freq.



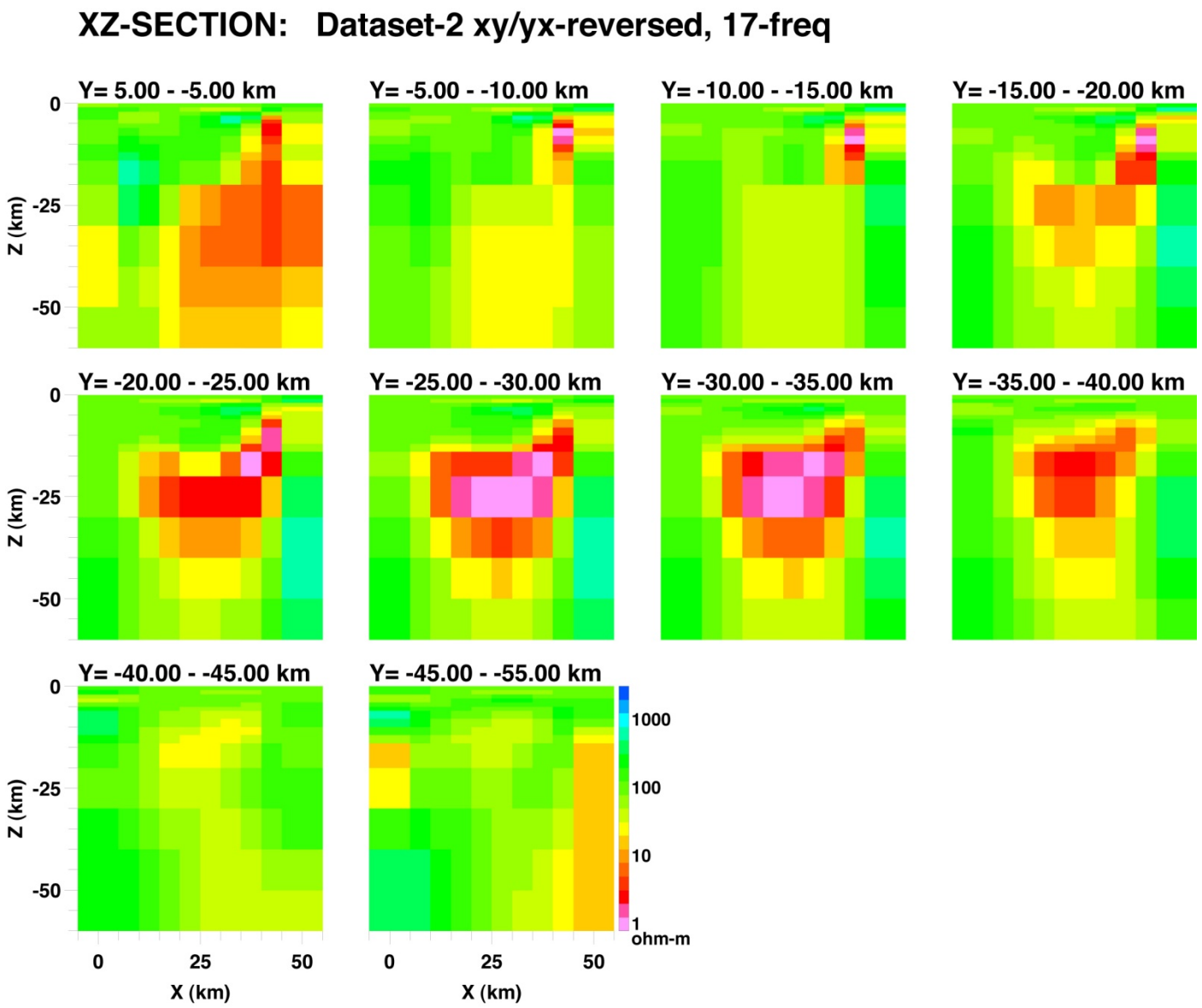
15 freqs.
iter = 15
rms = 9.43

Dataset-2, Zxy/Zyx swapped, depth slice, 17 freq.

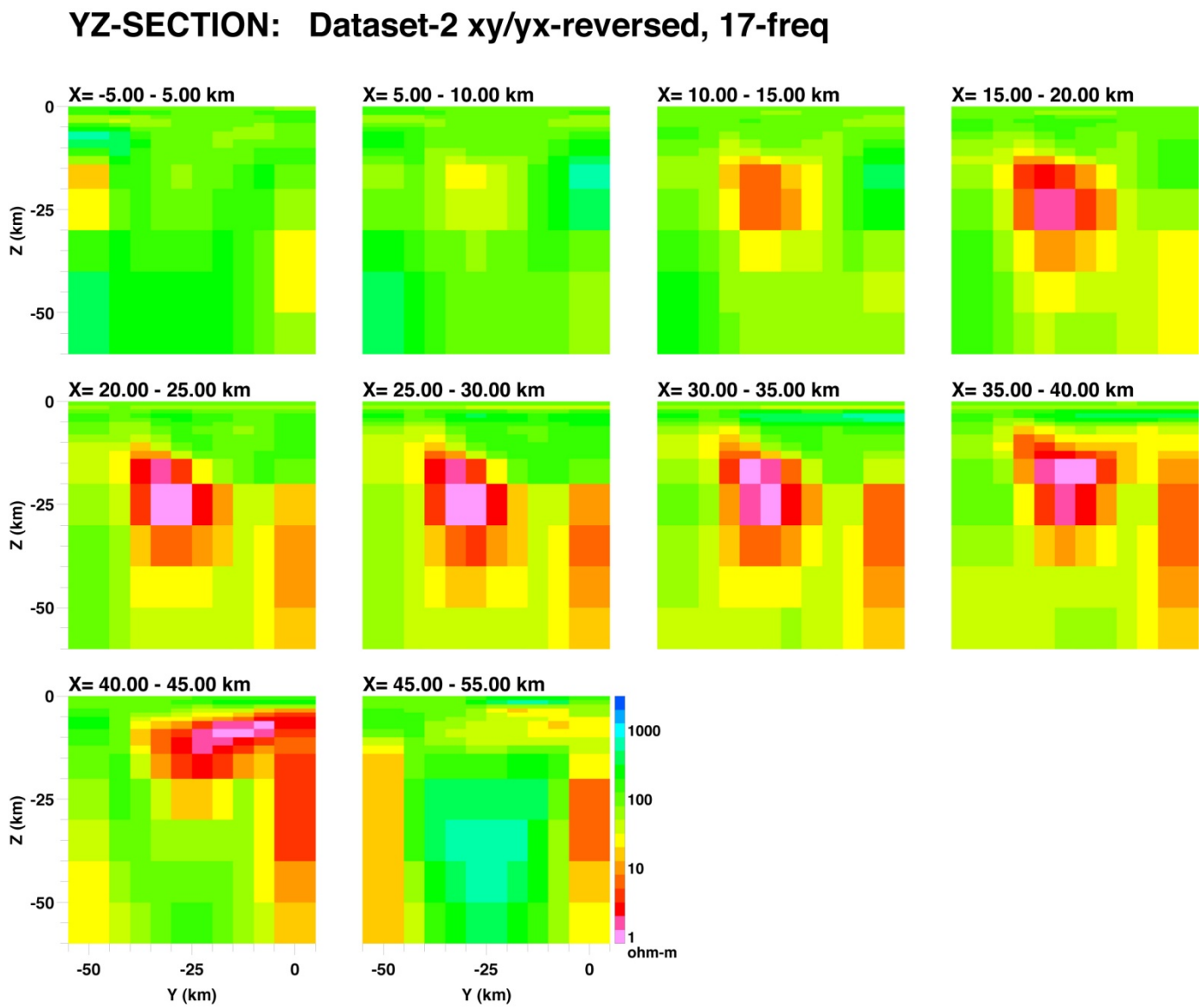


17 freqs.
iter = 15
rms = 11.3

Dataset-2, Zxy/Zyx swapped, 17 freqs, xz-slice



Dataset-2, Zxy/Zyx swapped, 17 freqs, yz-slice



Thank you!