Cortical Constraint Method

for Diffuse Optical Tomographic Brain Imaging

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Outline

- DOT Background
- Parametric Models for Optical Properties
- Numerical Results
- Conclusions and Future Work

Diffuse Optical Tomography

- tissue illuminated by near-infrared, frequency modulated light
- light detected in array(s)
- model of physics used to infer optical properties of tissue
- Differences in optical properties

  $\Longrightarrow$ 3D images with hot spots

Forward Model

$$Af \approx g$$

Difficulties in solving:

- Underdetermined
- Large number of voxels
- Sensitive to noise in data

Inverse Problem

Typical Tikhonov regularization:

$$\min_f \|W(Af - g)\|_2^2 + \lambda^2 \Omega(f),$$

f is absorption (diffusion) perturbation image(s).

Difficulties:

- Choosing Ω
- Choosing λ
- Computational complexity

Issues

Assumptions to exploit:

- region of activity is constrained to cortex.
- 1-1 map from cortical surface to subset of $\mathbb{R}^2$.

KEY:
Parameterized, 2D shapes can be mapped to shapes on surface of the cortex.

Inverse Problem Revisited

$$\min_{p} \|W(\tilde{A}\tilde{f}(p) - g)\|_2^2$$

where

- vector p describes anomaly shape(s) & optical property(ies).
- $\tilde{f}(p)$ represents the image(s) of absorption/diffusion
- $\tilde{A}$ is sampled at points on the cortical surface.

Model

Let $h(x, y)$ be the height of the surface of the cortex at x, y. Then for $r = (x, y, h(x, y))$:

$$\mu_a(r) = \alpha_a(1/2 + 1/2(\tanh(-\beta p(x, y))))$$

$$D(r) = \alpha_d(1/2 + 1/2(\tanh(-\beta \tilde{p}(x, y))))$$

The unknowns:

- α_a, α_d
- v_a, v_d – vectors of polynomial coefficients.

Discrete Model

If f_{μ_a} and f_D are the vectors of discrete values $\mu_a(r_i)$, $D(r_i)$,

$$\tilde{f}(p) = [f_{\mu_a}] \quad \text{or} \quad \tilde{f}(p) = \begin{bmatrix} f_{\mu_a} \\ f_D \end{bmatrix}$$

and

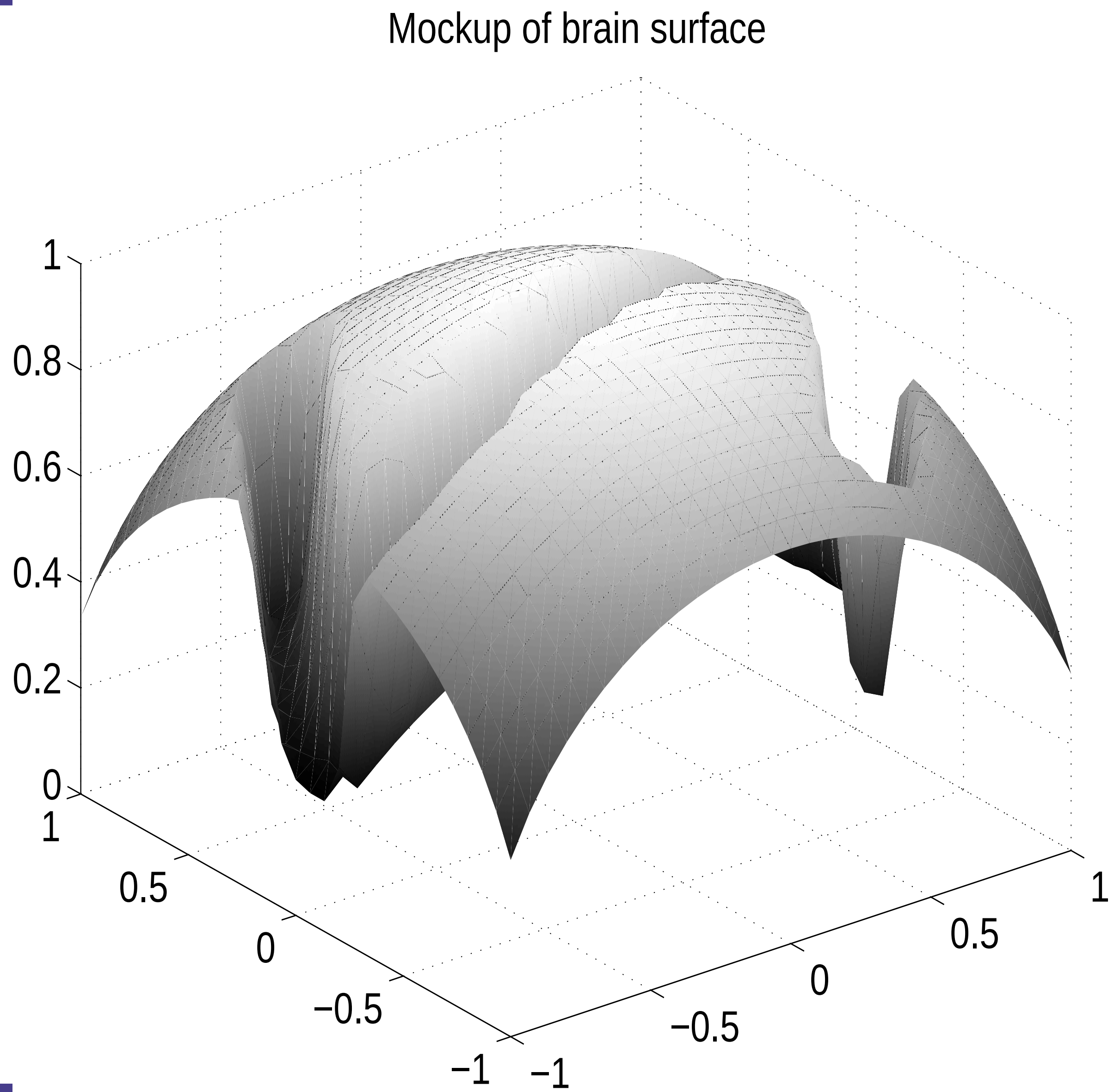
$$p = [\alpha_a, v_a] \quad \text{or} \quad p = [\alpha_a, v_a, \alpha_b, v_b].$$

Numerical Results

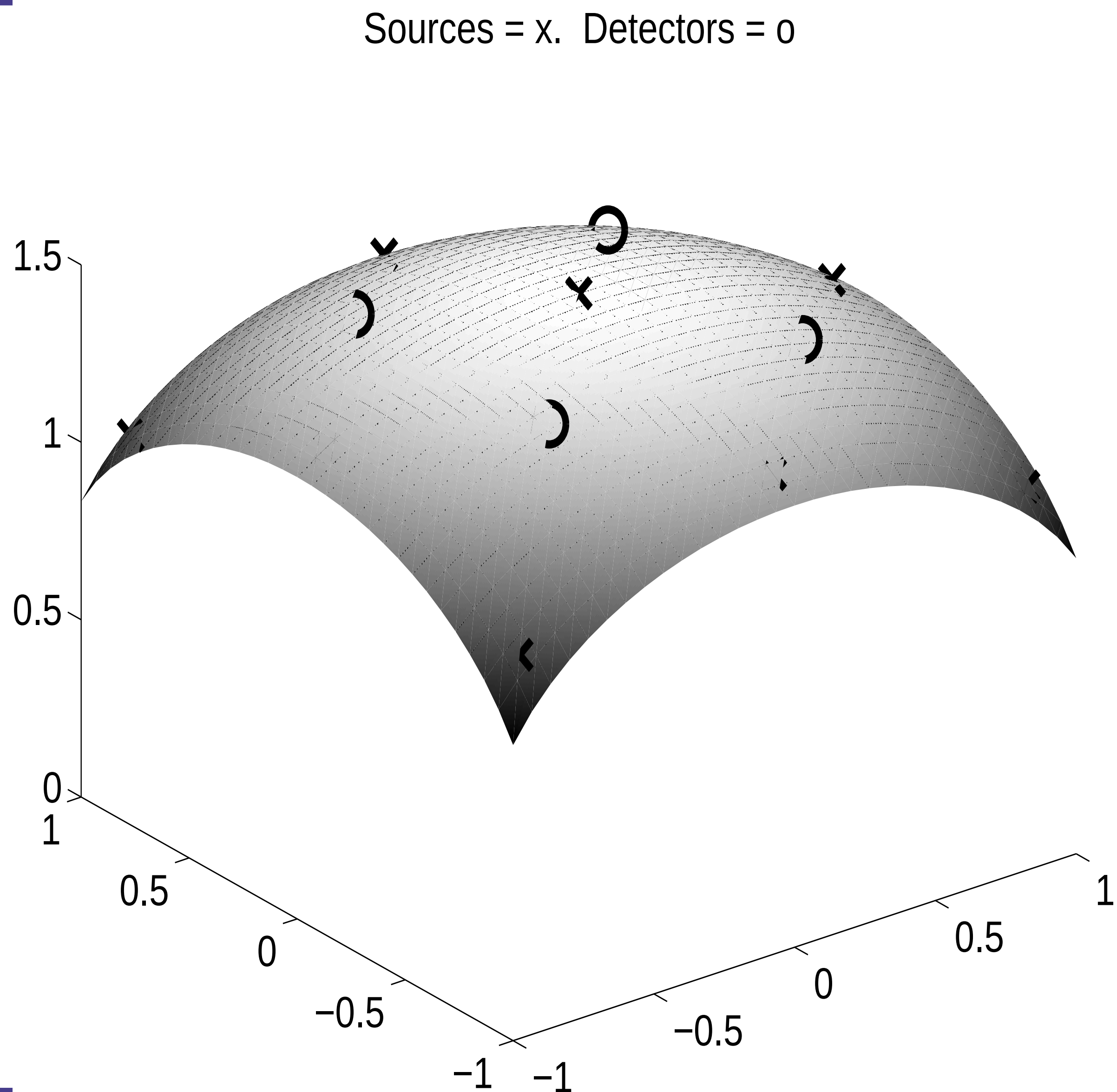
$$\min_p \|W(\tilde{A}\tilde{f}(p) - g)\|_2^2$$

- Experiments performed in Matlab 6
- Nonlinear least squares solver: Levenberg-Marquardt
- 4th order polynomials
- Stopping: where $\|W(\tilde{A}\tilde{f}(p) - g)\|_2^2 \approx \|Wn\|_2$
- $[-1,1] \times [-1,1]$ region, 31×31 grid
- Noise-to-signal ratio: $\|Wn\|_2 / \|Wg_{true}\|_2$

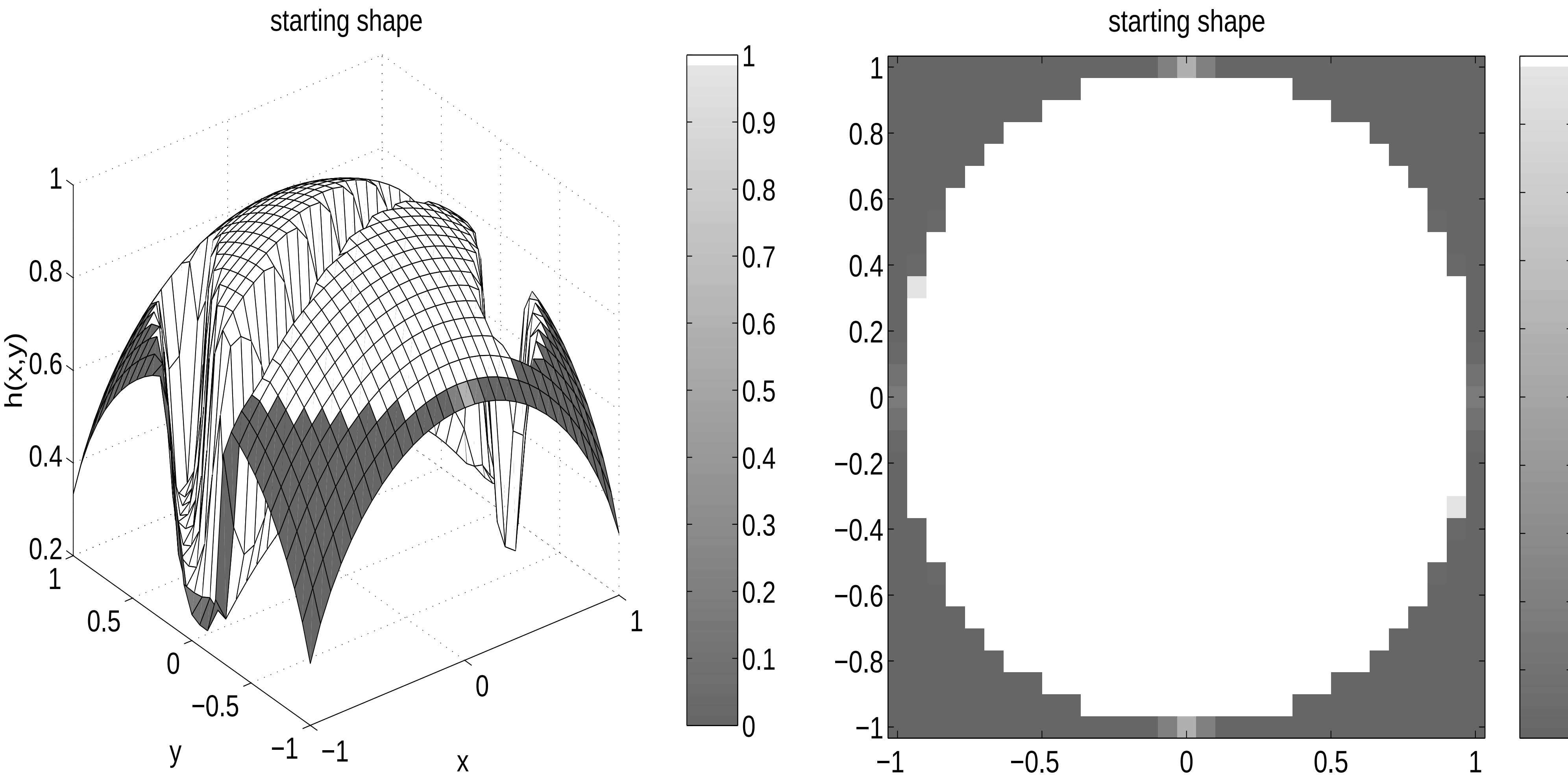
Mockup of Cortex



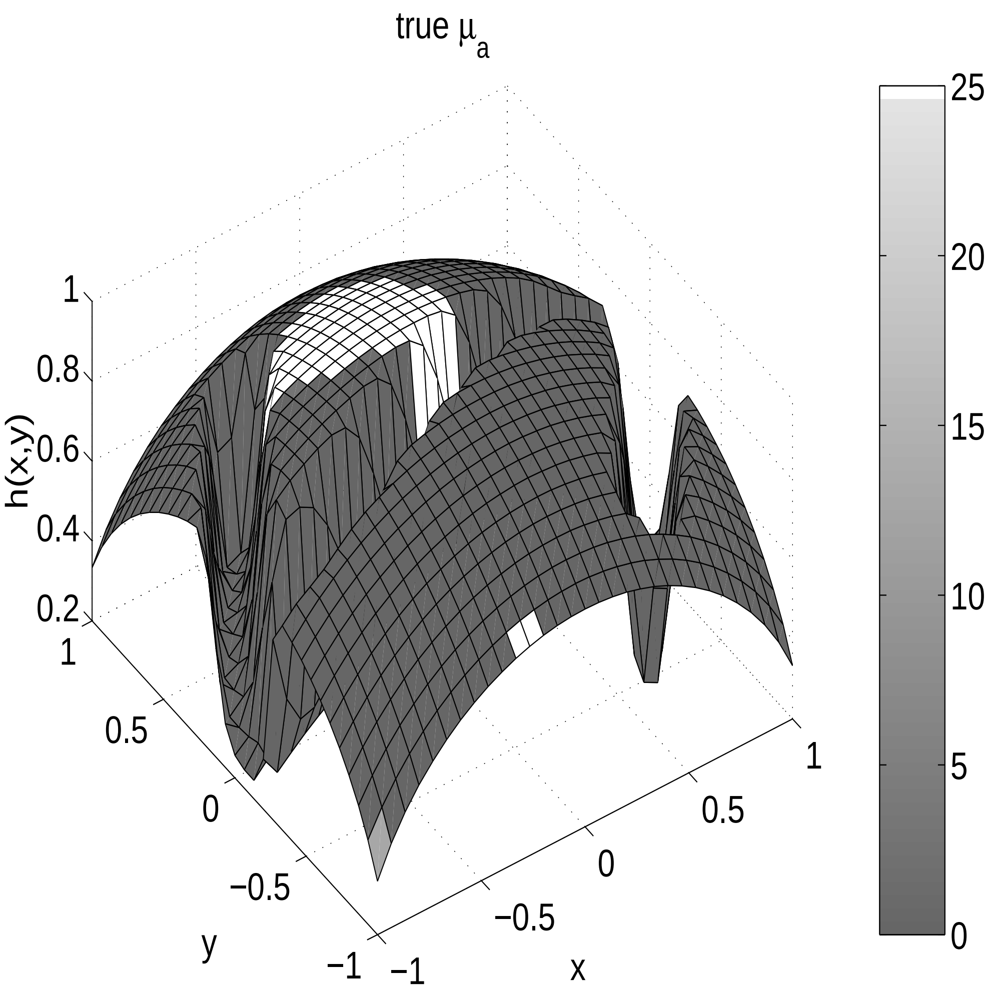
Location of Sources/Detectors

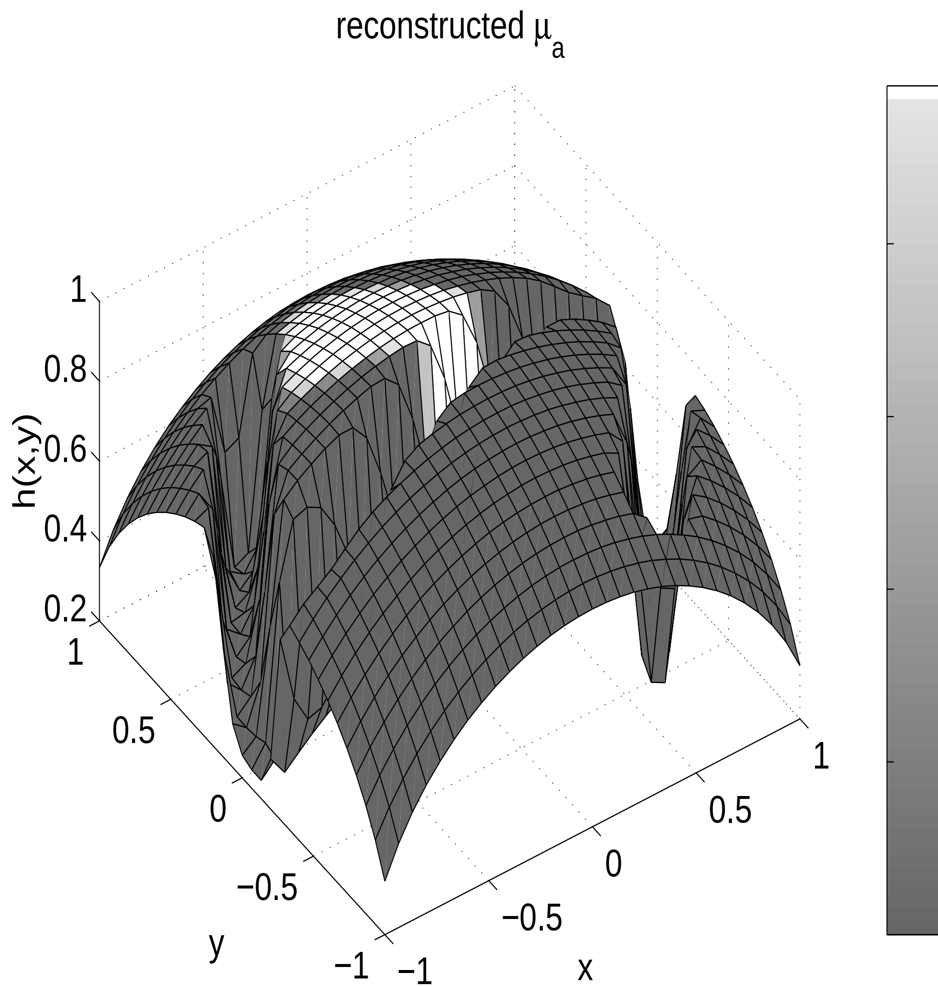


Starting Guess

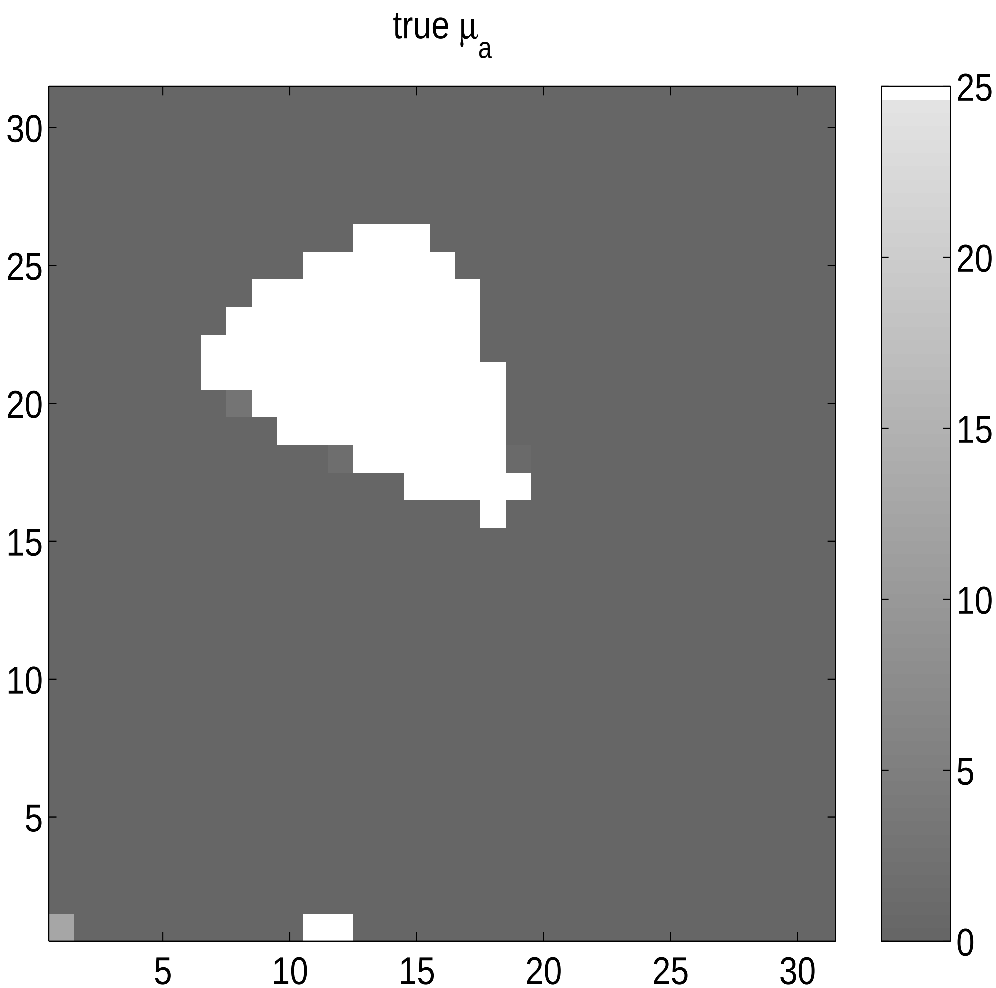


Ex. 1: Absorption; α_a: 30 ; NSR: 5 %

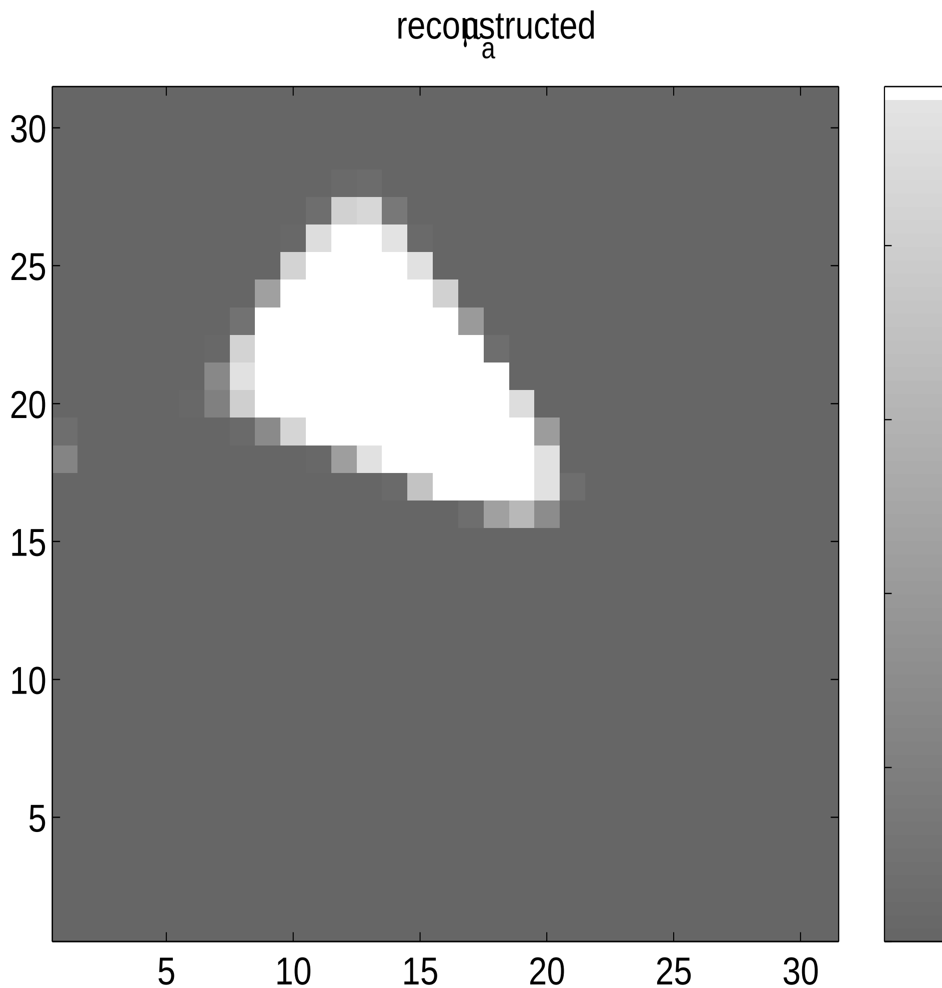




Ex. 1, Cont.

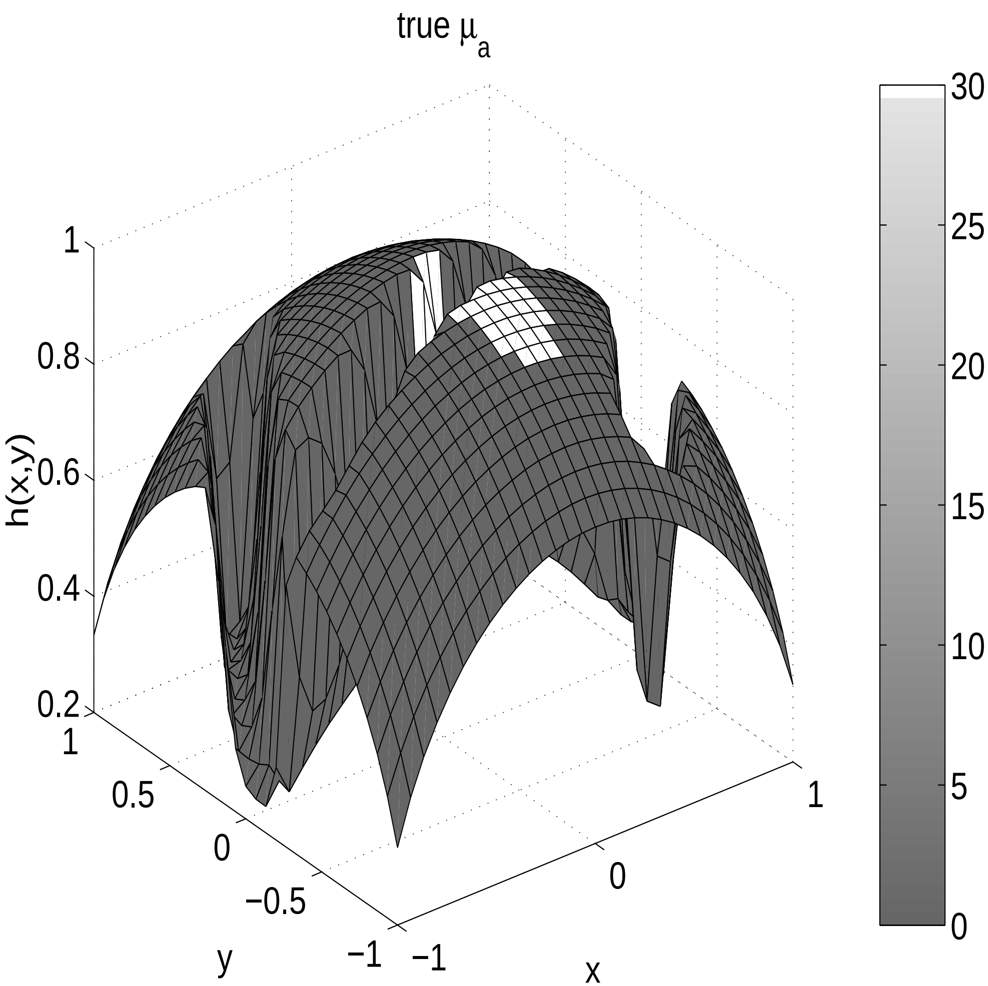


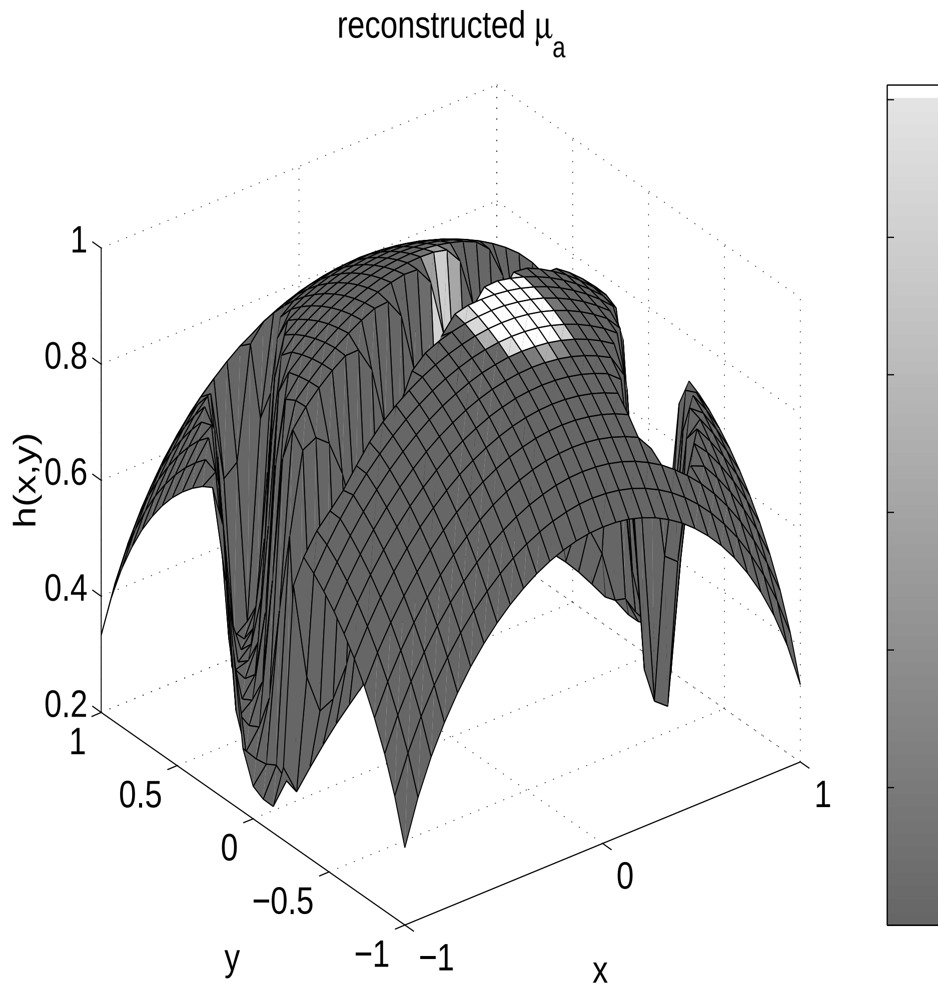
true μa
30
25
20
15
10
5
5
10
15
20
25
30
25
20
15
10
5
0



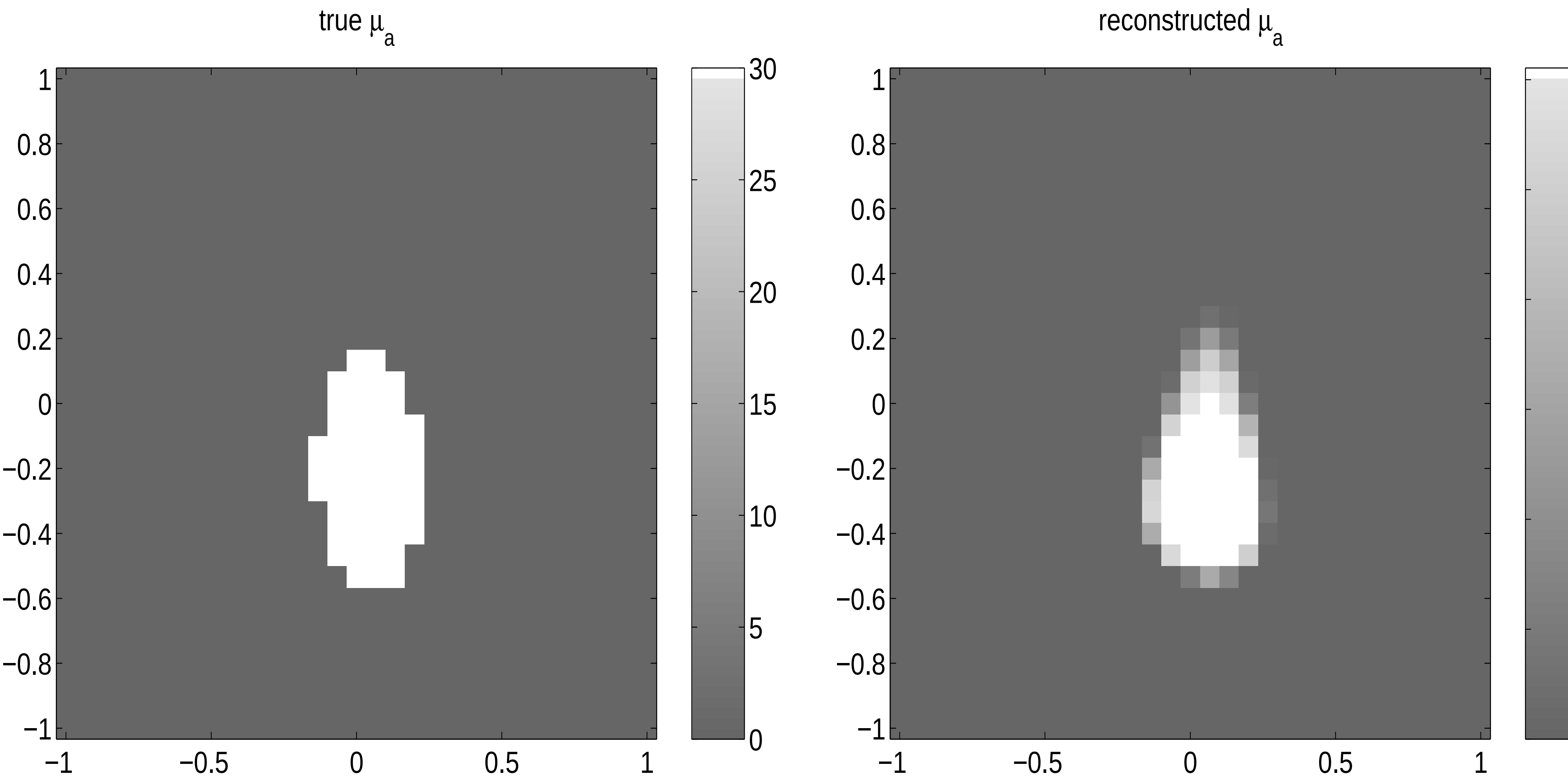
reconstructed μa
30
25
20
15
10
5
5
10
15
20
25
30

Ex. 2: α_a: 30; α_d: 1/750; NSR: 1 %

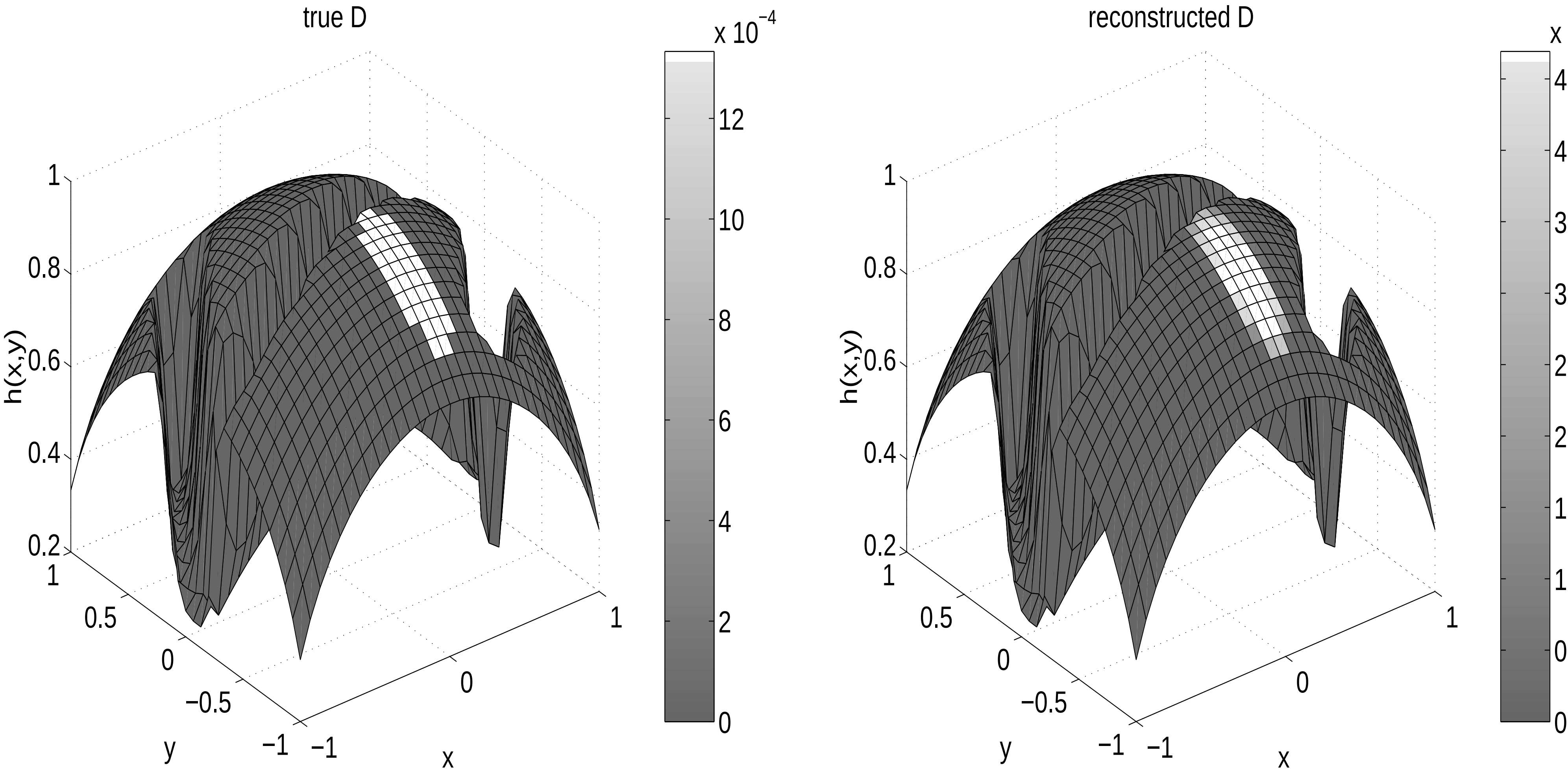




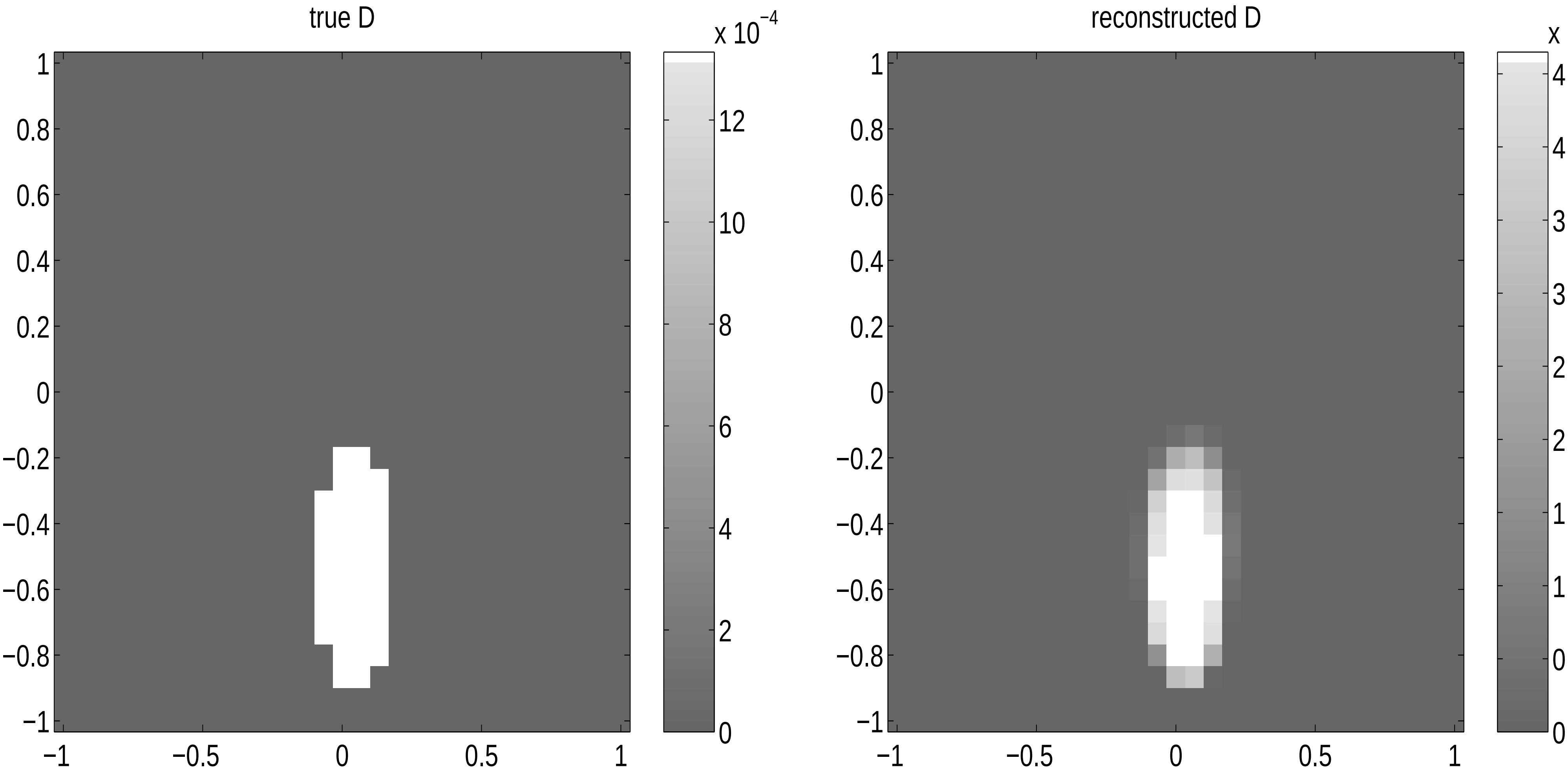
Ex. 2, absorption, projected view



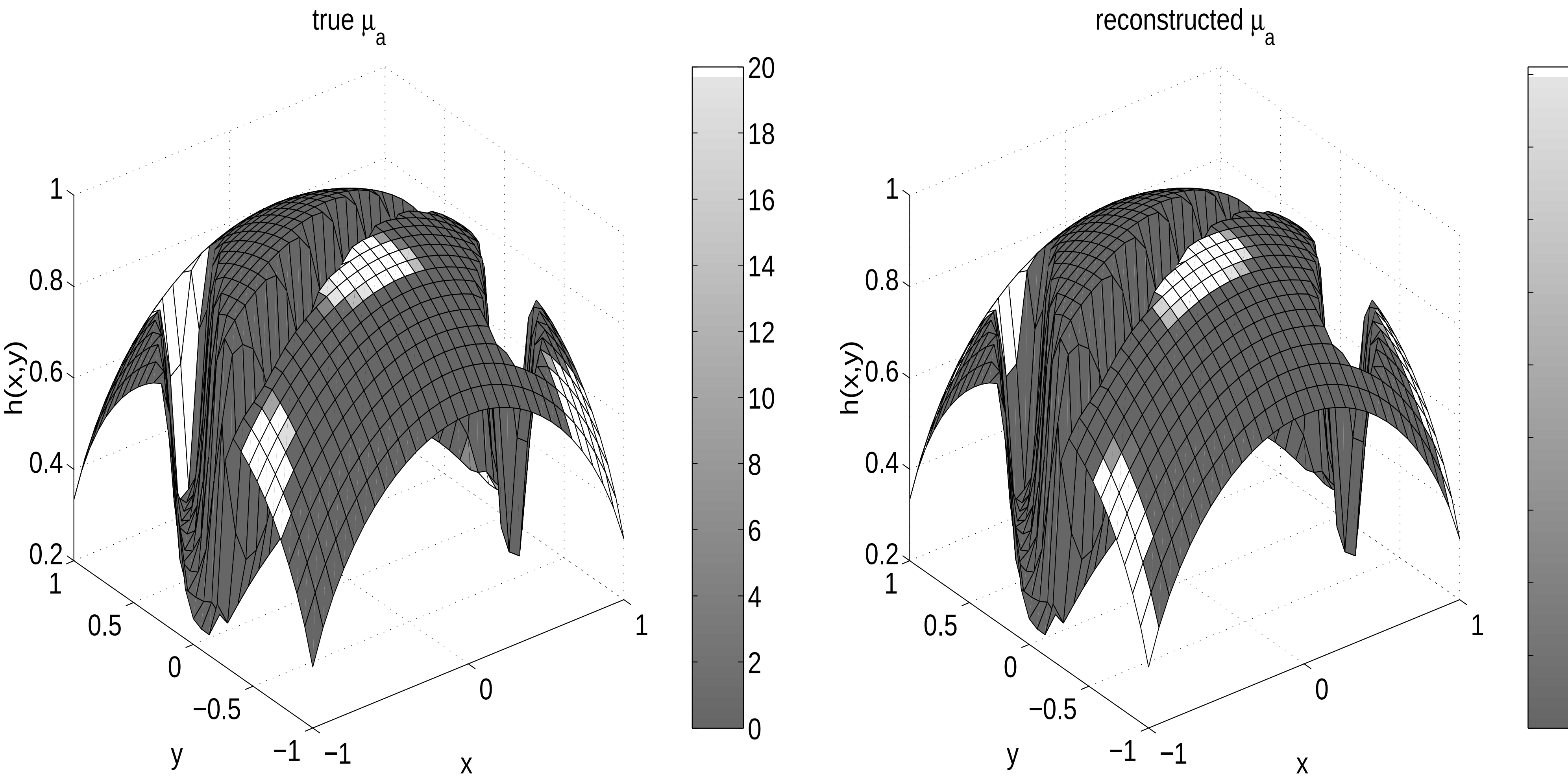
Ex. 2, Diffusion



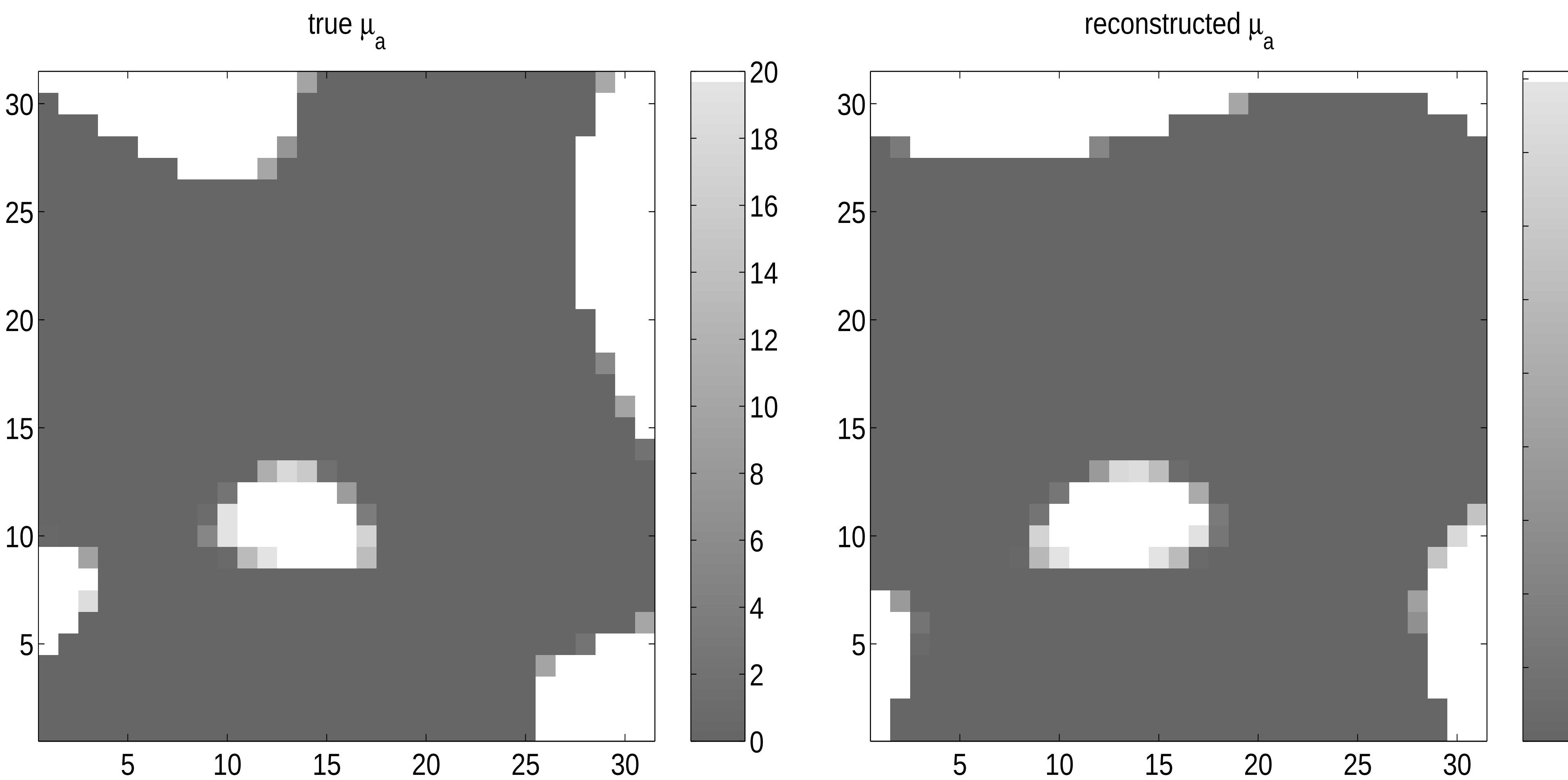
Ex. 2, Diffusion, projected view



Ex. 3, $\alpha_a = 20$; NSR: 10 %



Ex. 3, projected view



Conclusions and Future Work

- Presented model & algorithm for 3D imaging of optical properties of the cortex
- No additional regularization term
- Other shapes
- Unknown background can be modeled
- Multiple objects
- More realistic brain models
- Clinical data

Acknowledgements

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