

# Reservoir scale CO<sub>2</sub> plume migration prediction with deep neural networks

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2020

## Challenge:

Numerical simulation for CO<sub>2</sub>-water multiphase flow is very **computationally expensive**.

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## Goal:

A **deep learning** algorithm that can generate **accurate** predictions of the multiphase flow process with **high efficiency**.

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Numerical simulation for CO<sub>2</sub>-water multiphase flow is very **computationally expensive**.

## Goal:

A **deep learning** algorithm that can generate **accurate** predictions of the multiphase flow process with **high efficiency**.

## Method:

Use numerical simulator to generate **training data** of plume migration results. Use the data to train **deep neural network** models.

# Scientific Approach

What we (might) have:

## Reservoir condition

- Initial pressure
- Temperature
  - Salinity

## Geological model

- Permeability
  - Porosity
- Anisotropy ratio

## Rock properties

- Relative permeability
- Capillary pressure
  - Compressibility

## Injection design

- Injection rate
- Injection duration
- Perforation interval

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What we use:

Numerical  
simulator

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What we use:

Numerical  
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What we want:

CO<sub>2</sub> plume  
distribution

Pressure  
distribution

Trapping  
mechanism

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What we use:

Numerical  
simulator

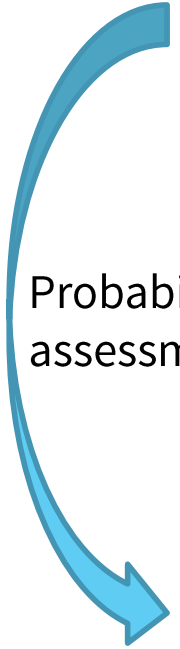
What we want:

CO<sub>2</sub> plume  
distribution

Pressure  
distribution

Trapping  
mechanism

Probabilistic  
assessment



History  
matching



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What we use:

**ML  
model**

What we want:

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# Scientific Approach – 2D radial system

## Reservoir condition

- Initial pressure
- Temperature
- Salinity

## Geological model

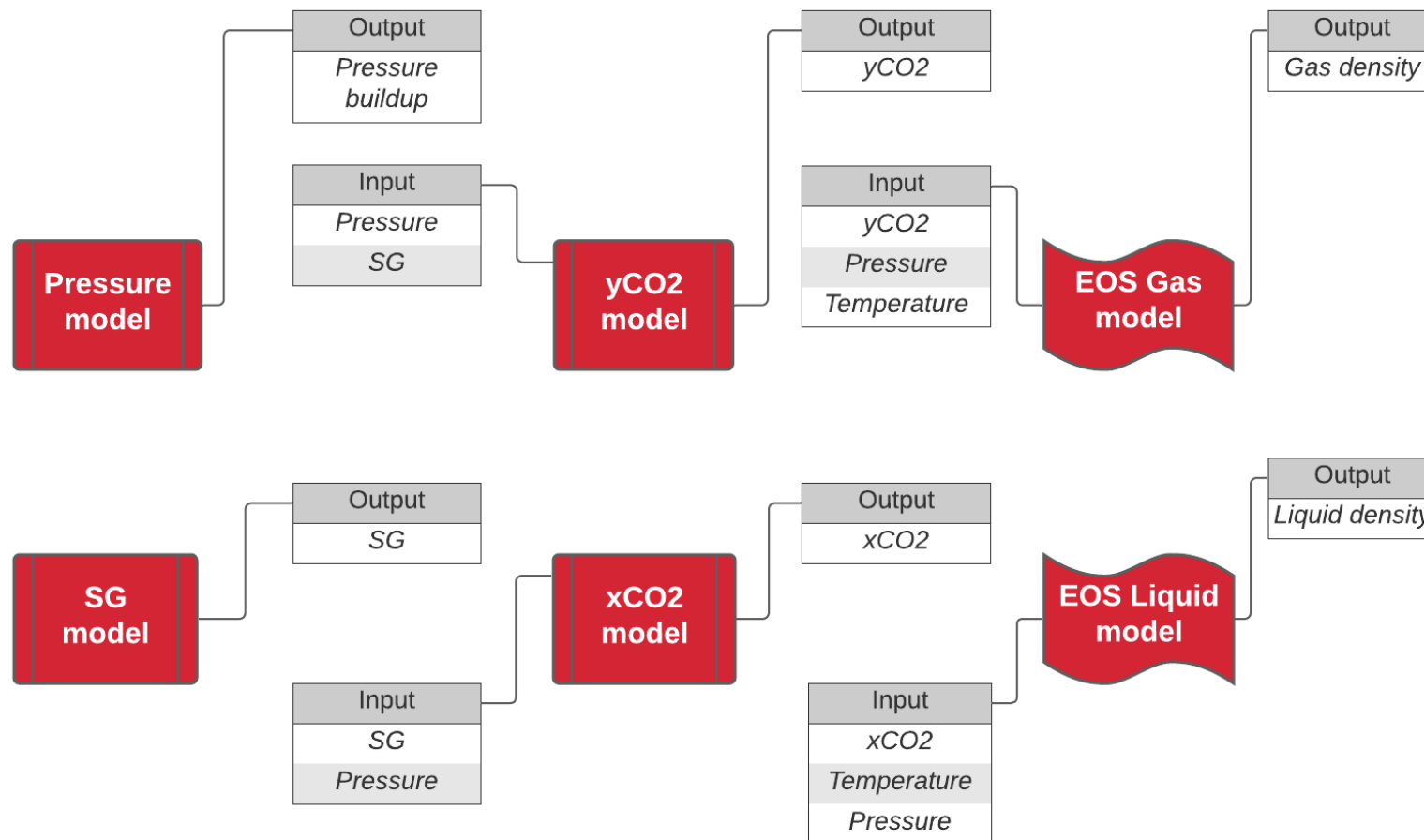
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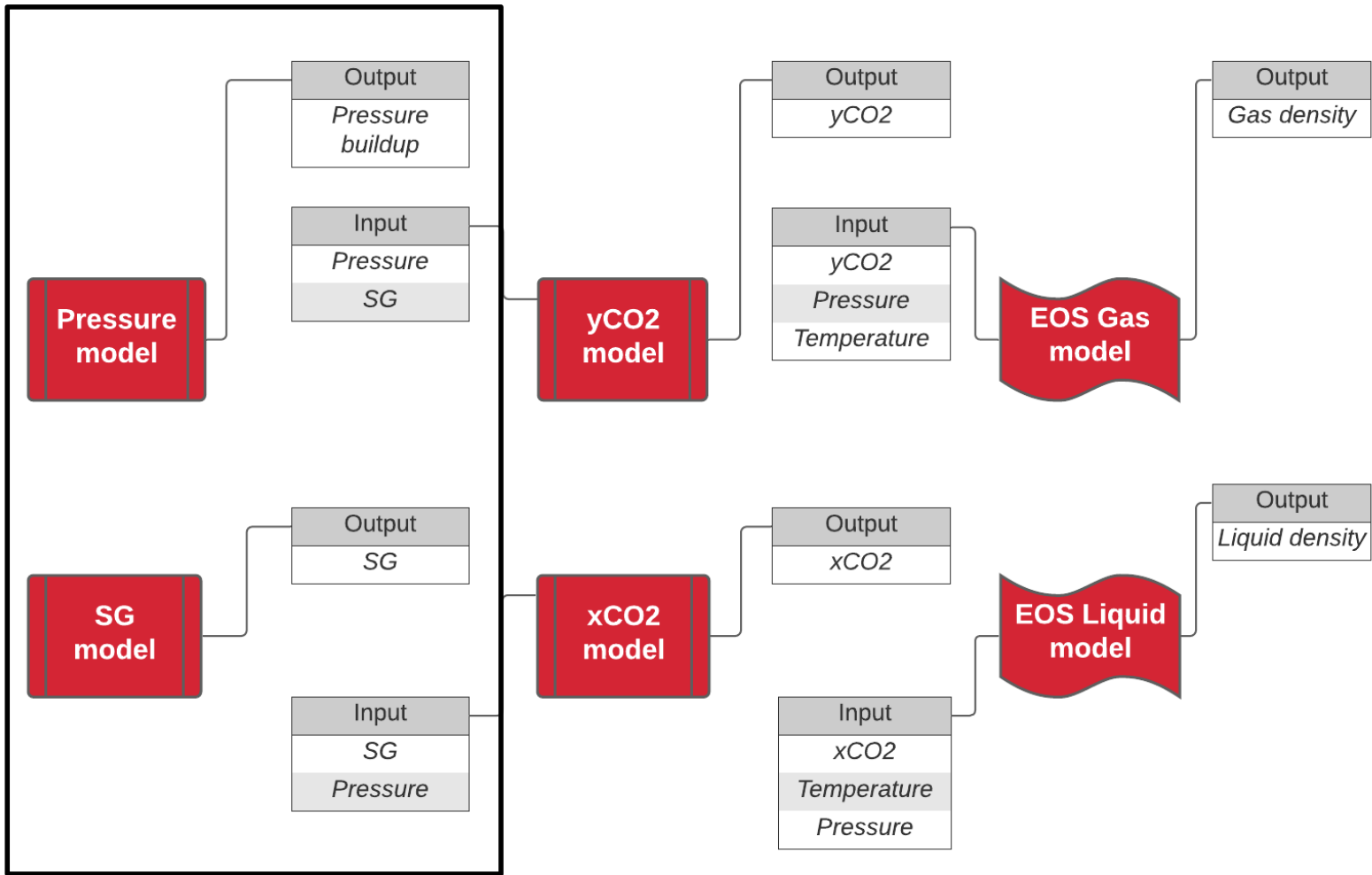
CO<sub>2</sub> plume distribution

Pressure distribution

Trapping mechanism

# Scientific Approach – 2D radial system

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  - Initial pressure
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- CO<sub>2</sub> plume distribution
- Pressure distribution
- Trapping mechanism

# Scientific Approach – 2D radial system

## Reservoir condition

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- Salinity

## Geological model

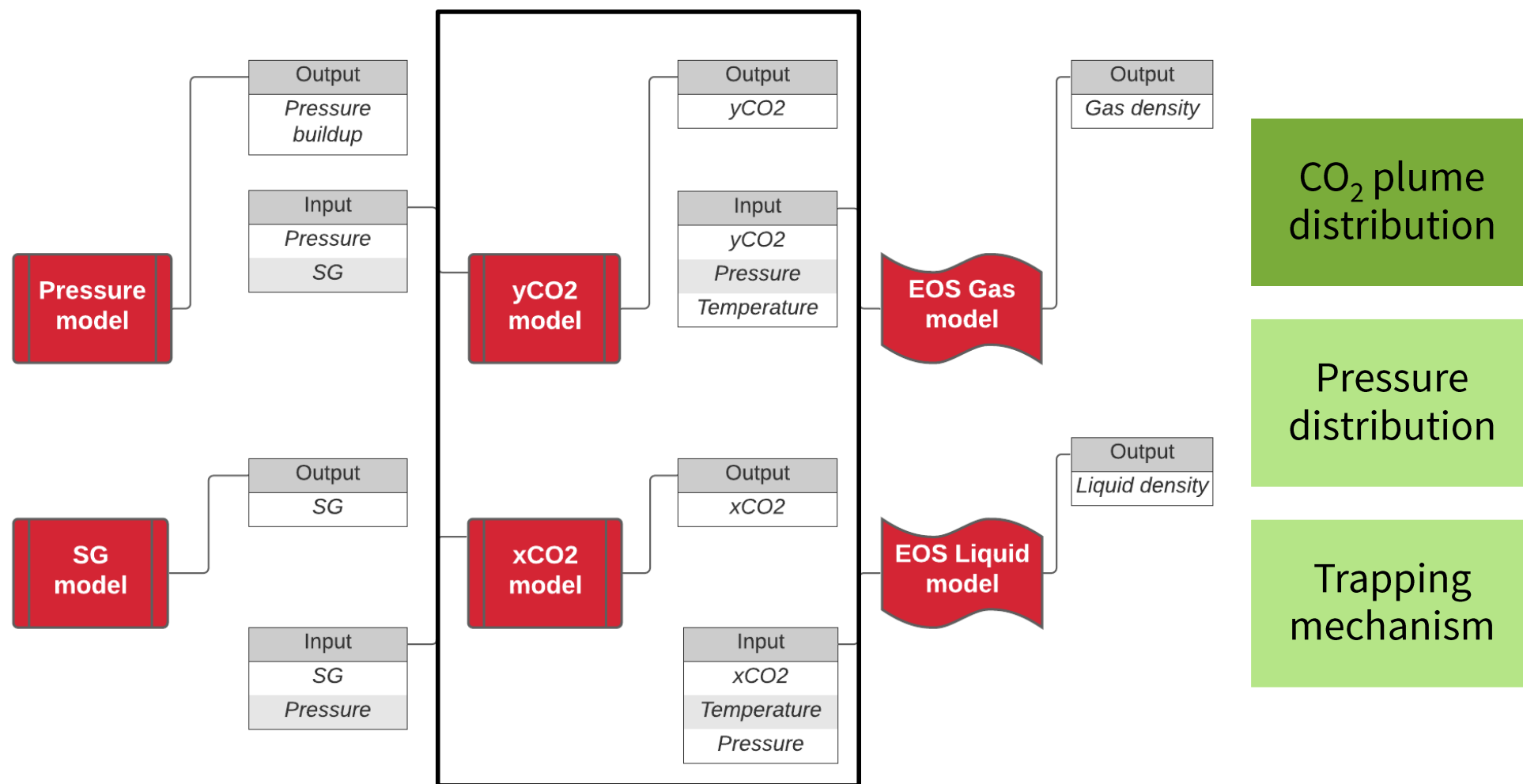
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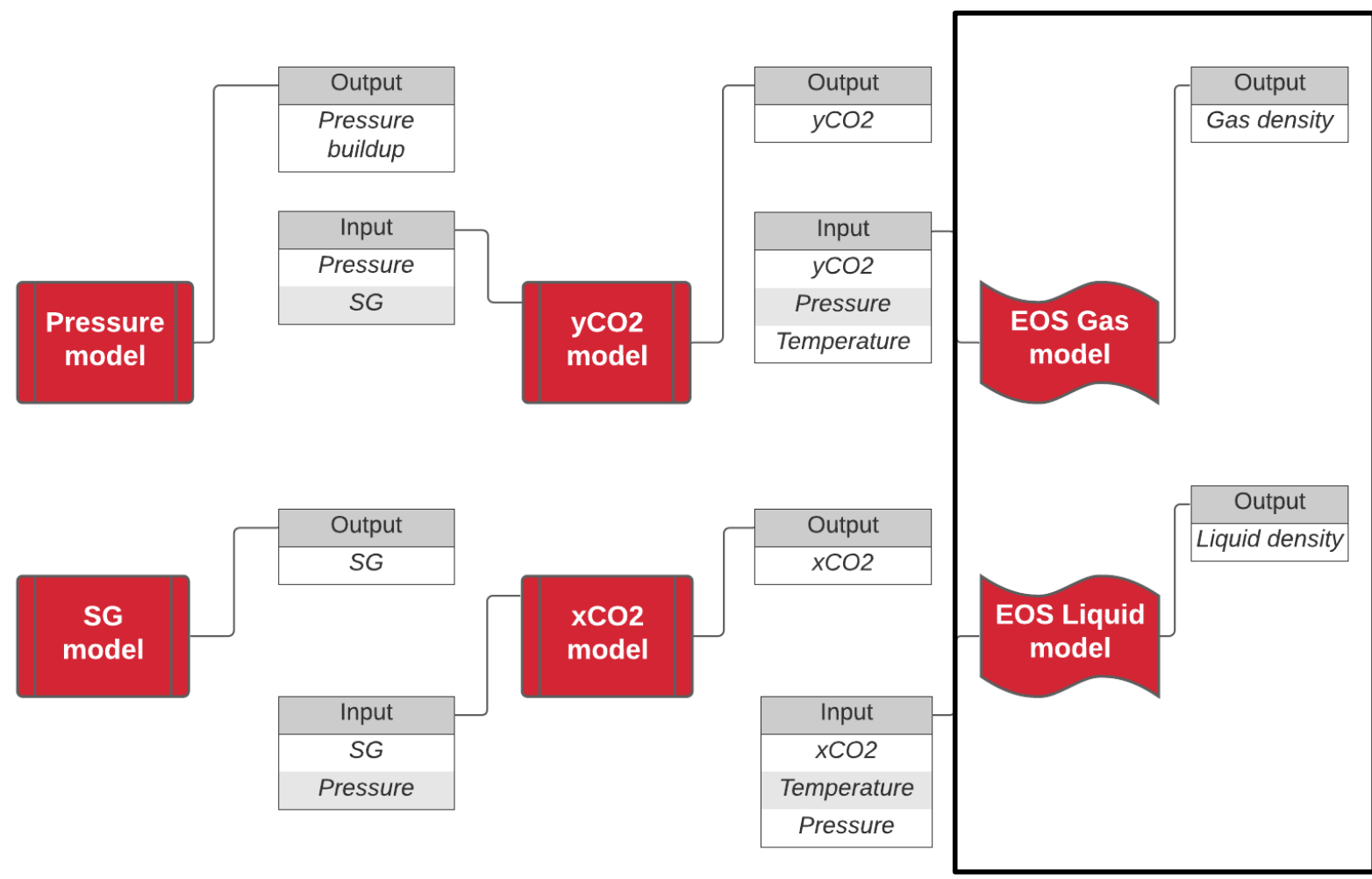
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CO<sub>2</sub> plume distribution

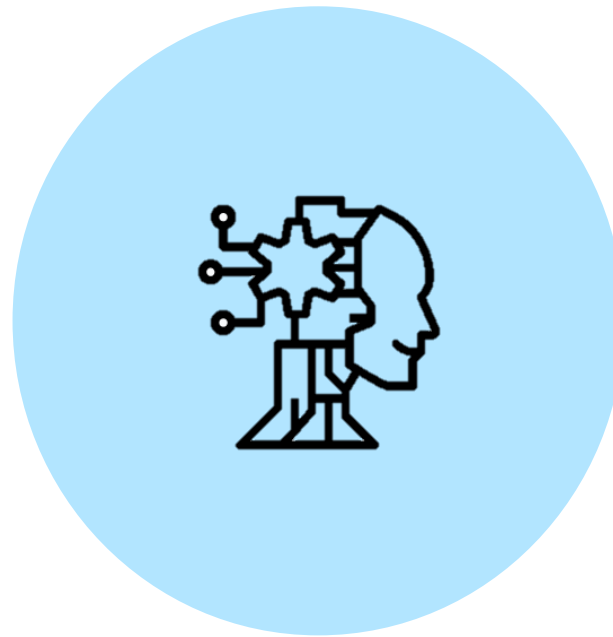
Pressure distribution

Trapping mechanism

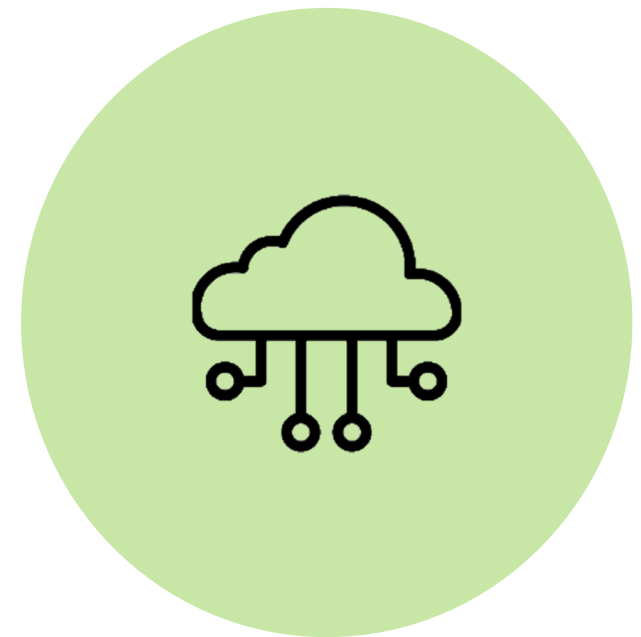
# General machine learning task procedure



**Step 1**  
Data Preparation

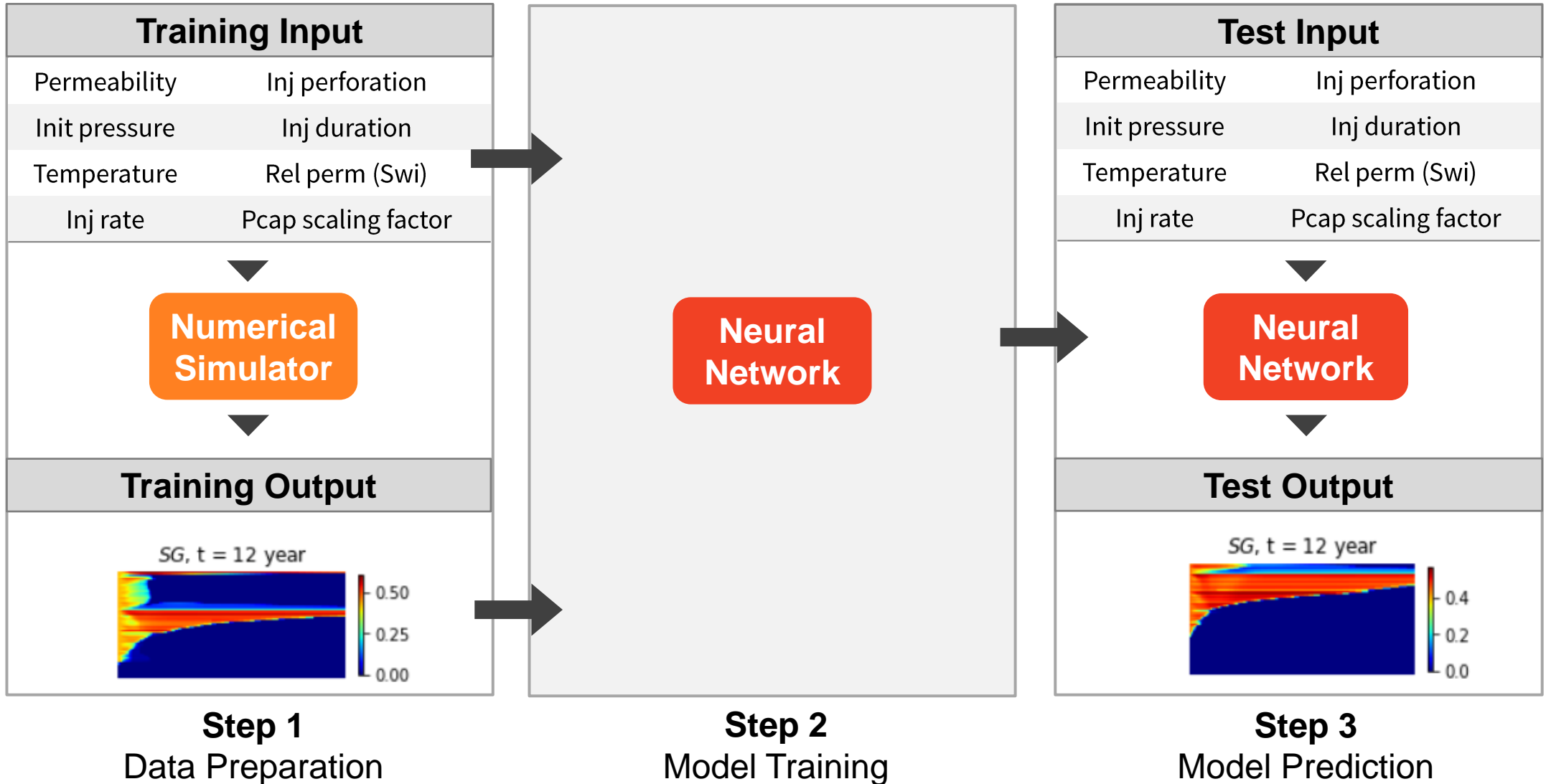


**Step 2**  
Model Training

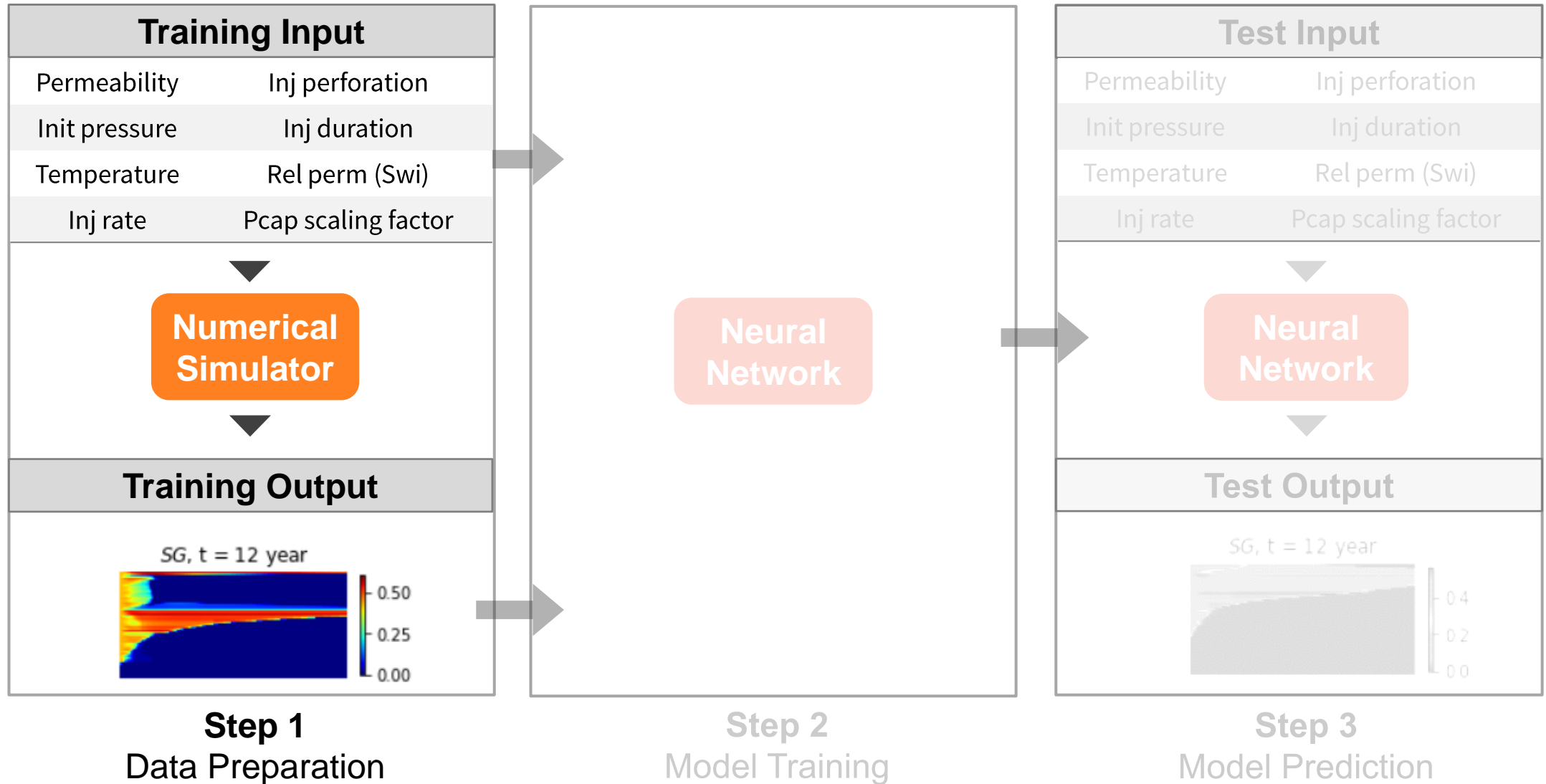


**Step 3**  
Model Prediction

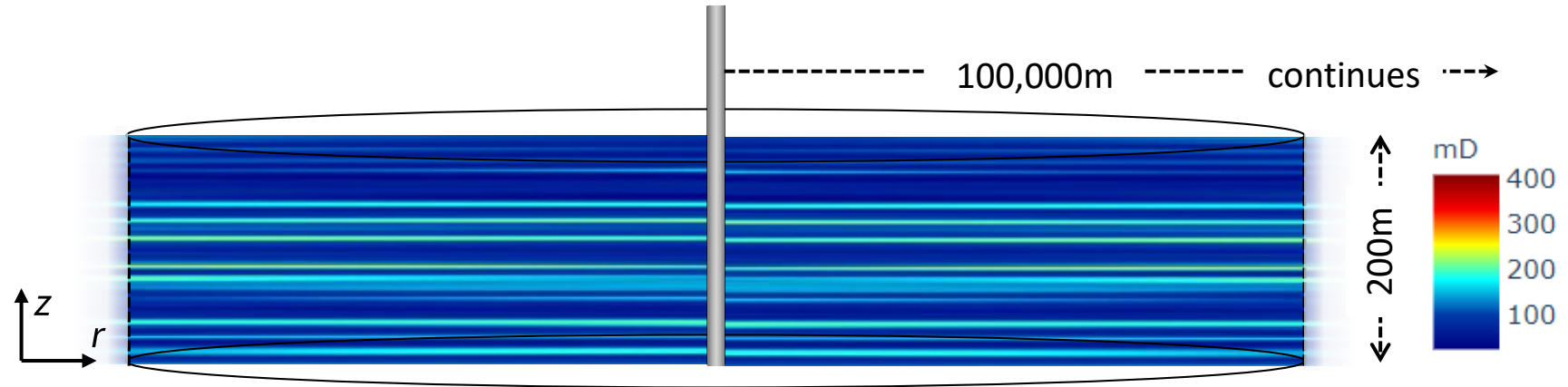
# 2D reservoir ML model task procedure



# 2D reservoir ML model task procedure



# Training Input

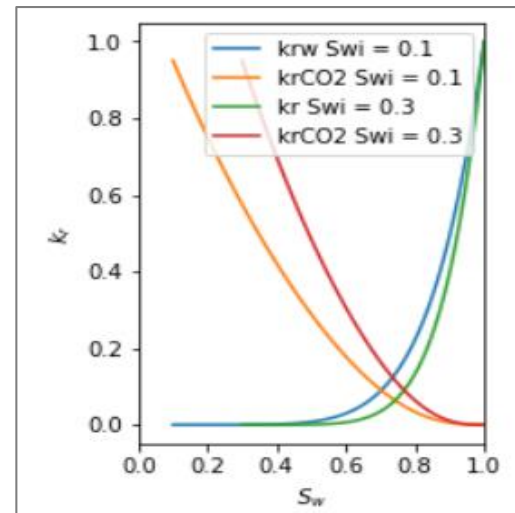


Injection rate

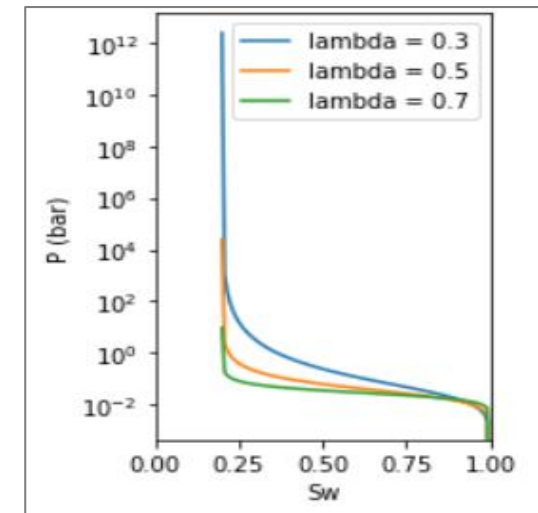
Perforation interval

Initial pressure

Reservoir temperature

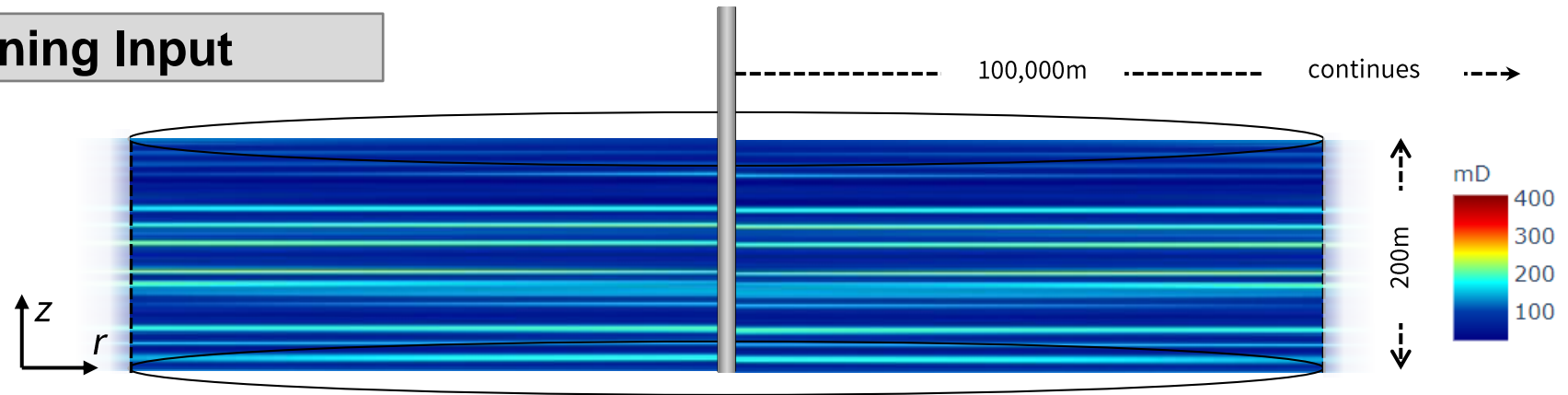


Irreducible water saturation

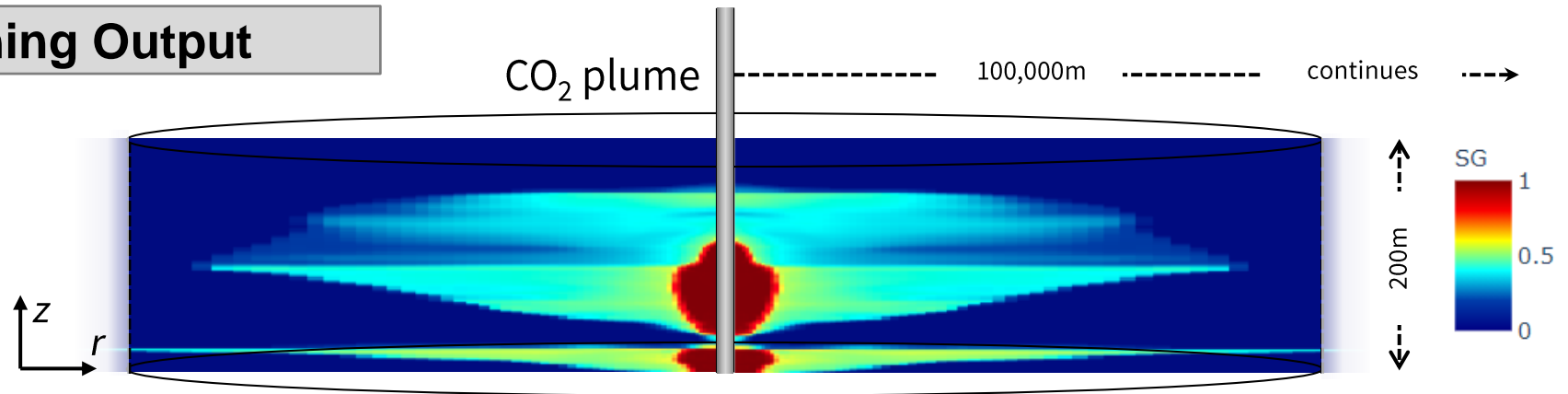


van Genuchten scaling factor

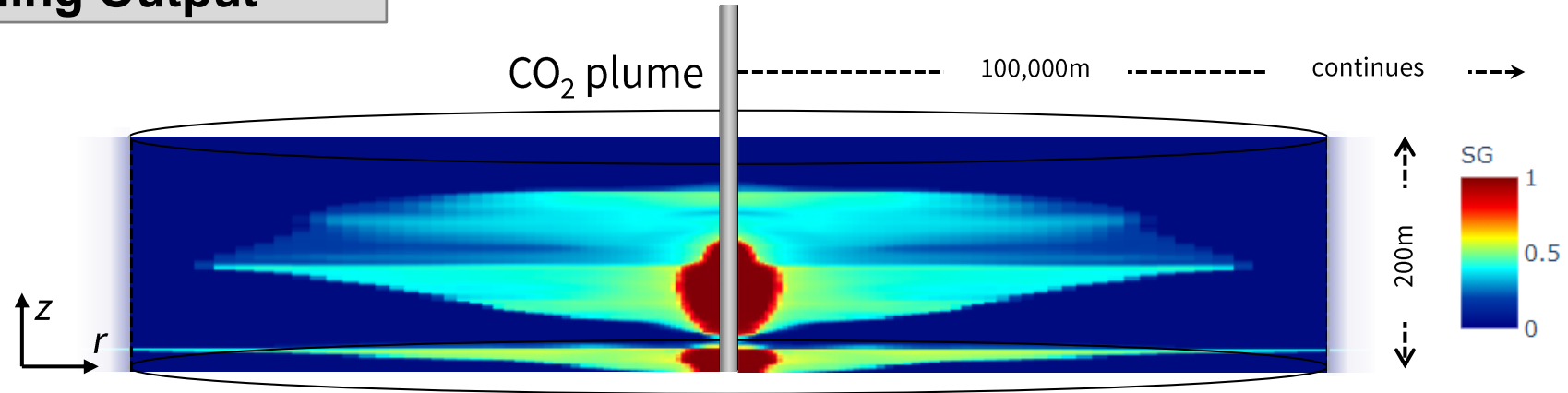
## Training Input



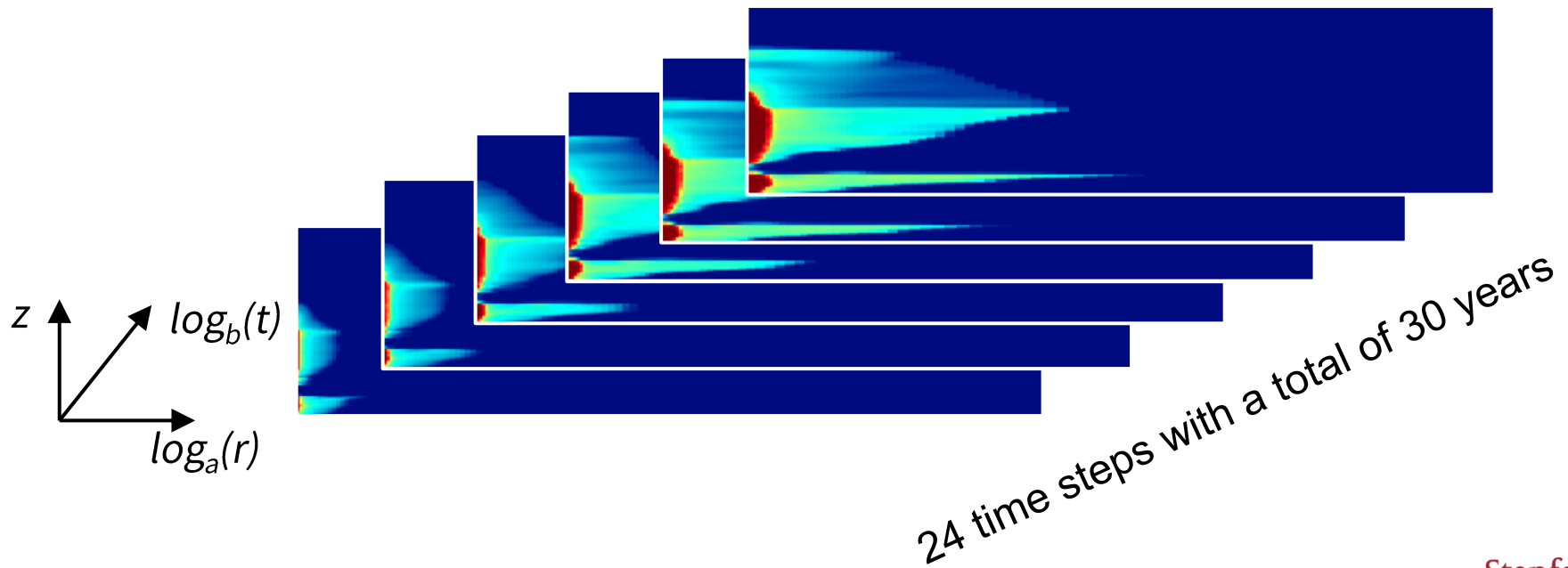
## Training Output



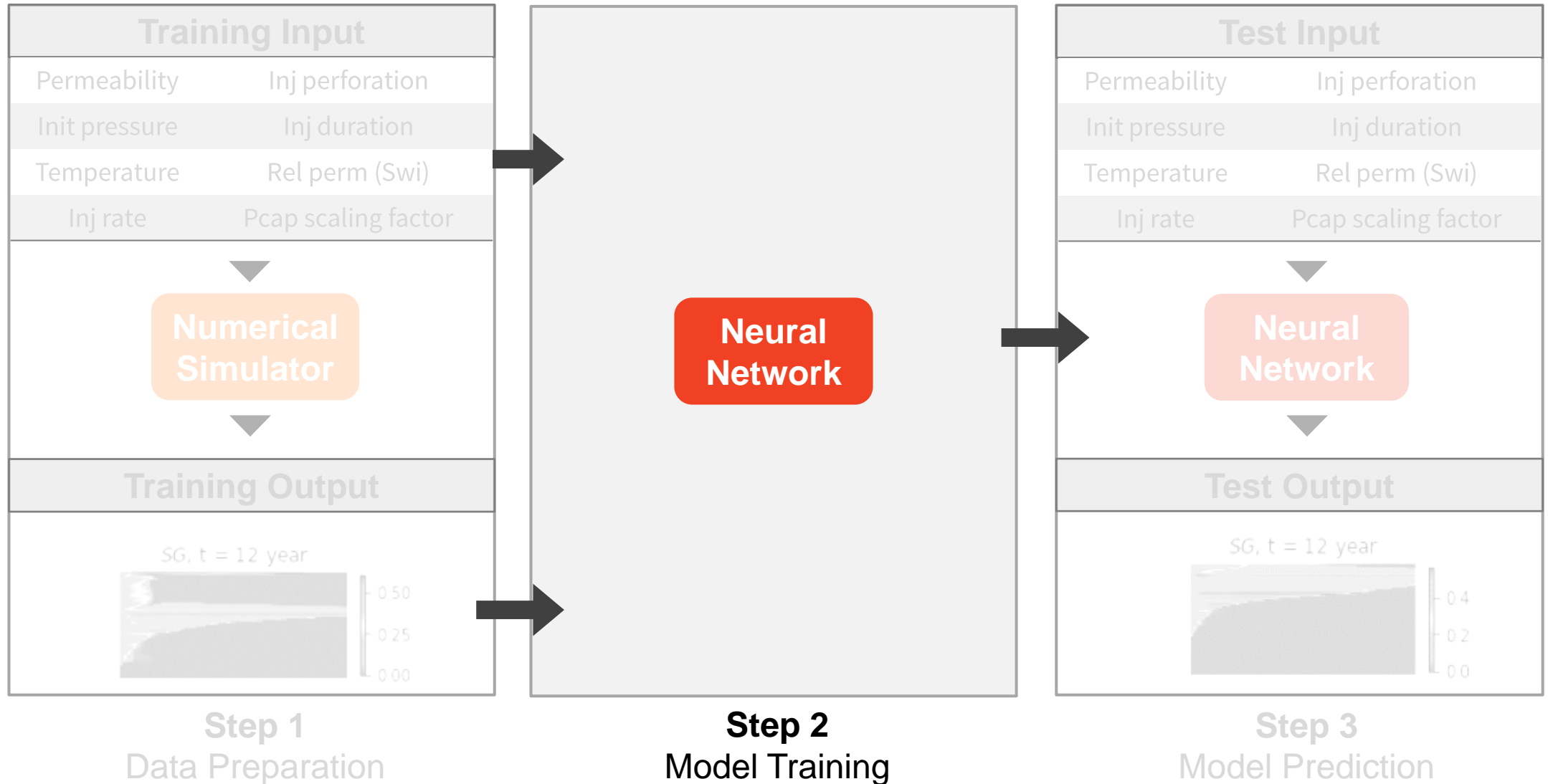
# Training Output



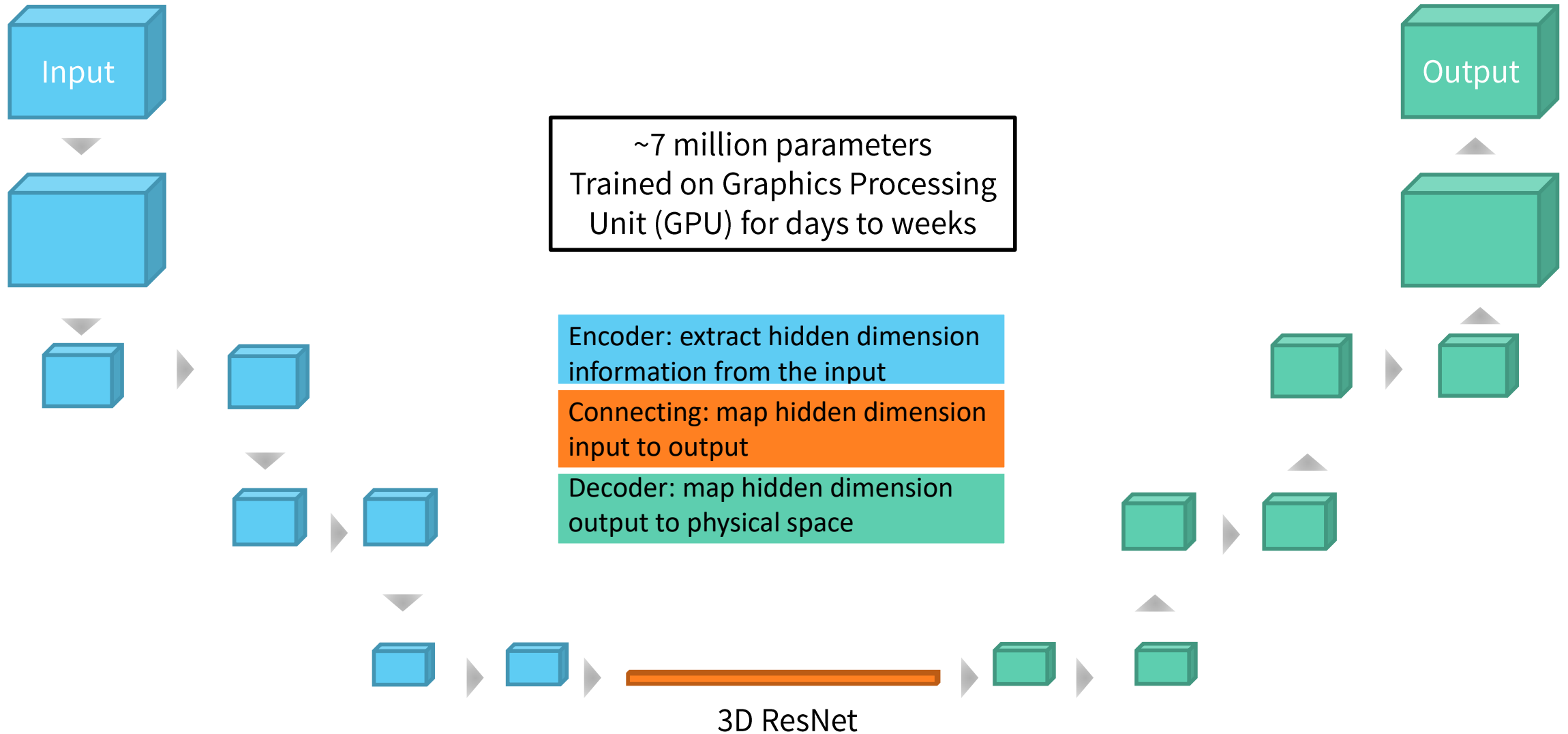
CO<sub>2</sub> gas saturation field - data of neural network



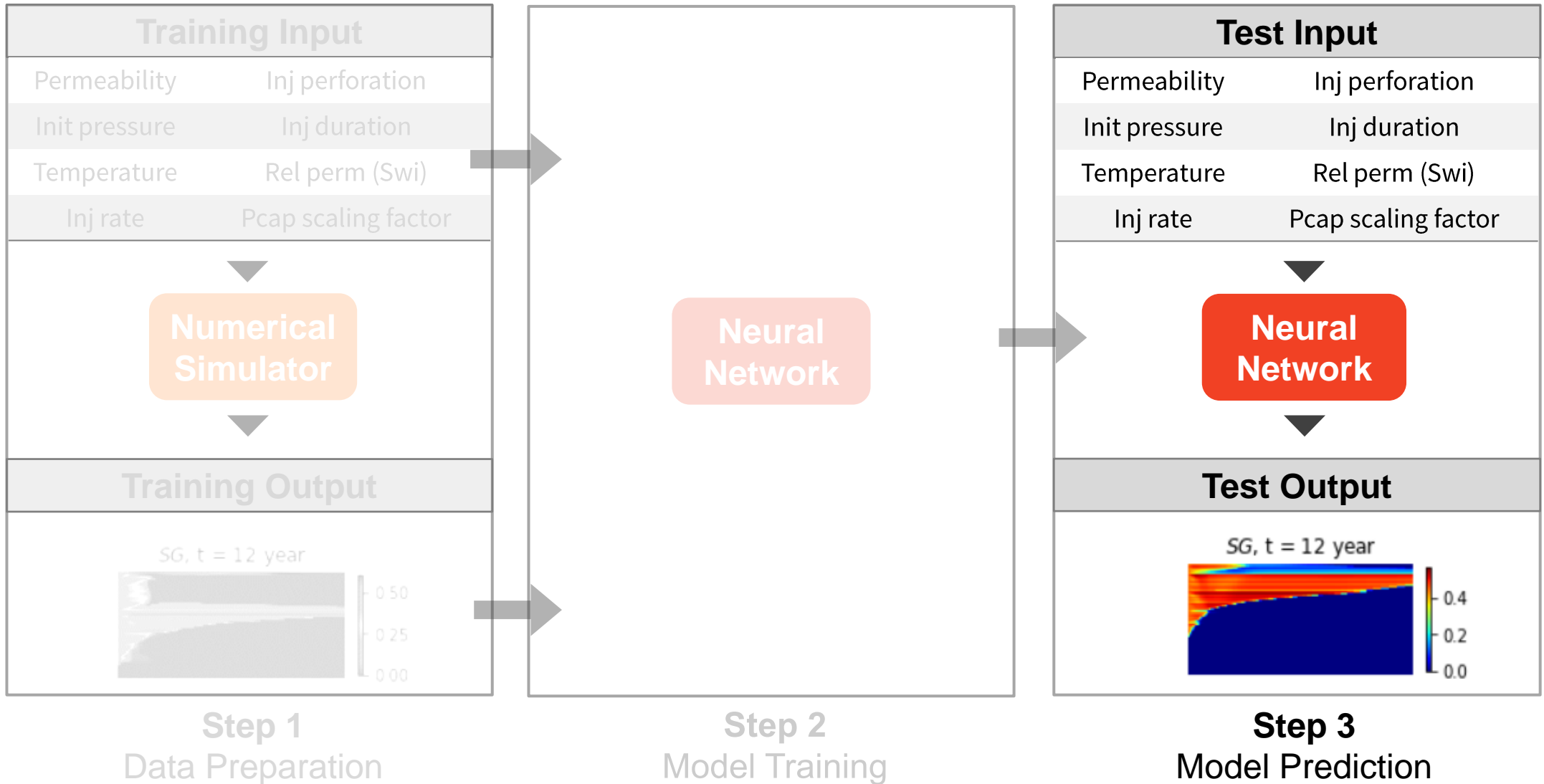
# 2D reservoir ML model task procedure



# Temporal 3D-Net Model Architecture

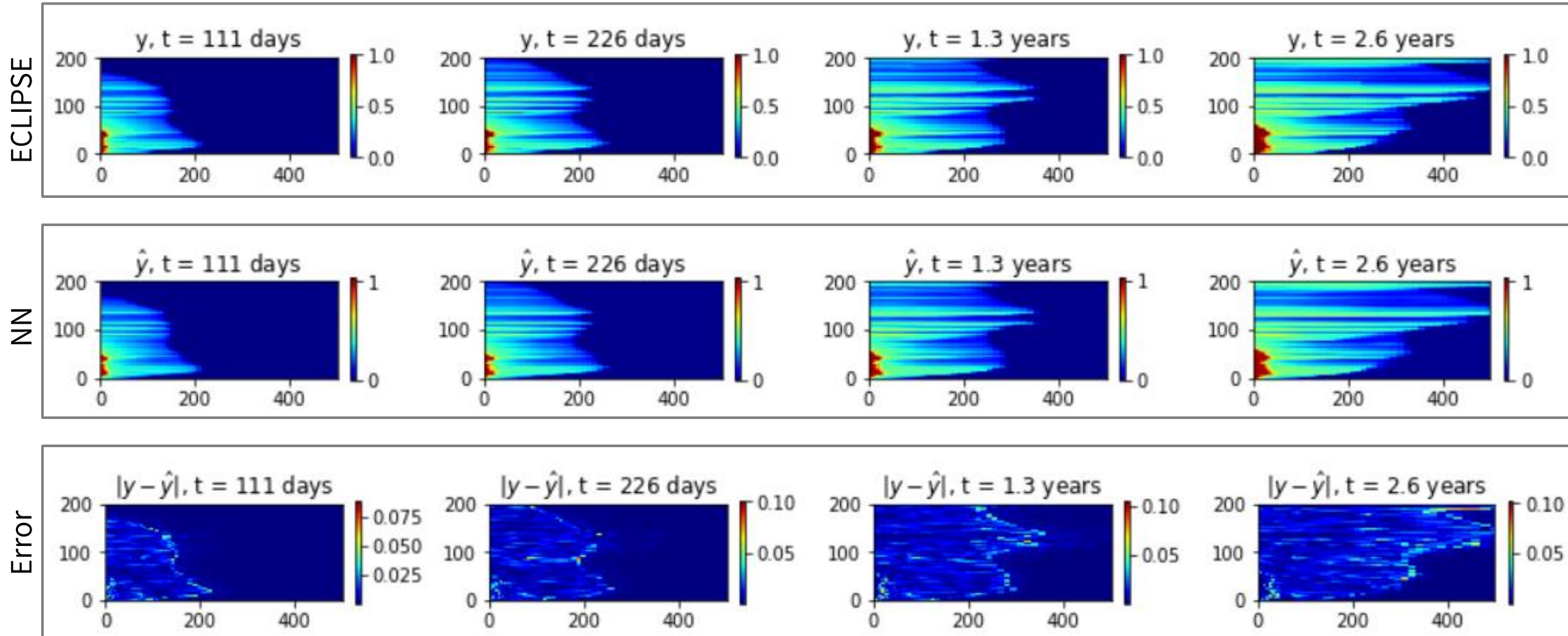


# 2D reservoir ML model task procedure

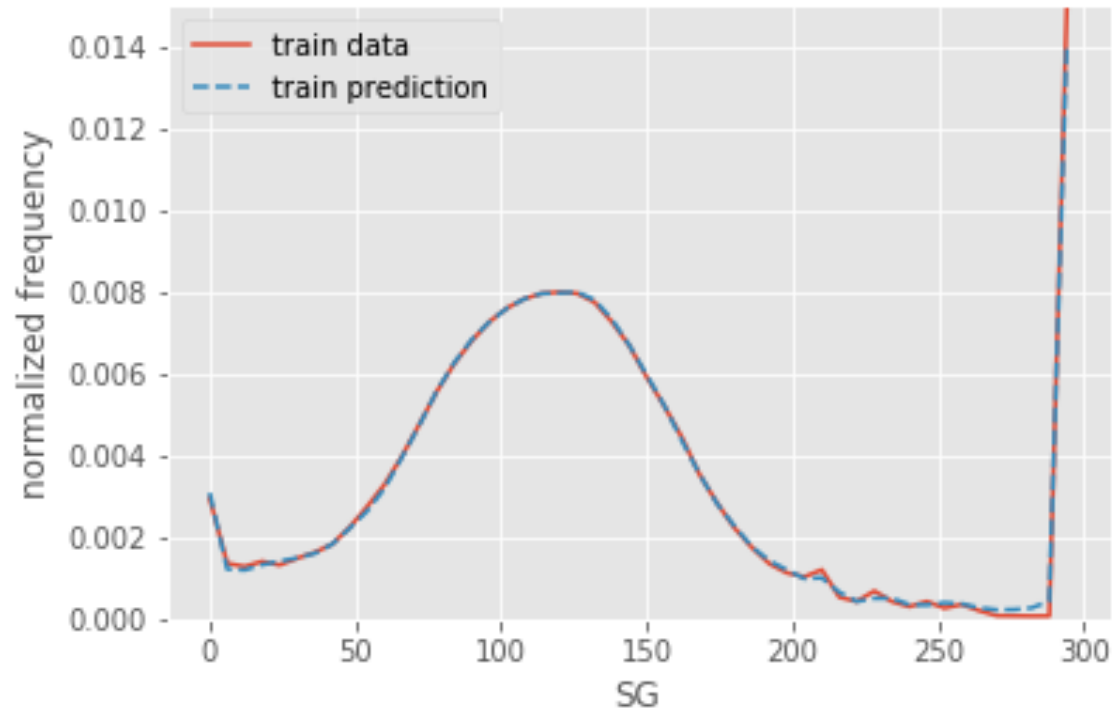


# Test set example – CO<sub>2</sub> saturation

ML~0.5 s  
ECLIPSE~30 m

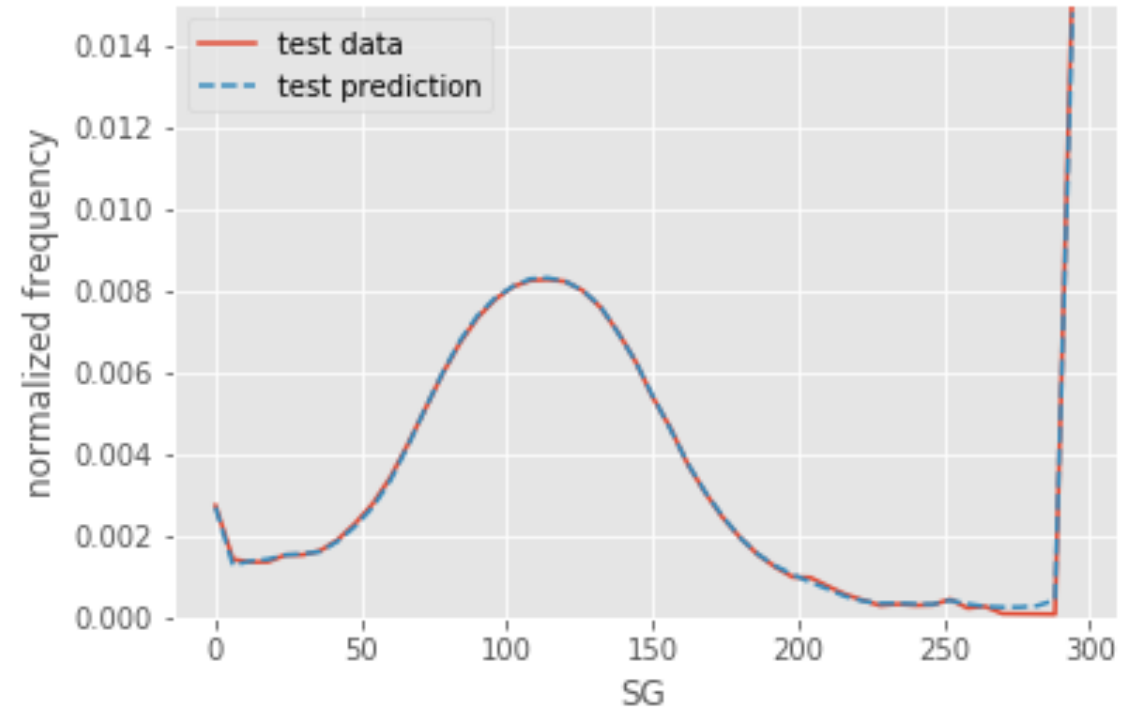


# CO<sub>2</sub> saturation distribution prediction



Mean absolute error: 0.0012  
Absolute error std: 0.0055

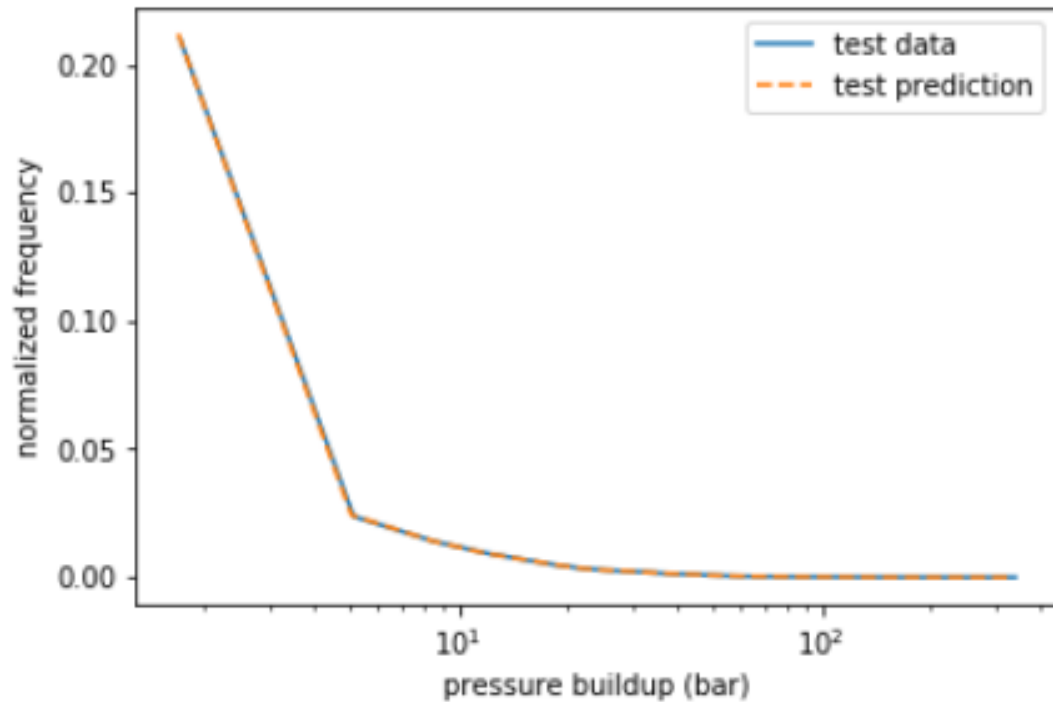
Mean plume abs error: 0.0086  
Absolute plume abs error std: 0.013



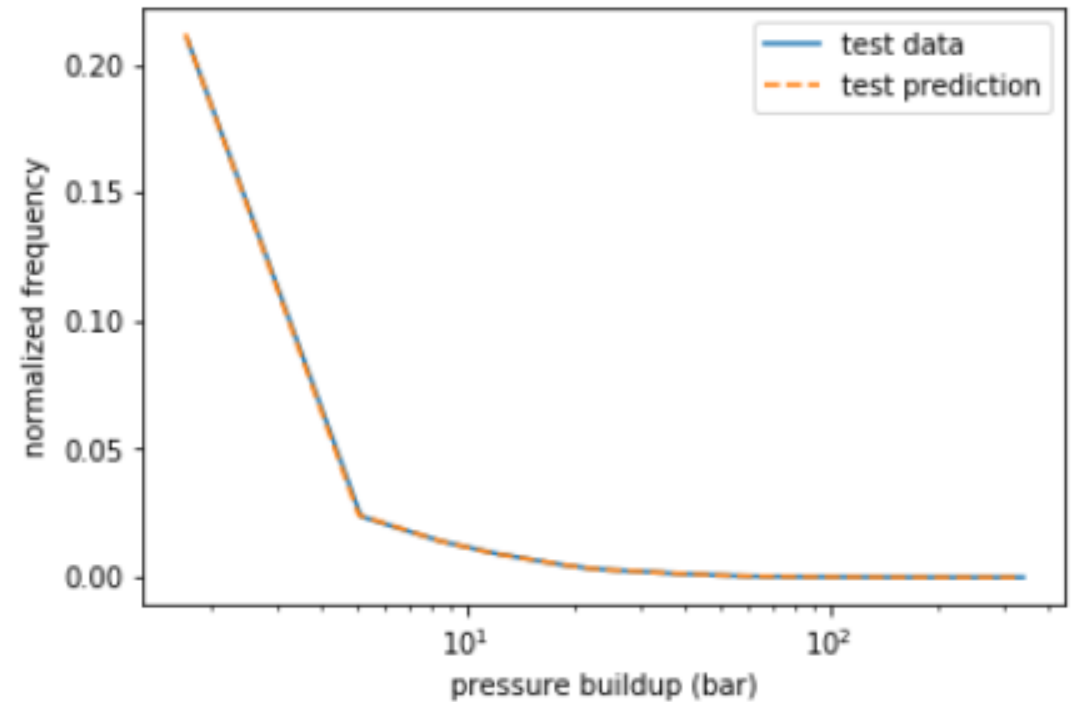
Mean absolute error: 0.0013  
Absolute error std: 0.0060

Mean plume abs error: 0.0091  
Absolute plume abs error std: 0.014

# Pressure buildup distribution prediction

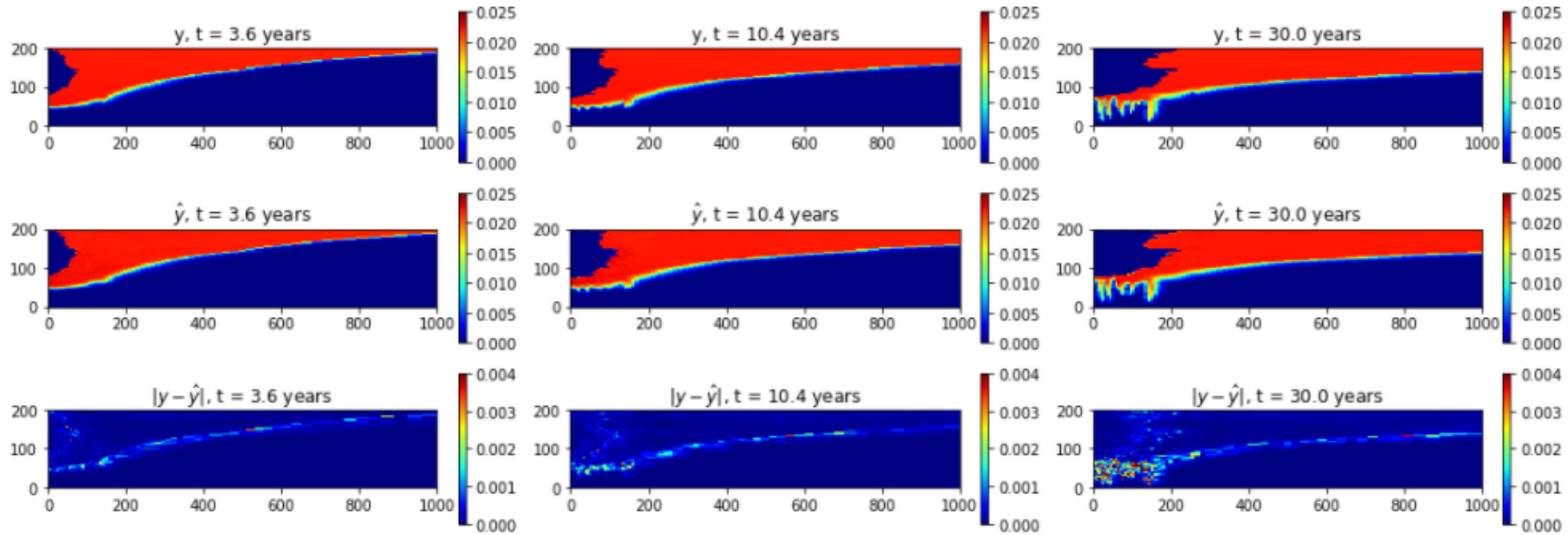


Mean relative error: 0.023  
Relative error std: 0.051

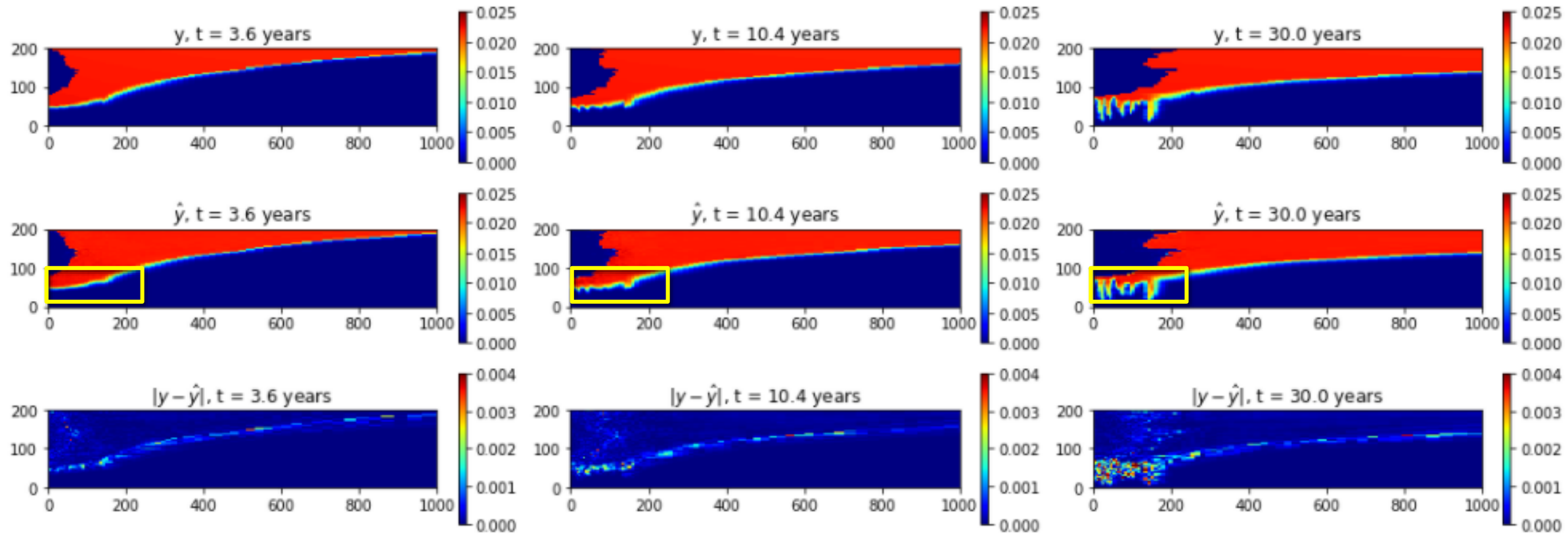


Mean relative error error: 0.025  
Relative error std: 0.058

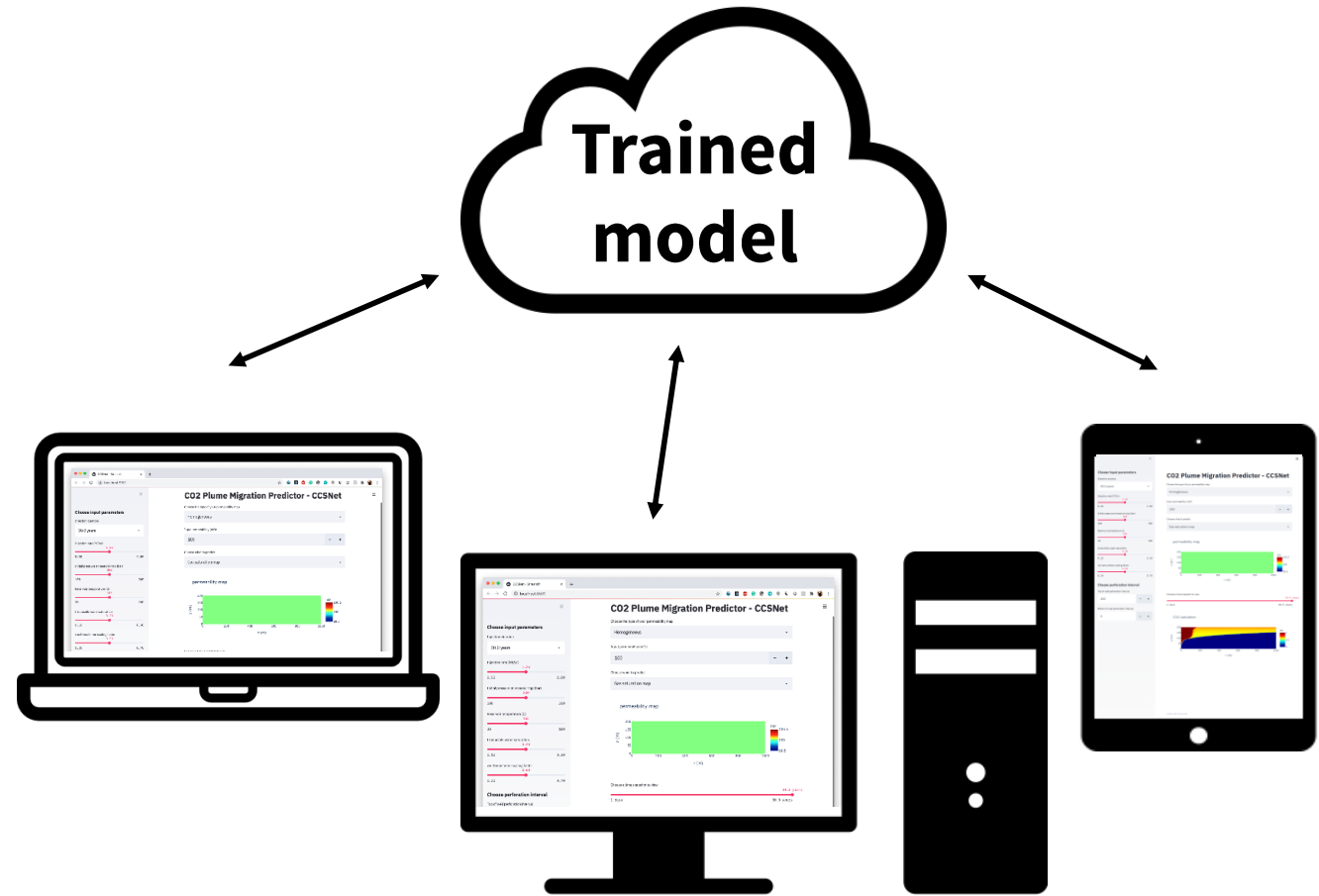
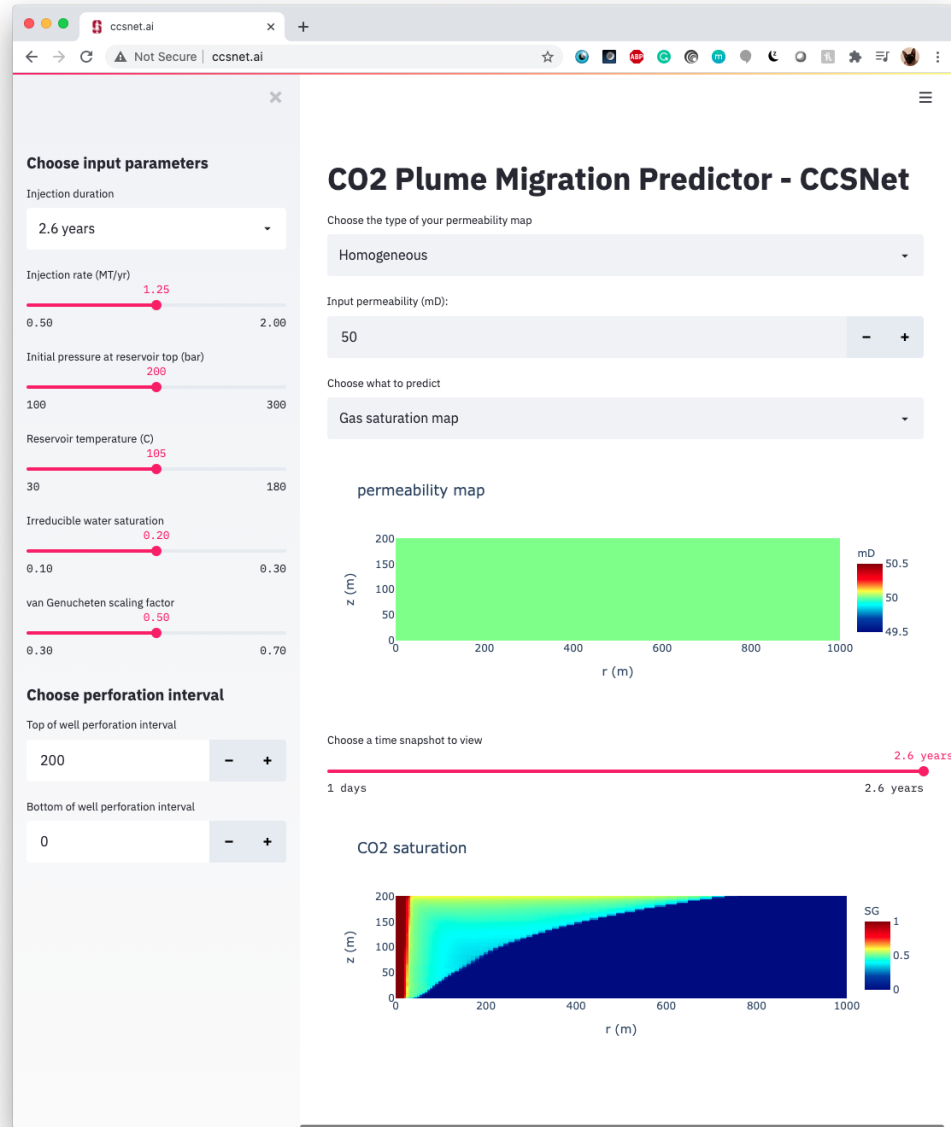
# Test set example – Molar fraction of dissolved CO<sub>2</sub>



# Test set example – Molar fraction of dissolved CO<sub>2</sub>



# Trained ML model is served as a web application



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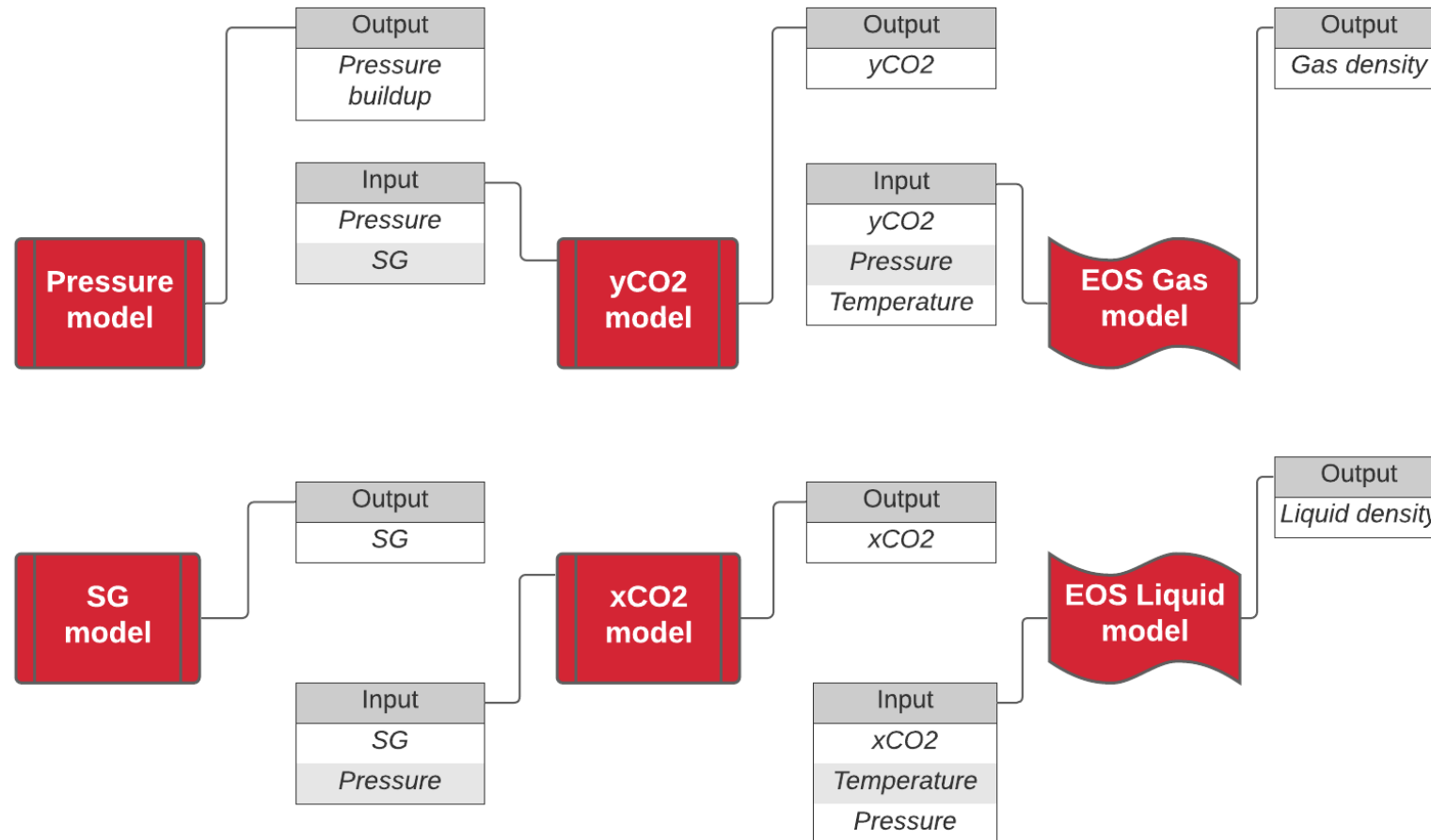
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**Thank you for listening!**

**We acknowledge ExxonMobil for supporting this work.**