SLIM

ML4Seismic

Fracture risk

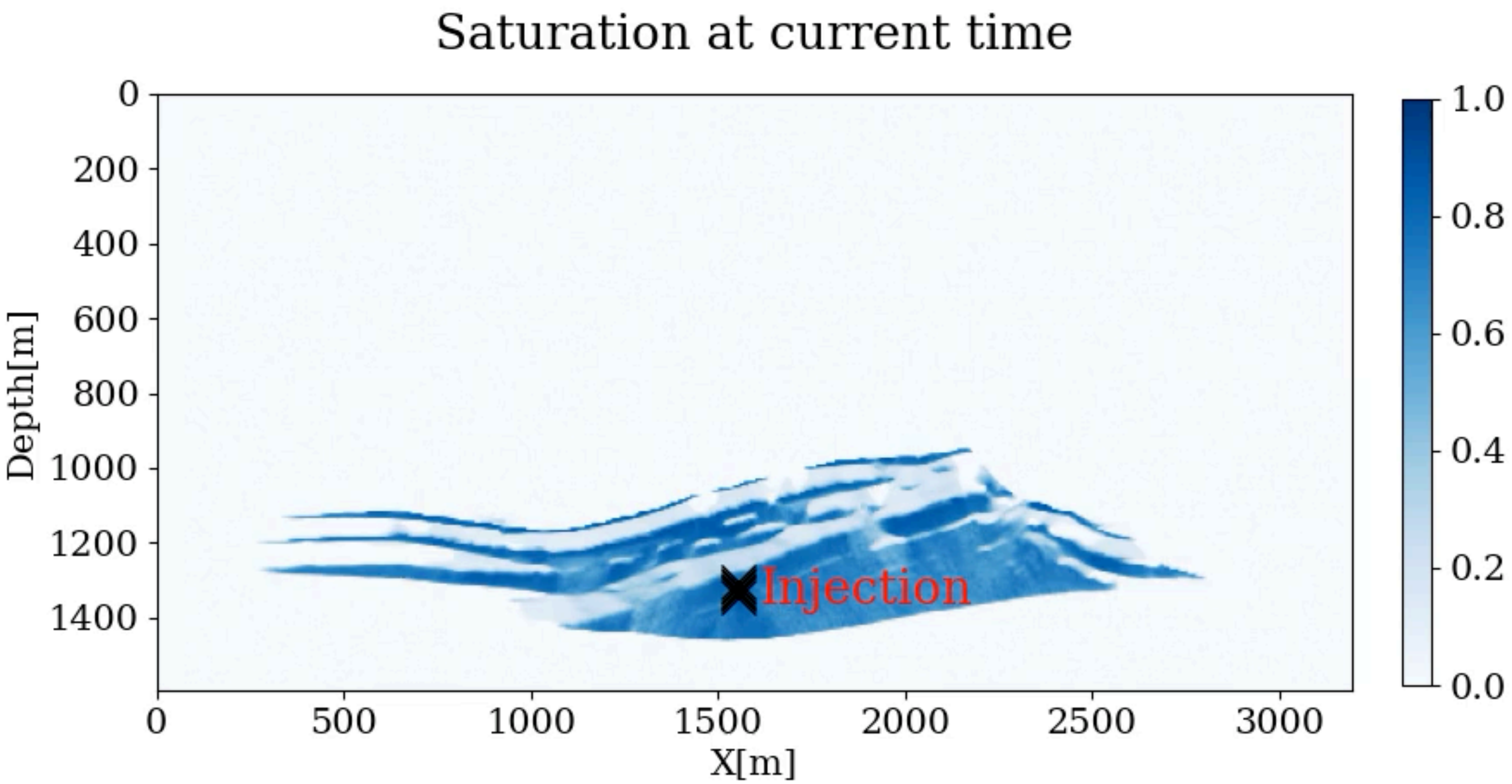
w/o *pressure* control

- **Initial** *injection* rate**:** $q = 0.05\mathrm{m}^3/\mathrm{s}$

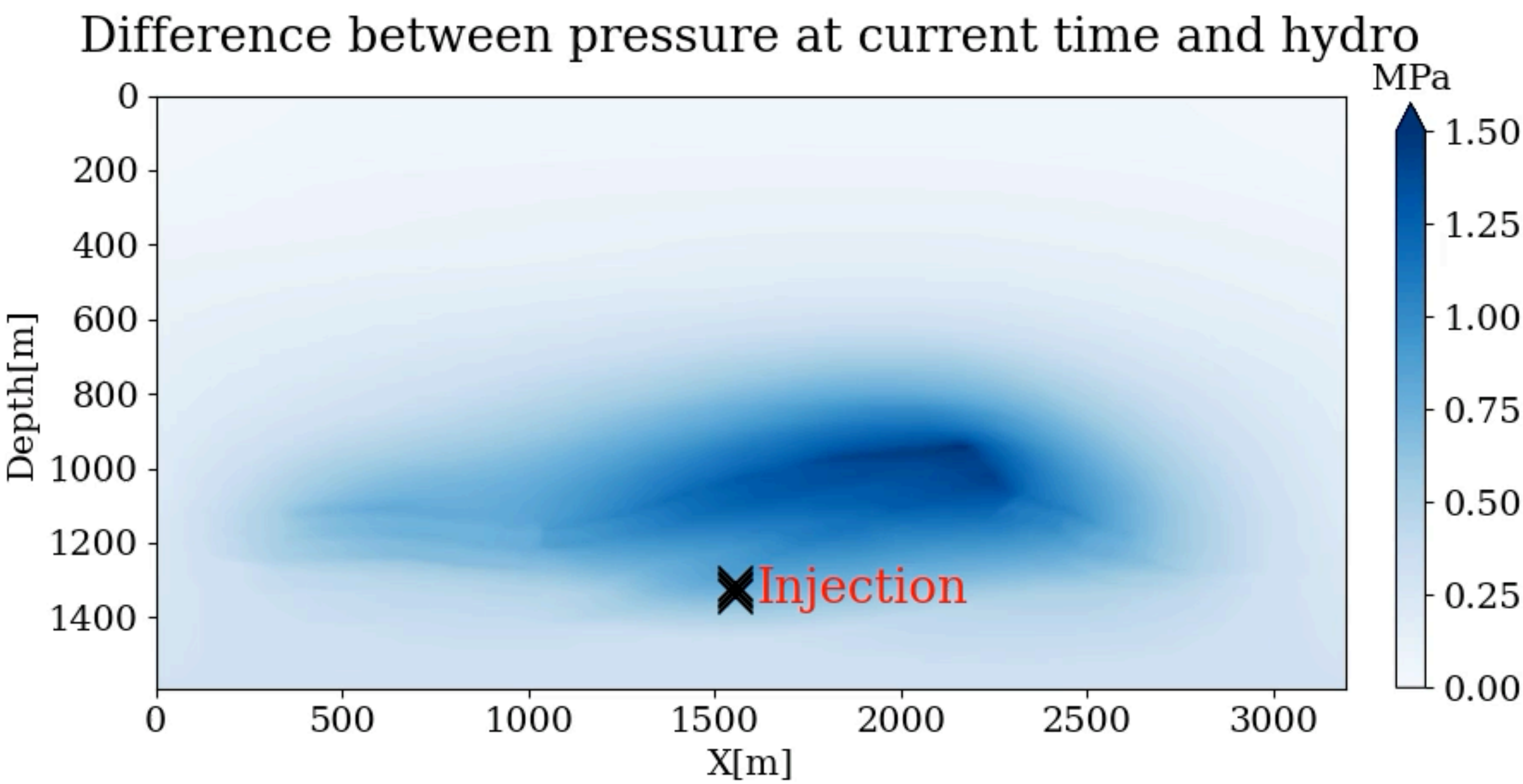
- Leads to *over* pressure after 1920 days of injection

- Seal *fractures* due to *over pressure* denoted by **red** areas

- Unacceptable risk



Saturation at current time
Depth[m]
X[m]
Injection
0
200
400
600
800
1000
1200
1400
0
500
1000
1500
2000
2500
3000
1.0
0.8
0.6
0.4
0.2
0.0

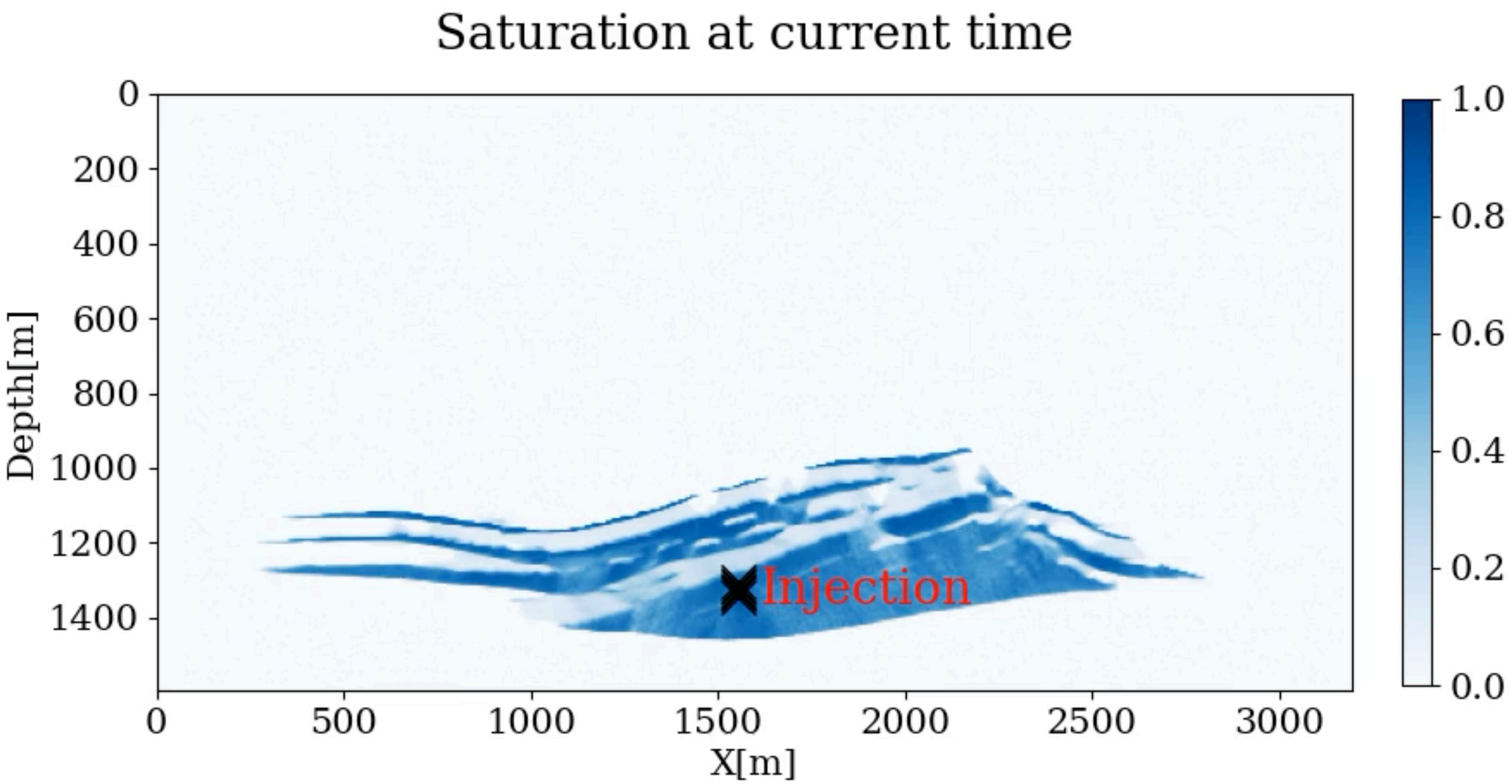


Difference between pressure at current time and hydro
MPa
Depth[m]
X[m]
Injection
0
200
400
600
800
1000
1200
1400
0
500
1000
1500
2000
2500
3000
1.50
1.25
1.00
0.75
0.50
0.25
0.00

$$\mathbf{x}_4 \sim p(\mathbf{x}_4 \mid \bar{\mathbf{y}}^{\mathrm{o}}_4)['S']$$

$$\mathbf{x}_4 \sim p(\mathbf{x}_4 \mid \bar{\mathbf{y}}_4^{\mathrm{o}})[' \delta p']$$

Ringrose, Philip. "How to store CO2 underground: Insights from early-mover CCS projects." (2020): 978-3.


Saturation at current time
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X[m]
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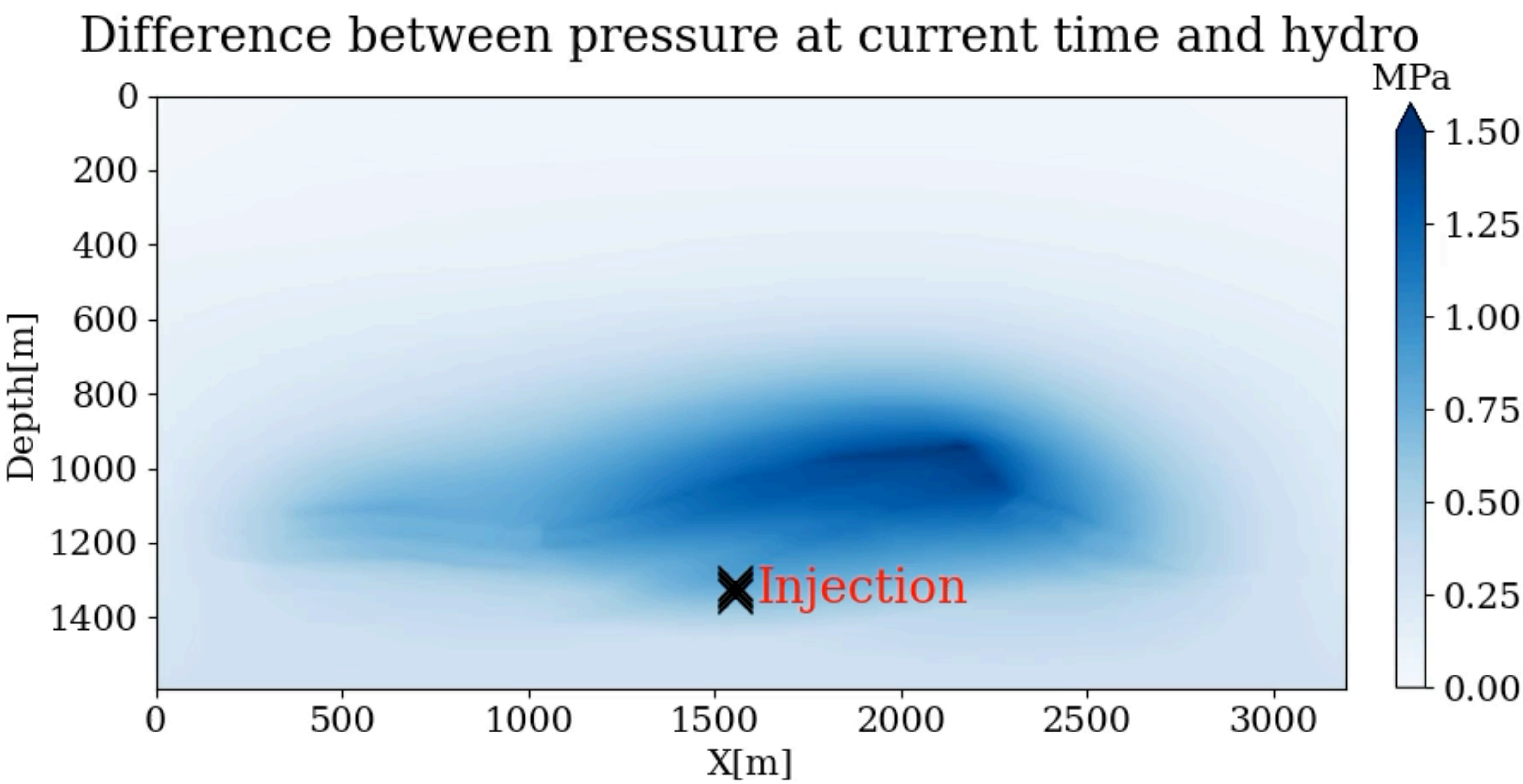
0.2
0.4
0.6
0.8
1.0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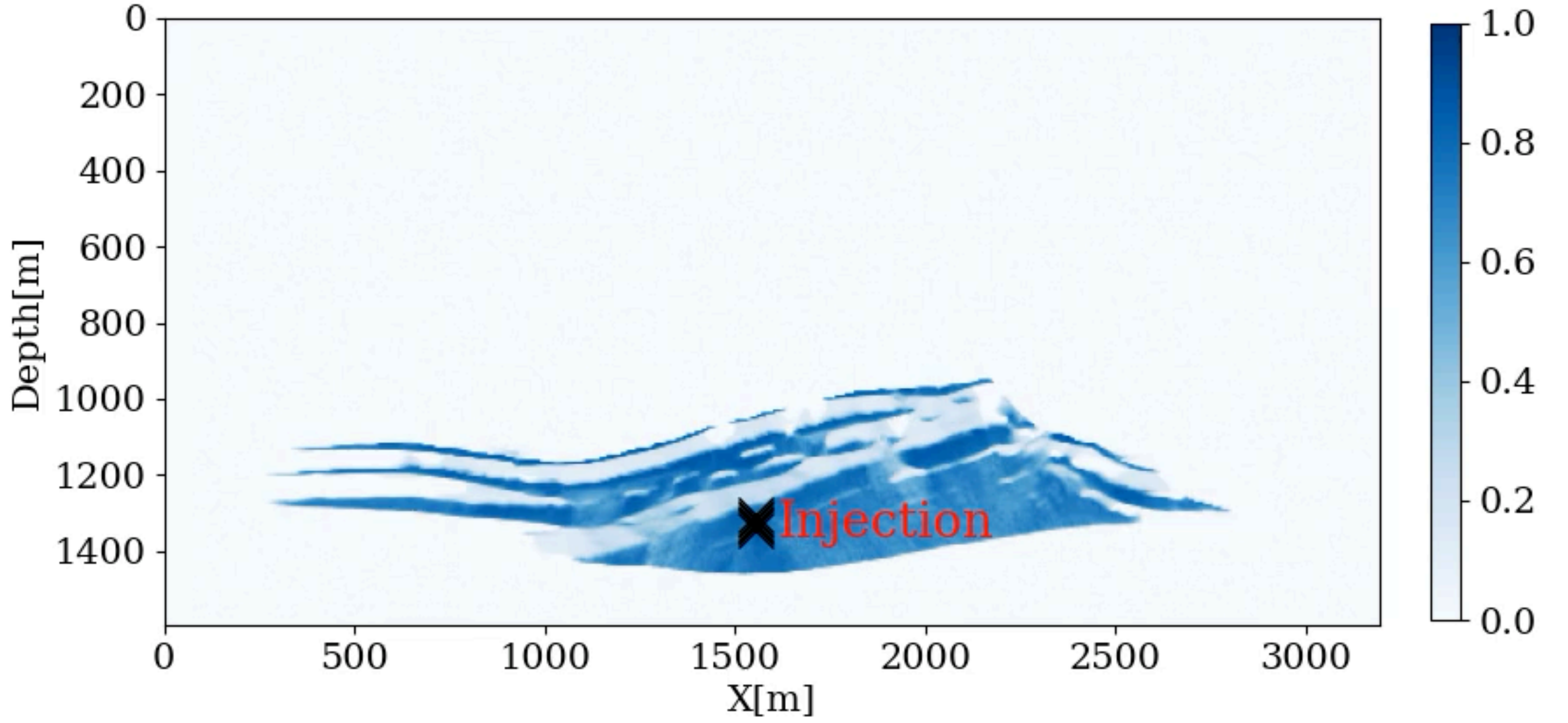
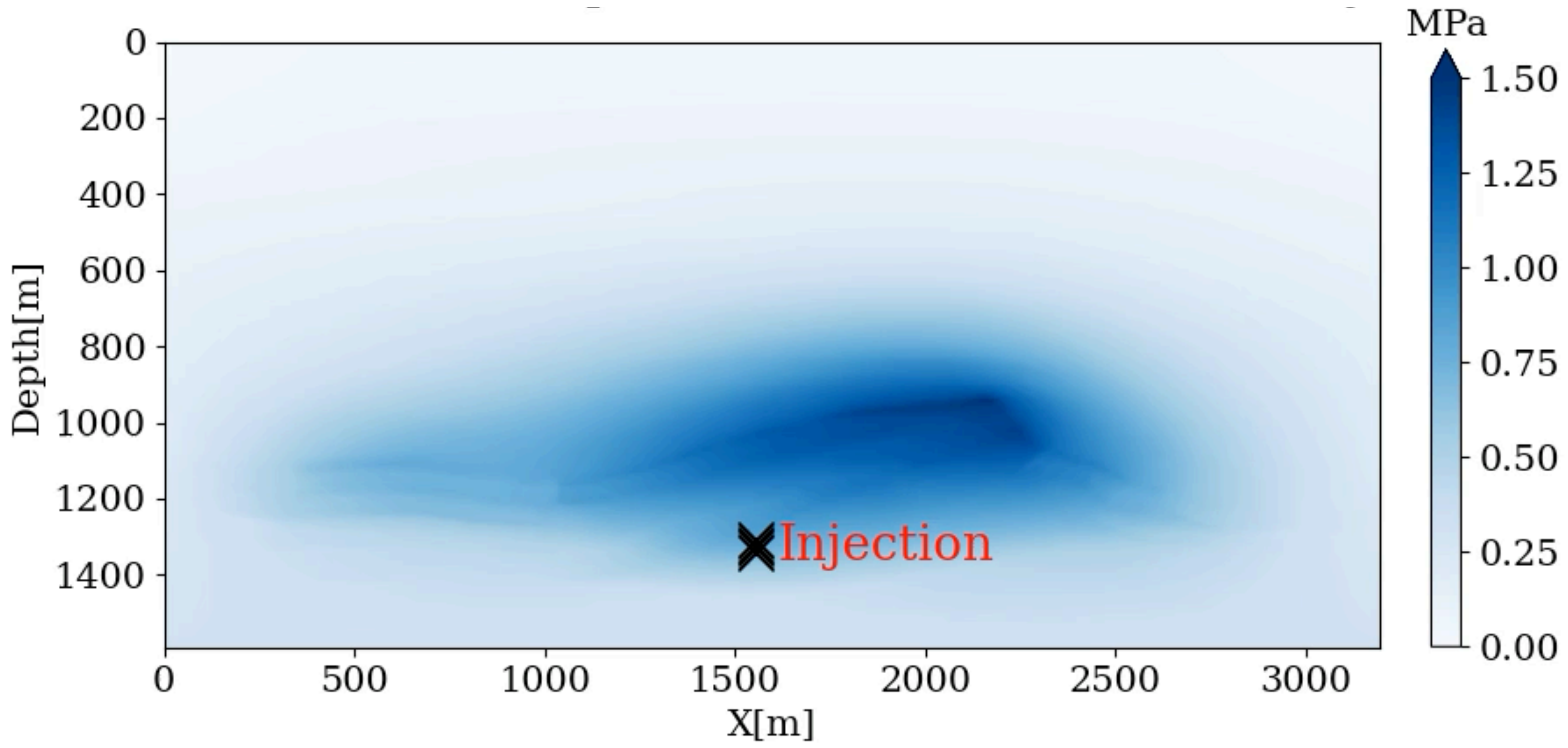


$$\mathbf{x}_4 \sim p(\mathbf{x}_4 \,|\, \bar{\mathbf{y}}_4^{\mathrm{o}})['\delta p']$$



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https://en.wikipedia.org/wiki/Kernel_density_estimation

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Controlled injection rates

k=3

Compute *controlled* injection rates

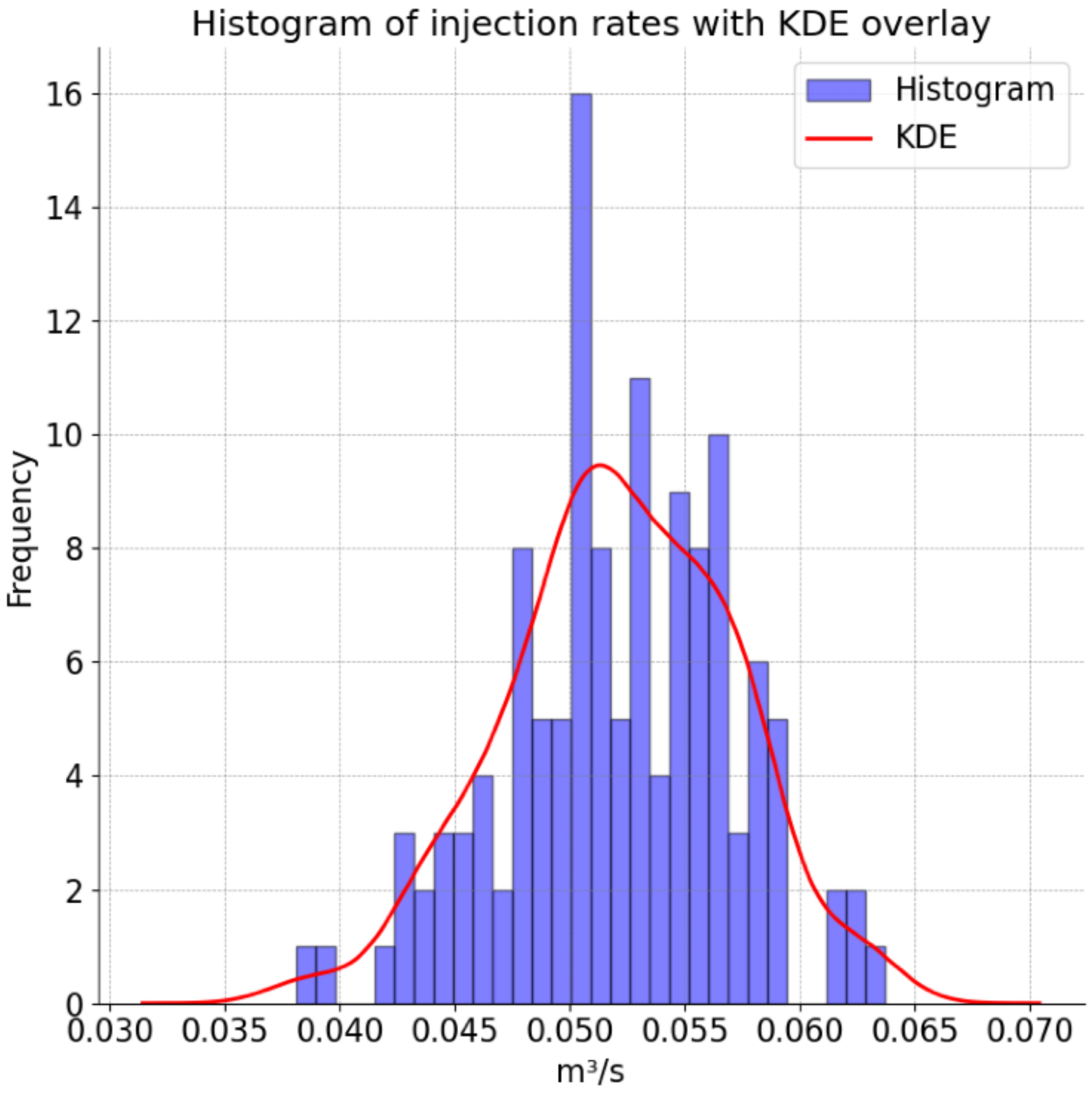
- for $N = 128$ samples of $\mathbf{K} \sim p(\mathbf{K})$ and $\mathbf{x}_3 \sim p(\mathbf{x}_3 \,|\, \bar{\mathbf{y}}_3^{\mathrm{o}})$

- *by* finding injectivities, q_3, that *maximize* the total CO_2 injected volume while ***not*** *exceeding* the *fracture* pressure via

$$\max_{q_3} q_3 \Delta t \quad \text{subject to} \quad \mathbf{x}_4['p'] < \mathbf{p}_{\max}$$
$$\mathbf{x}_4 = \mathscr{M}_3(\mathbf{x}_3, \mathbf{K}; q_3)$$

- use Gaussian kernel density estimation

- approximate the probability density function of the *controlled* injection rates



q_3