Multiphase Flow Prediction with Deep Neural Network

Gege Wen, Meng Tang, Sally M. Benson

SCCS Affiliates meeting, Nov 7, 2019

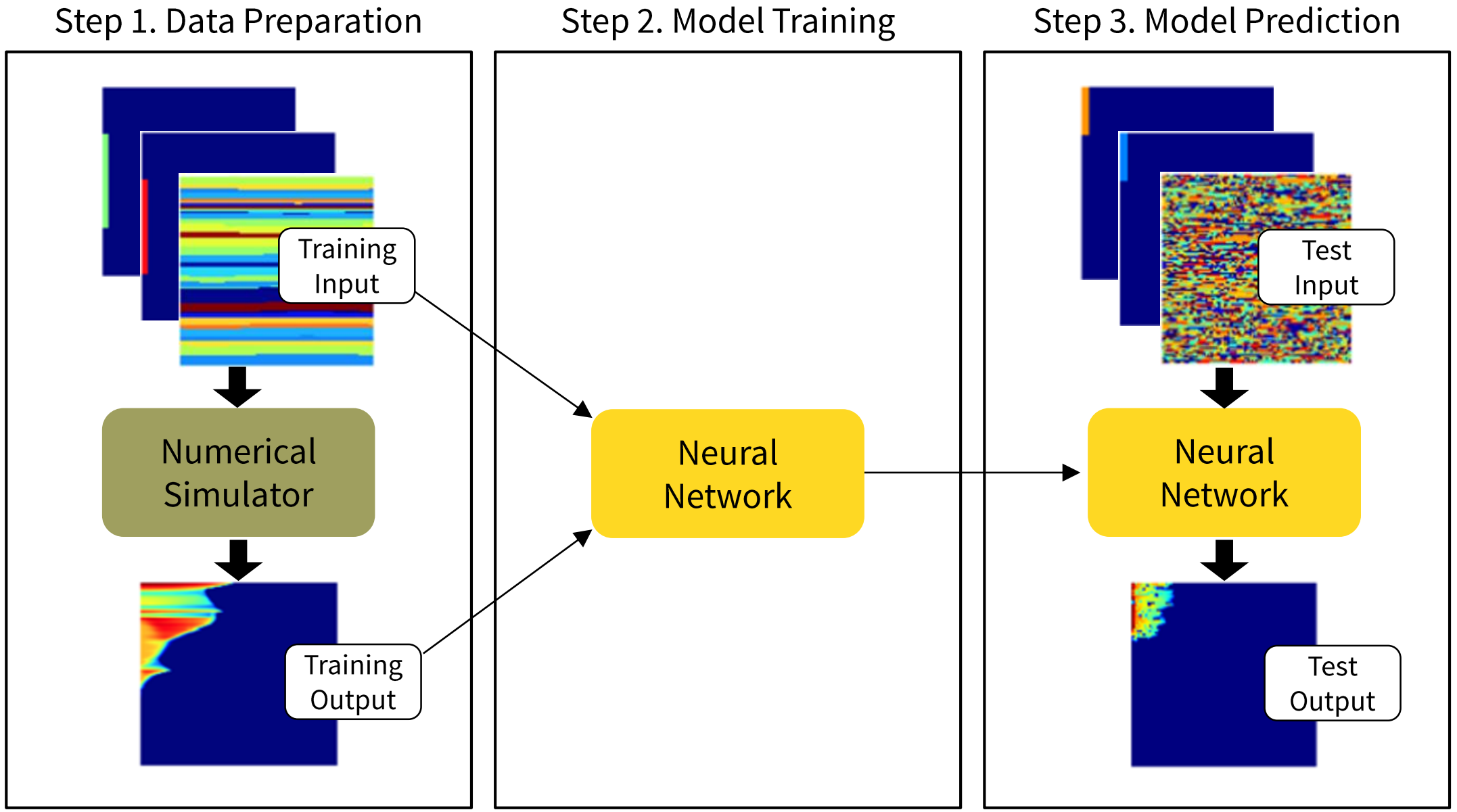
Challenges:

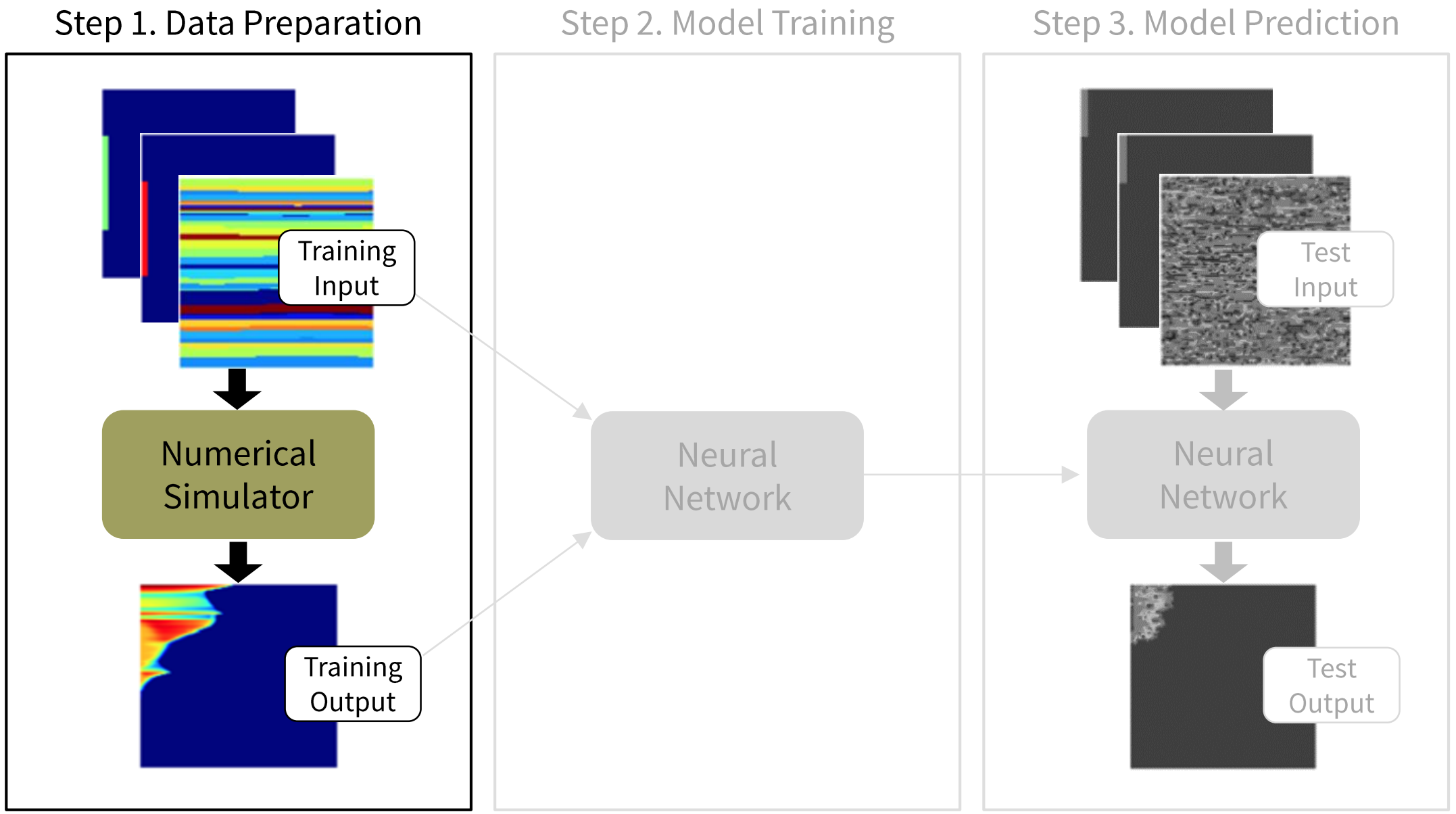
Simulation of the CO_2 plume migration is a **computationally expensive** task

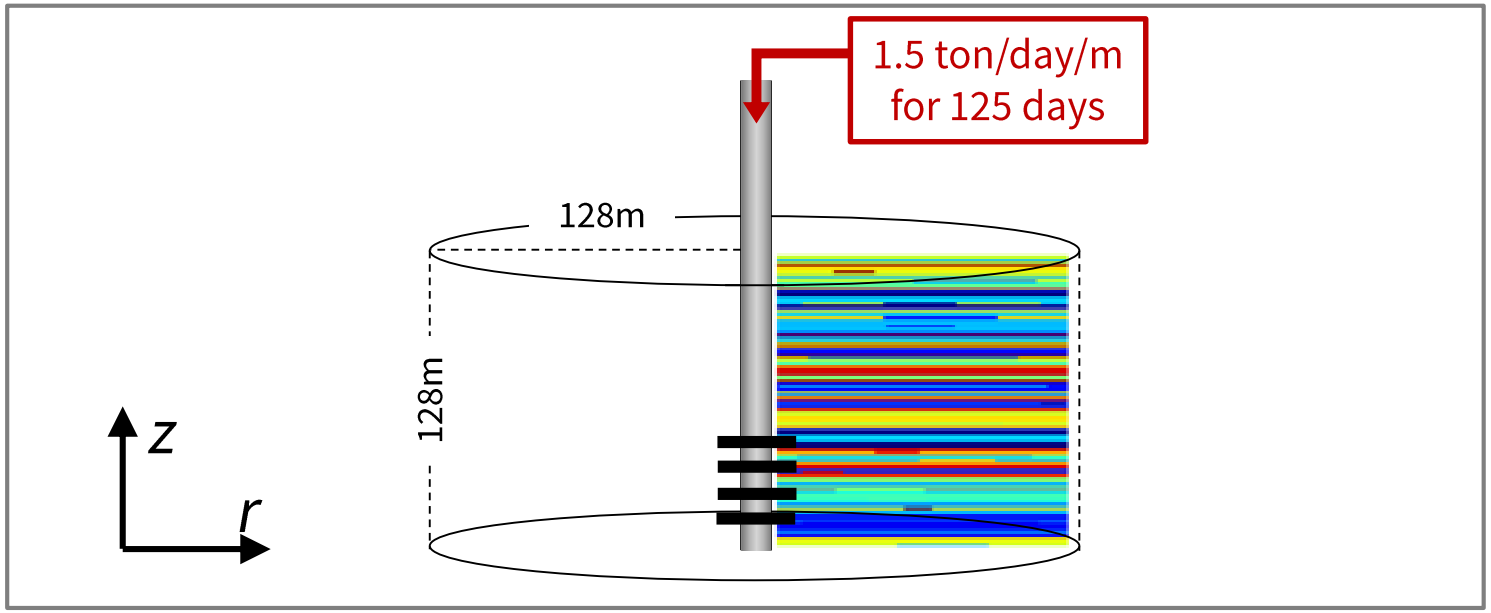
A **large number of iterations** needed due to uncertainty and heterogeneity in reservoirs

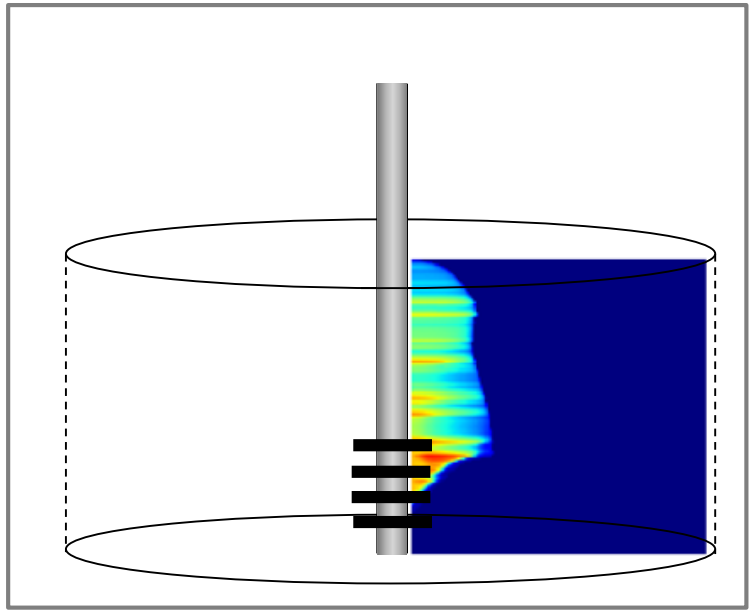
Goal:
fast and **accurate** CO_2 plume prediction

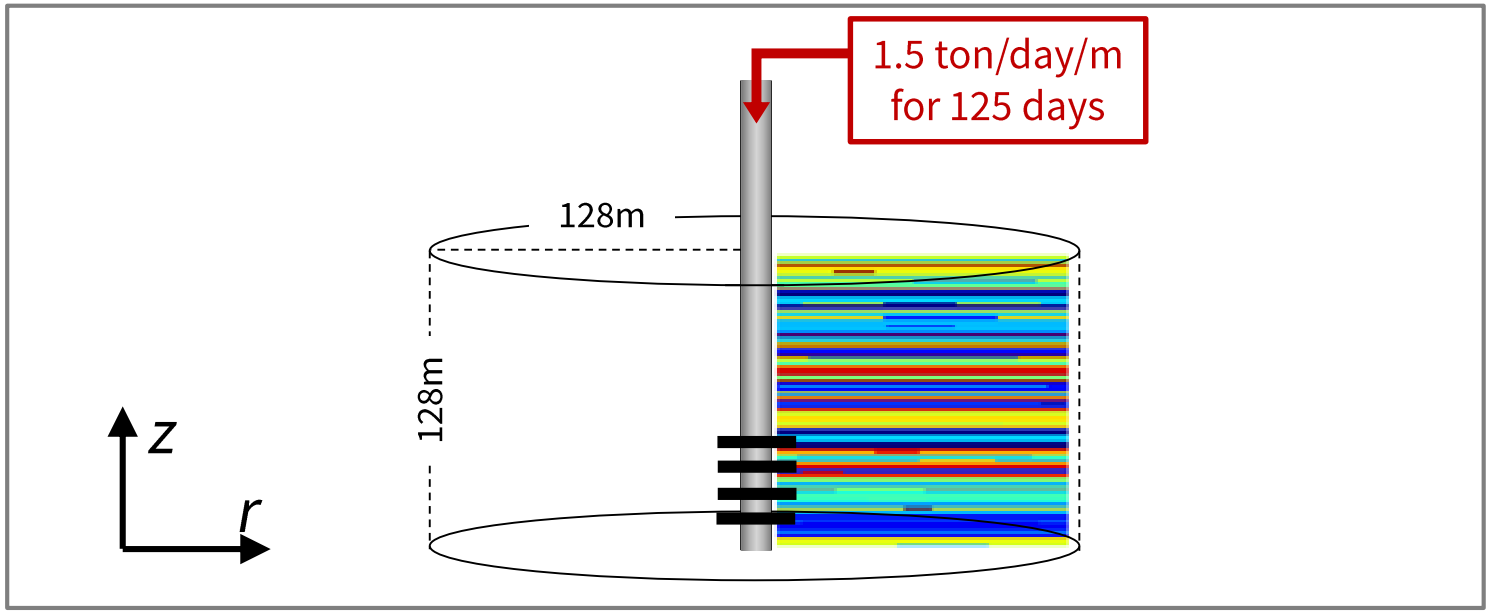
METHODOLOGY

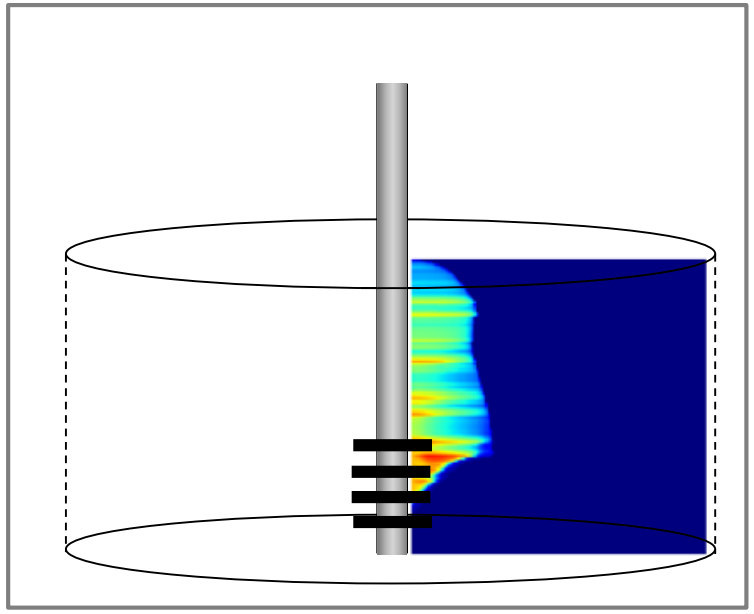

Step 1. Data Preparation
Step 2. Model Training
Step 3. Model Prediction
Training Input
Numerical Simulator
Training Output
Neural Network
Neural Network
Test Input
Test Output


Step 1. Data Preparation
Step 2. Model Training
Step 3. Model Prediction
Training Input
Numerical Simulator
Training Output
Neural Network
Neural Network
Test Input
Test Output


1.5 ton/day/m
for 125 days
128m
128m
z
r

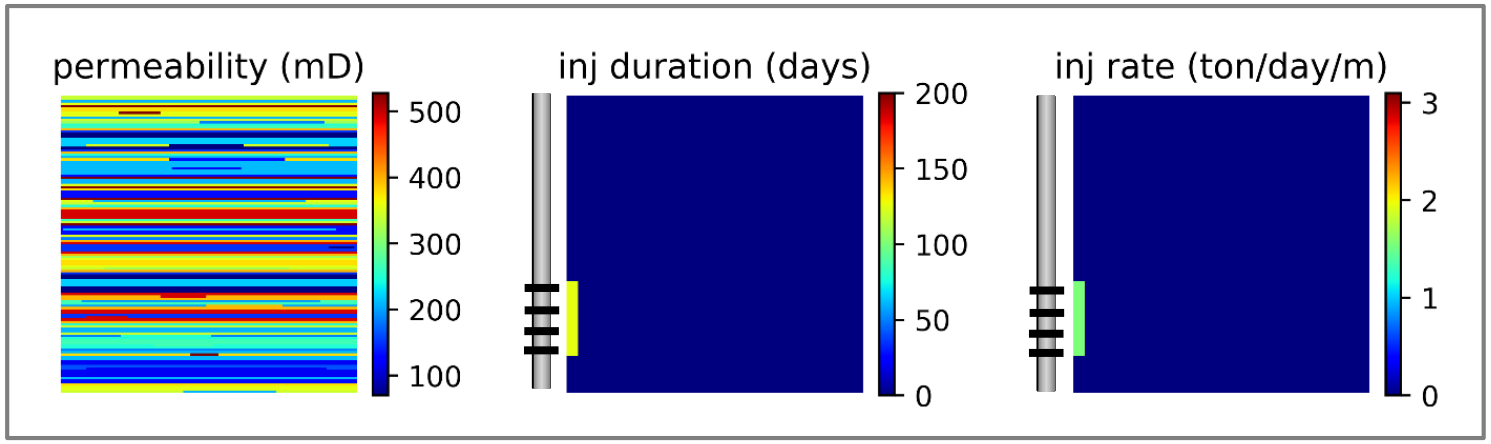


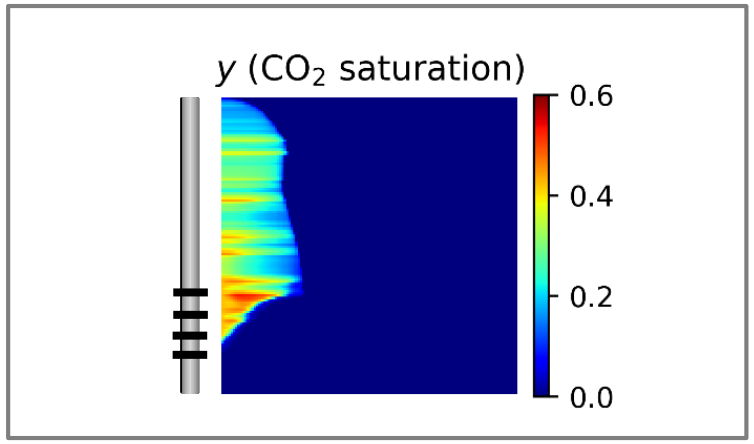




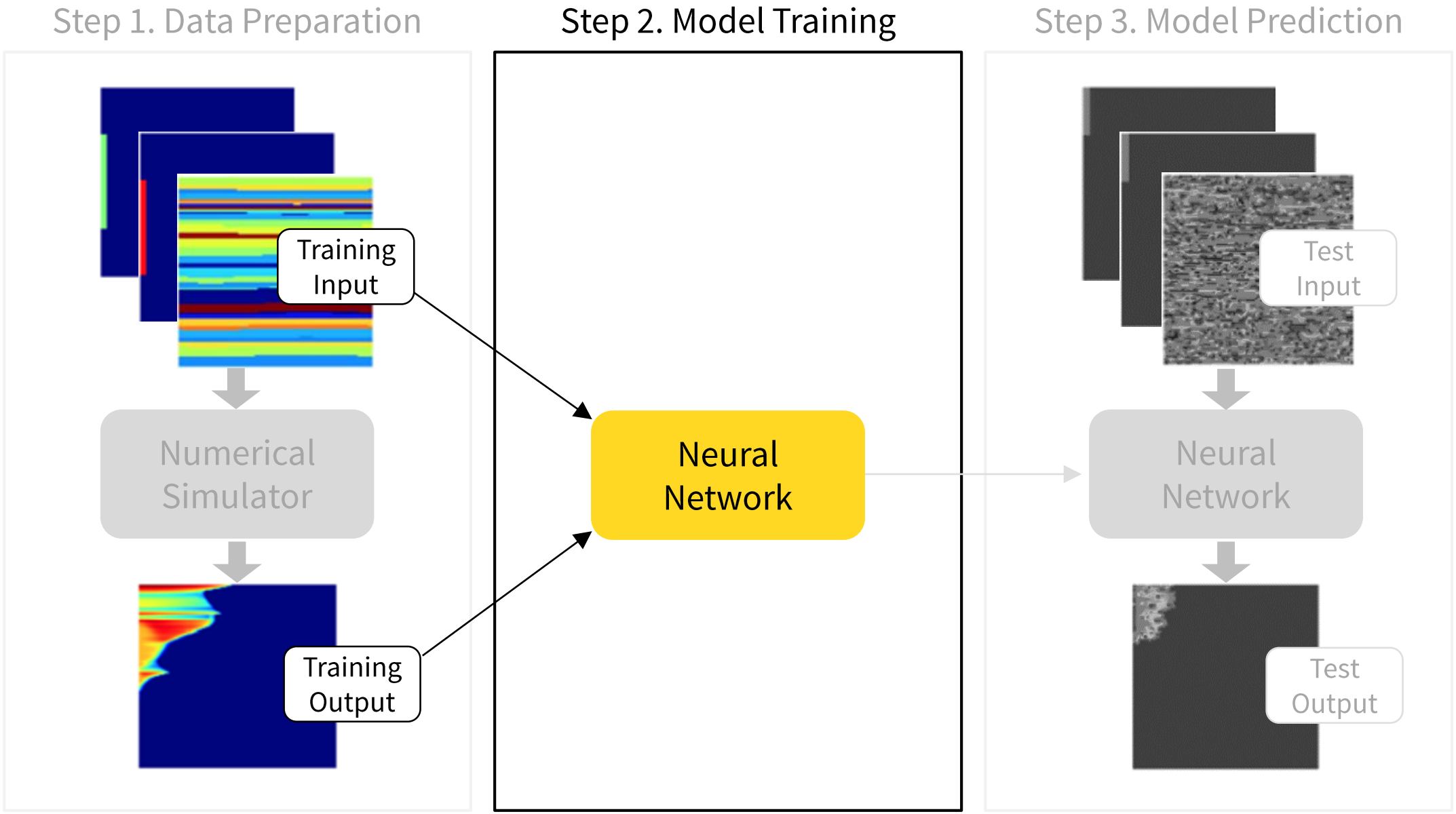
input

output

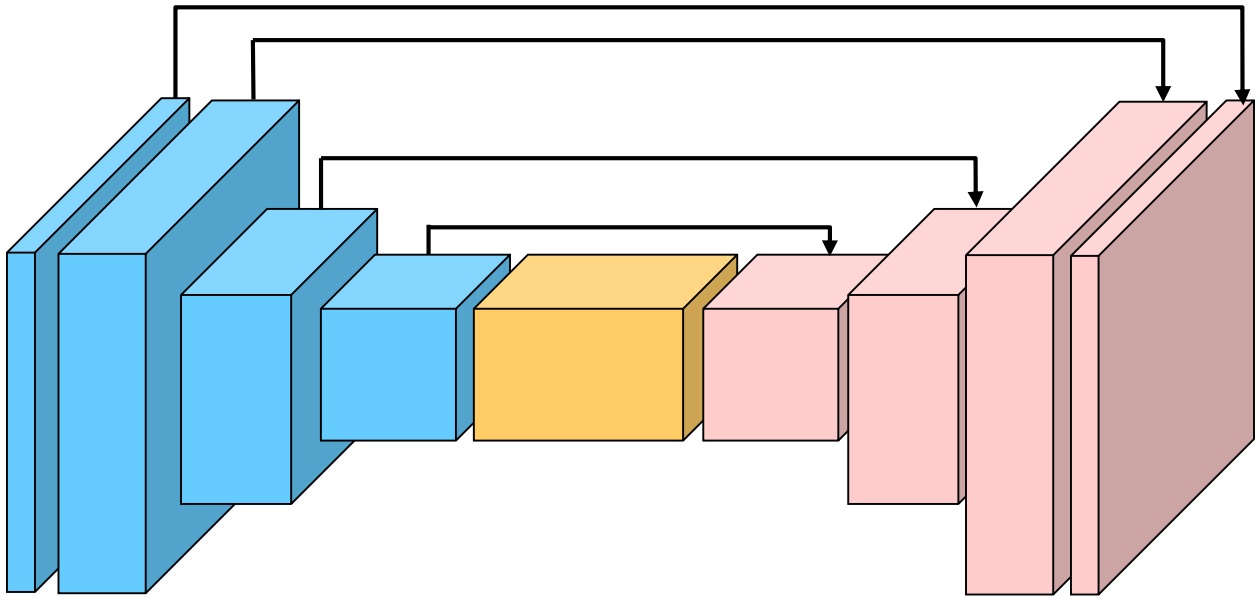




200 perm map x 8 injection duration x 4 injection rate x 36 perforation = 230,400 samples

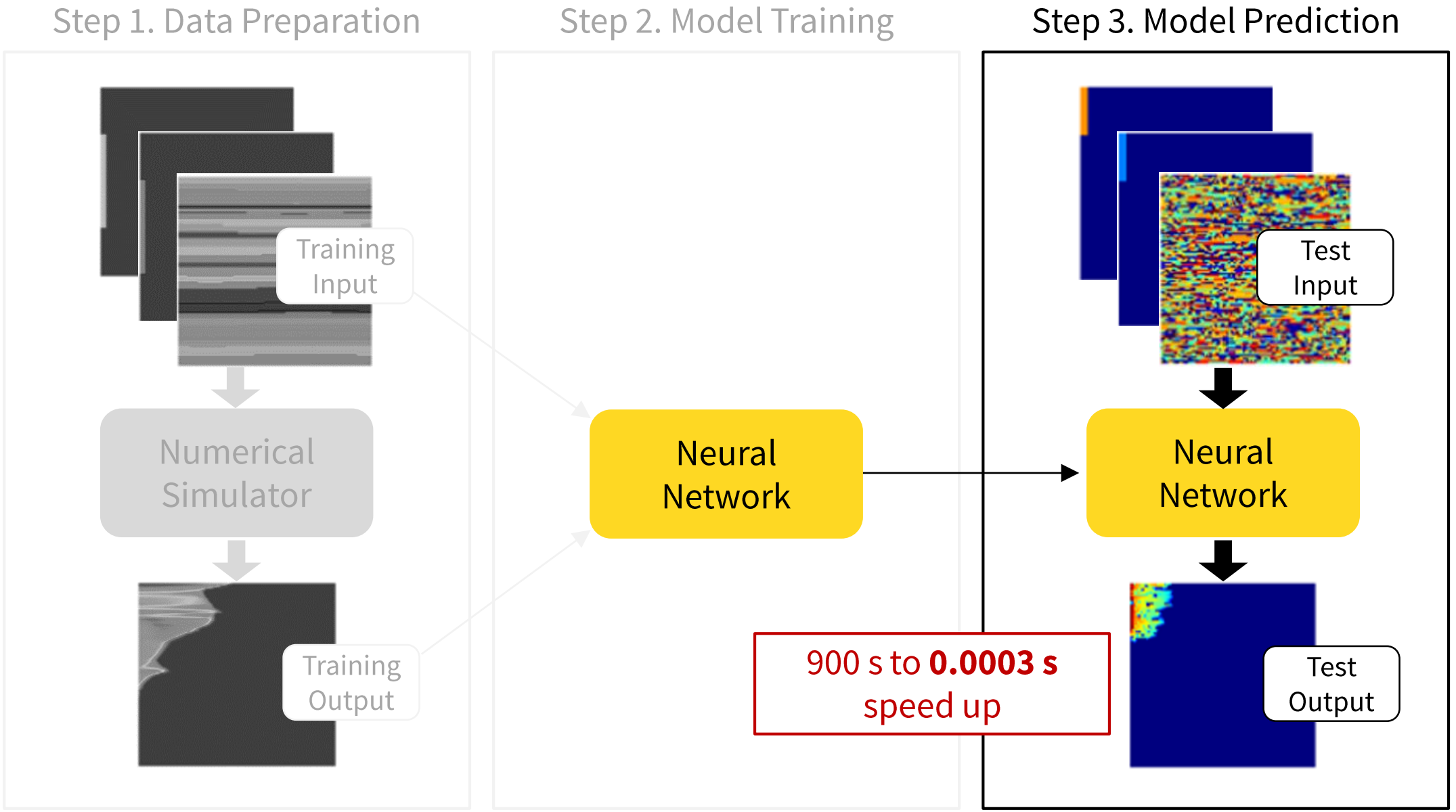

Step 1. Data Preparation
Step 2. Model Training
Step 3. Model Prediction
Training Input
Numerical Simulator
Training Output
Neural Network
Test Input
Neural Network
Test Output

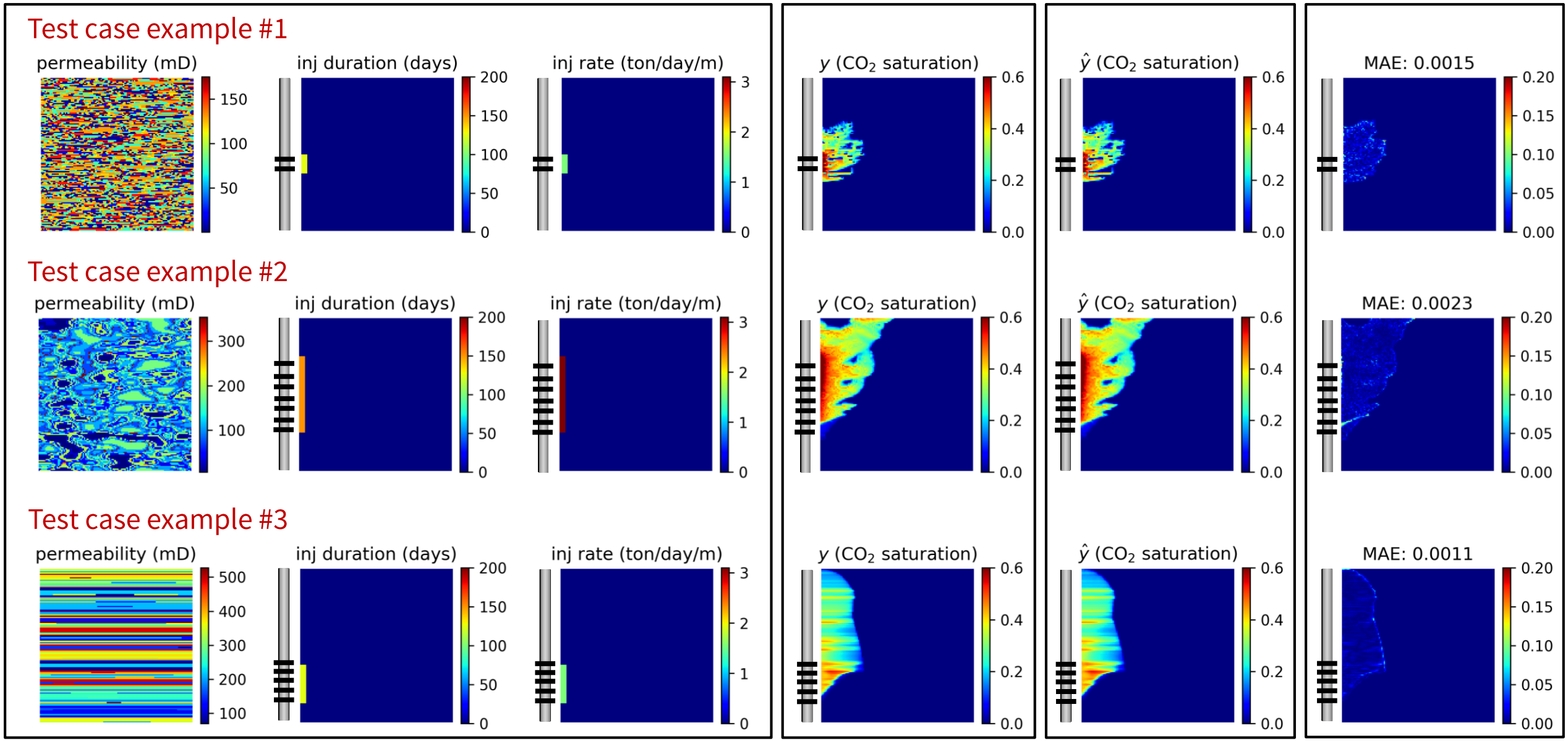
Neural network structure

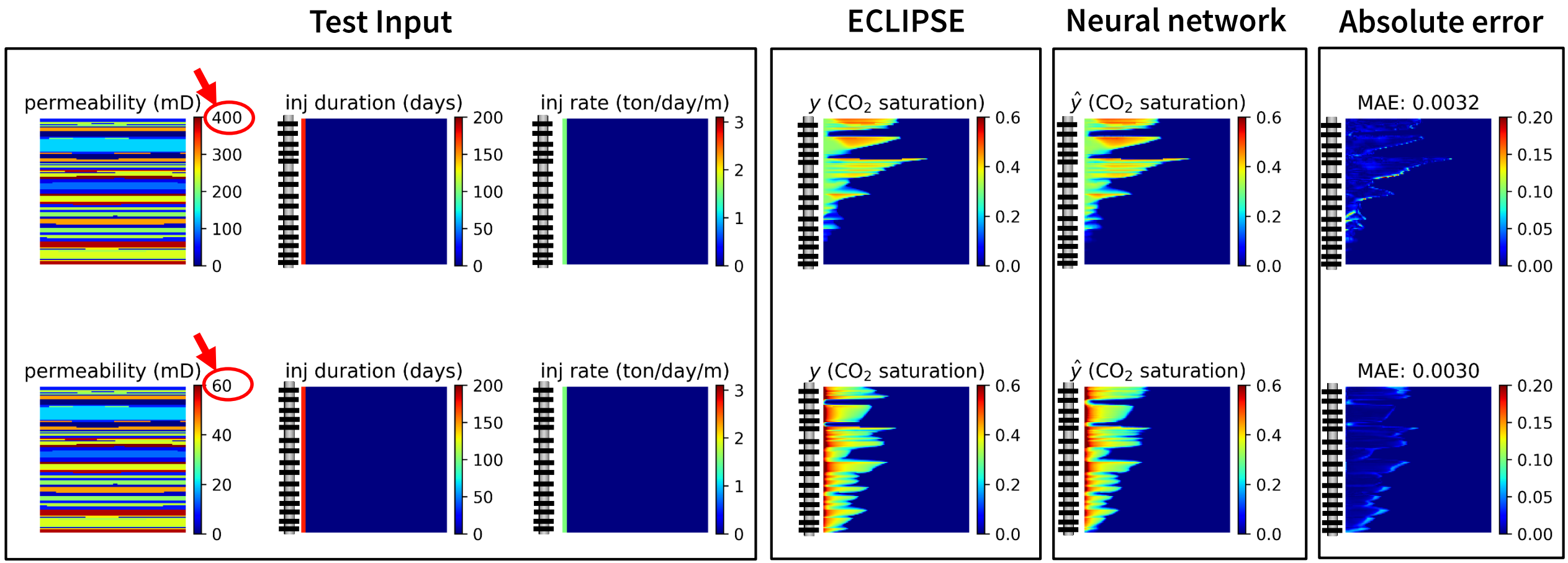


Loss function

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \|y_i - \hat{y}_i\|_2^2}{N}}$$

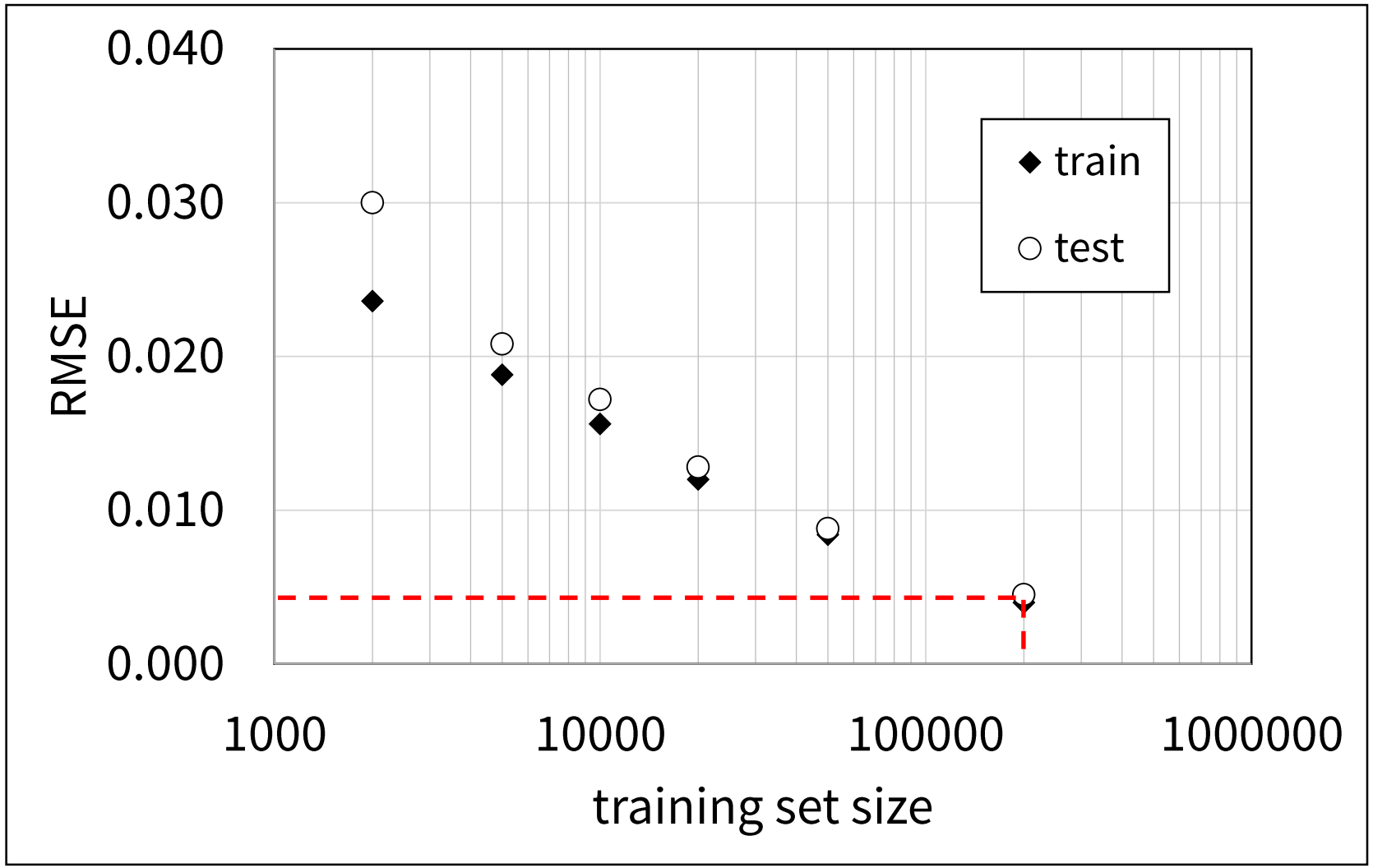

Step 1. Data Preparation
Step 2. Model Training
Step 3. Model Prediction
Training Input
Numerical Simulator
Training Output
Neural Network
900 s to **0.0003 s** speed up
Test Input
Neural Network
Test Output


Test Set Input
ECLIPSE
Neural network
Absolute error
Test case example #1
permeability (mD)
150
100
50
inj duration (days)
200
150
100
50
0
inj rate (ton/day/m)
3
2
1
0
y (CO_2 saturation)
$\hat{y}$ (CO_2 saturation)
0.6
0.4
0.2
0.0
MAE: 0.0015
0.20
0.15
0.10
0.05
0.00
Test case example #2
permeability (mD)
300
200
100
inj duration (days)
200
150
100
50
0
inj rate (ton/day/m)
3
2
1
0
y (CO_2 saturation)
$\hat{y}$ (CO_2 saturation)
0.6
0.4
0.2
0.0
MAE: 0.0023
0.20
0.15
0.10
0.05
0.00
Test case example #3
permeability (mD)
500
400
300
200
100
inj duration (days)
200
150
100
50
0
inj rate (ton/day/m)
3
2
1
0
y (CO_2 saturation)
$\hat{y}$ (CO_2 saturation)
0.6
0.4
0.2
0.0
MAE: 0.0011
0.20
0.15
0.10
0.05
0.00



Same **degree** of heterogeneity, different **absolute** permeability

SENSITIVITY ON TRAINING SIZE


0.040
0.030
0.020
0.010
0.000
RMSE
train
test
1000
10000
100000
1000000
training set size

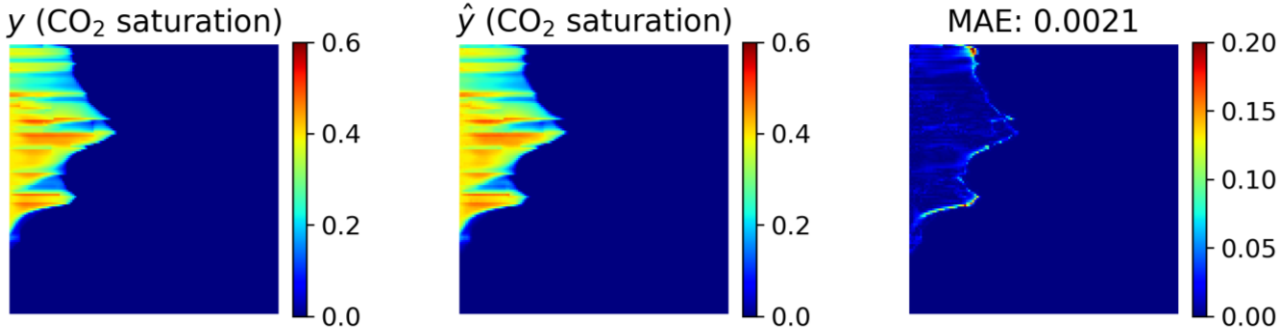
CAN THE NEURAL NETWORK

INTERPOLATE AND **EXTRAPOLATE**?

Duration Interpolate

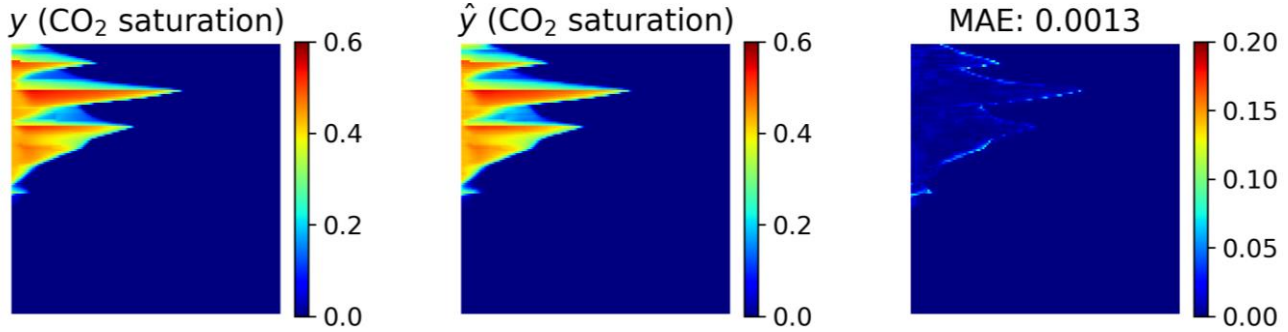
Train: 25, 75, 125, and 175 days of injection
Test: 50, 100, and 150 days of injection

In this example:
150 days of injection



Location Interpolate

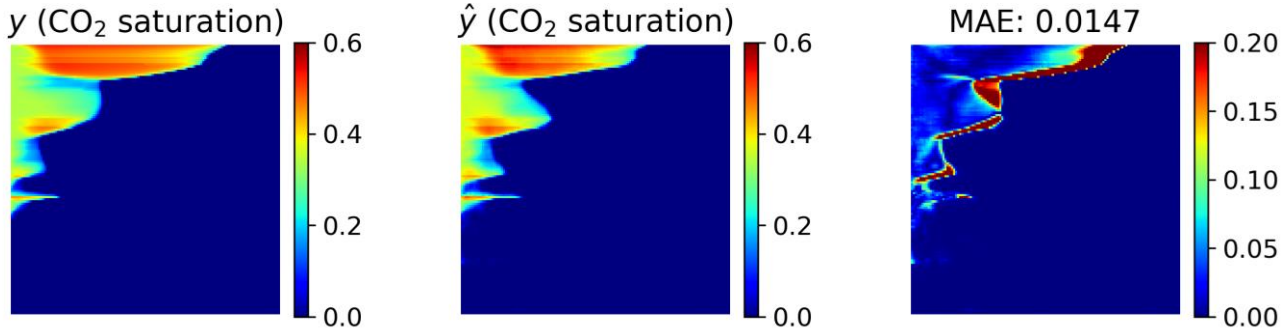
Train: randomly selected from half of the well perforation cases
Test: randomly selected from the other half of the well perforation cases



Duration Extrapolate

Train: 25, 50, 75, 100, and 125 days of injection
Test: 150, 175, and 200 days of injection

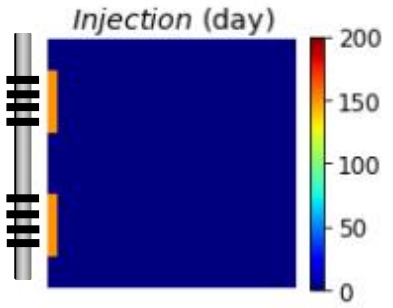
In this example:
175 days of injection



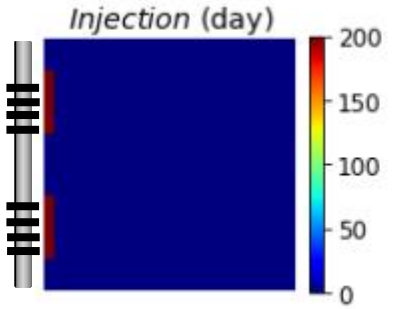
TRANSFER LEARNING

Multi-perforation

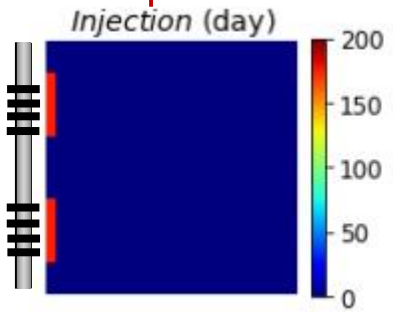
Example #1



Example #2



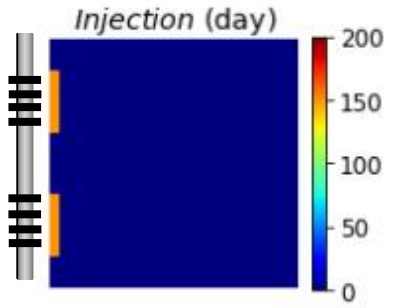
Example #3

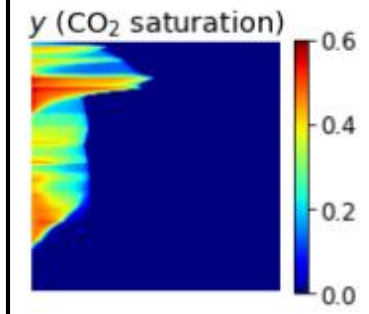


Multi-perforation

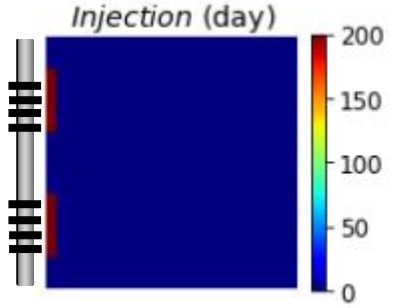
ECLIPSE

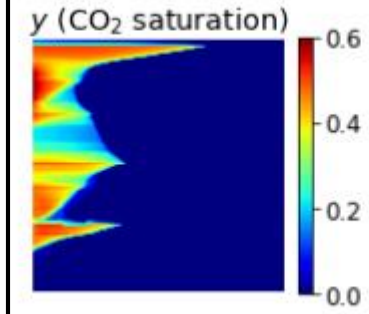
Example #1



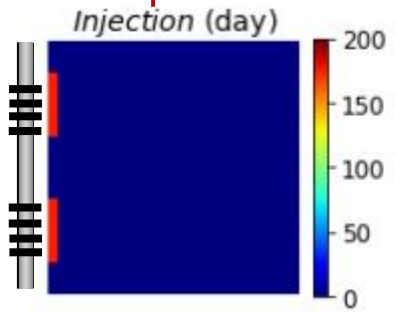


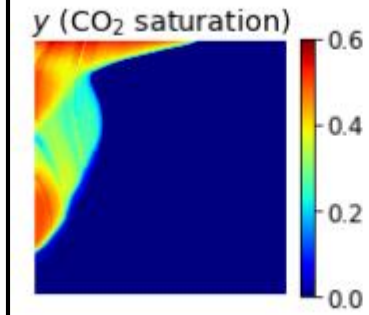
Example #2





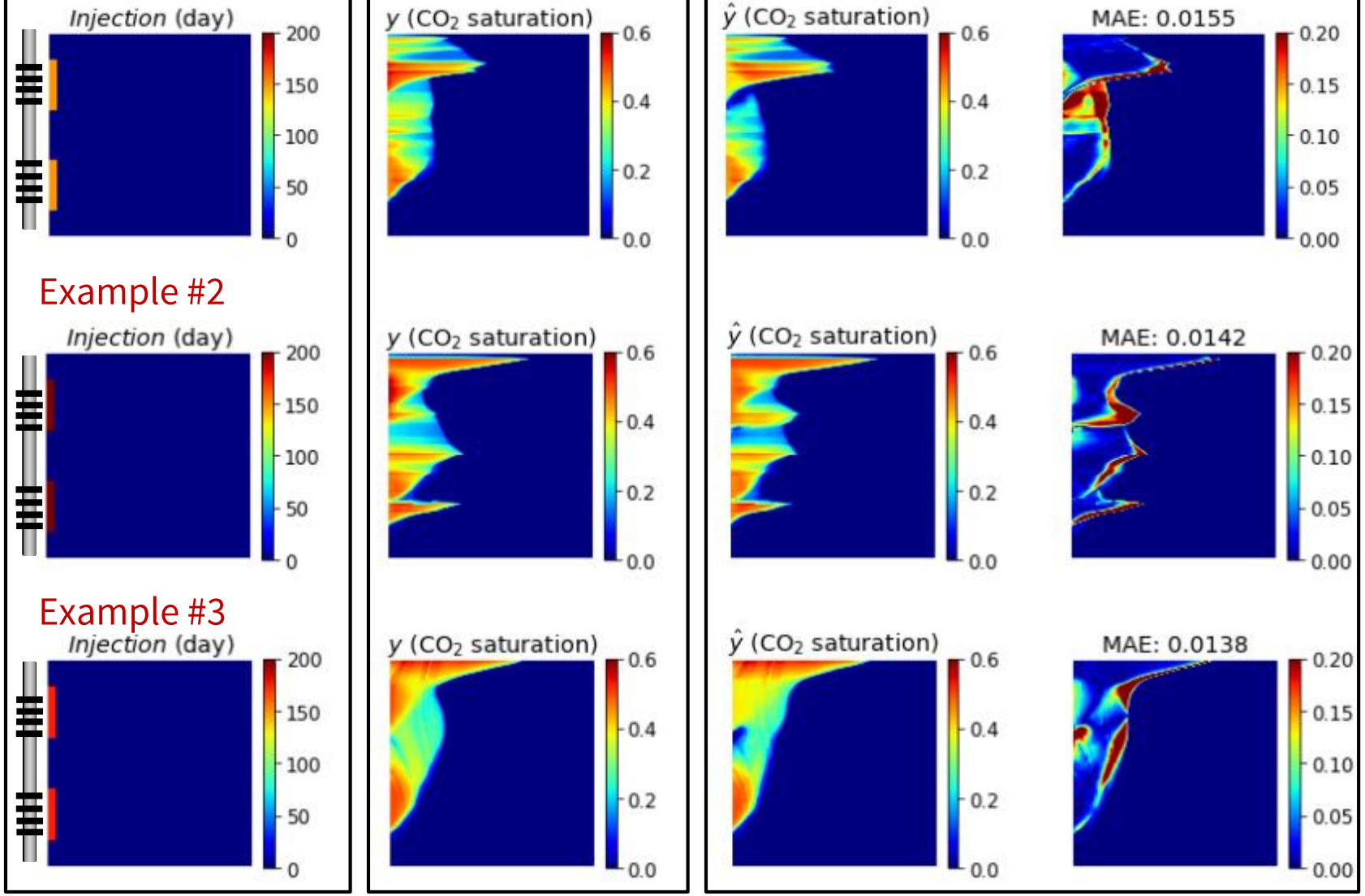
Example #3





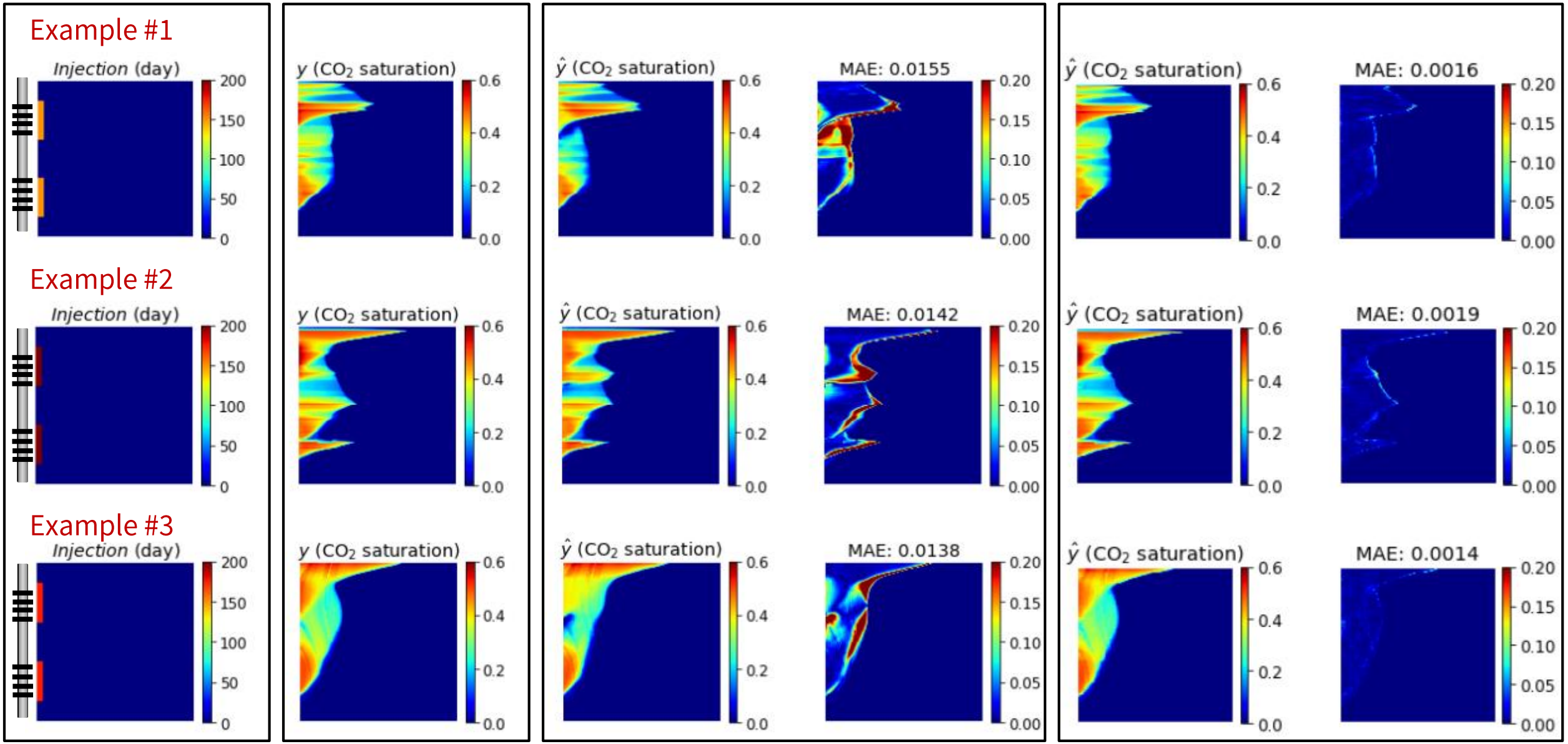
Multi-perforation | ECLIPSE | Neural network before transfer learning

Example #1



Example #2

Example #3


Multi-perforation
ECLIPSE
Neural network before transfer learning
Neural network after transfer learning
Example #1
Example #2
Example #3
Injection (day)
y (CO2 saturation)
ŷ (CO2 saturation)
MAE: 0.0155
MAE: 0.0016
MAE: 0.0142
MAE: 0.0019
MAE: 0.0138
MAE: 0.0014

Thank you for listening!