Parametric analysis of the Area-of-Review (AoR) using CCSNet

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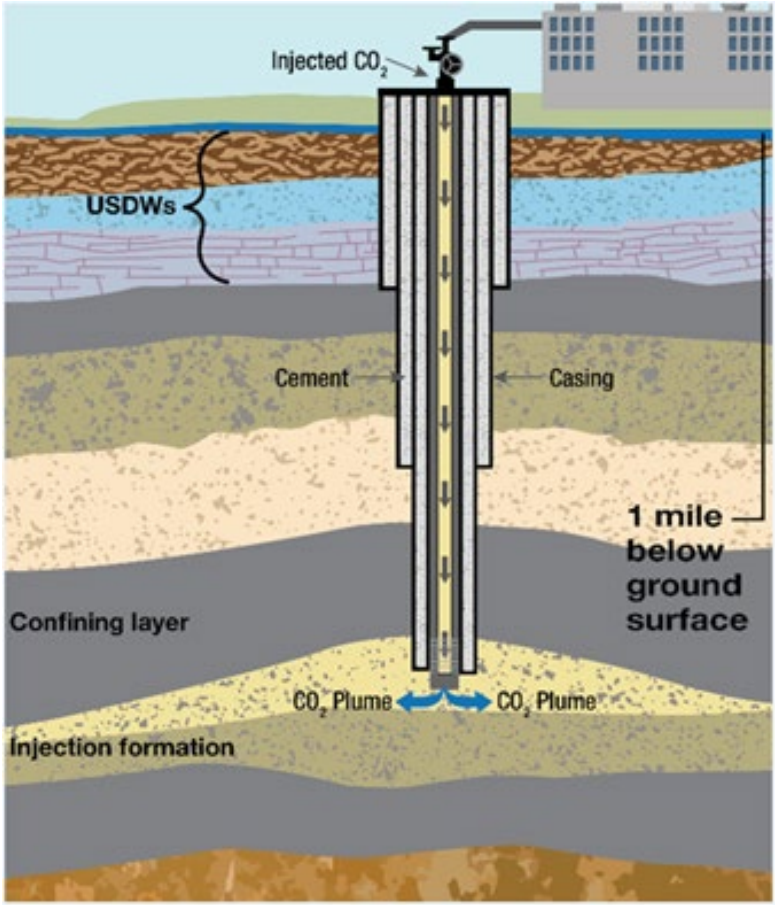
Introduction

- EPA Class VI well – geological storage of CO_2
- Area of Review (AoR) – region with risk of brine leakage into underground source of drinking water (USDW)
- AoR – typically delineated using computational modeling
- AoR impacts project economics – monitoring legacy wells, land acquisition or access – the smaller the better!
- Our work: Parametric tool and chart - quick estimate of the AoR for site screening and early-stage projects

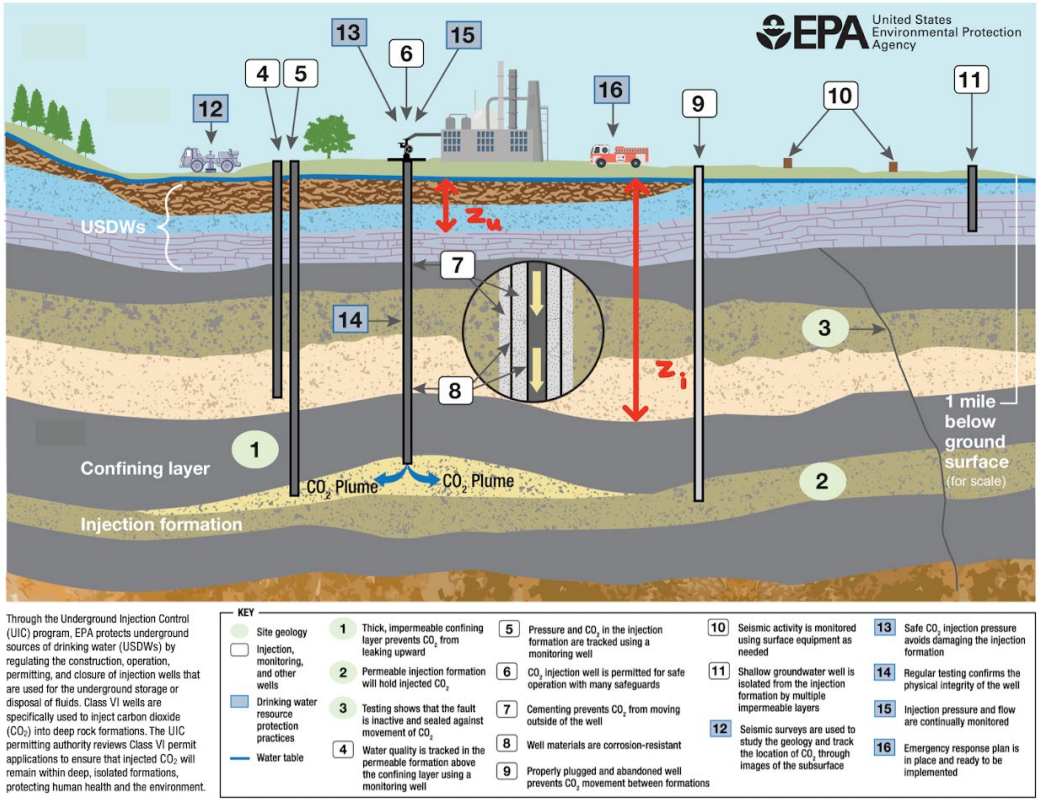


Critical pressure calculation

- Critical pressure region – the region inside which pressure buildup high enough to cause brine flow up a hypothetical well/fault from injection zone into USDW

$$\Delta P = (\rho_b - \rho_w)\, g\, (z_i - z_u)$$

ΔP – critical pressure buildup for brine leakage
ρ_b - brine density
ρ_w – USDW fluid density
z_u – depth to bottom of USDW
z_i – depth to top of injection reservoir



AoR – maximum extent of plume and pressure regions

- AoR = max(CO_2 plume region, critical pressure region)
- AoR can be plume-dominated, pressure-dominated or a combination of the two

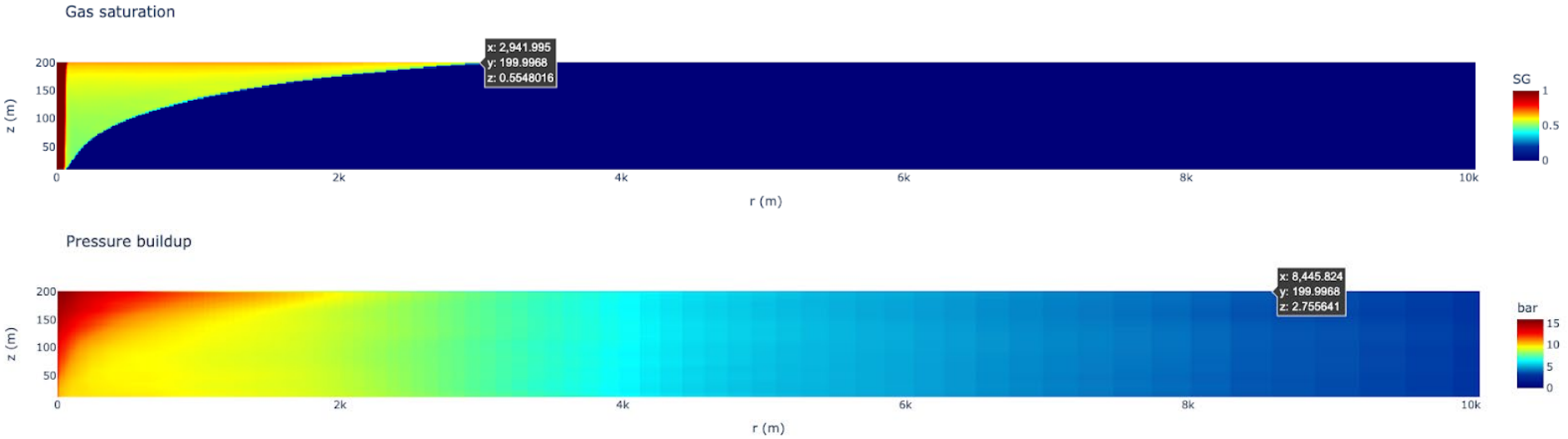
Method

- CCSNet – world's first deep-learning based modeling suite for carbon storage
- CCSNet's API used to run ~500k trials for different parameters

S.No	Parameter	Symbol	Unit	Minimum	Maximum
1	Brine density	ρ_{brine}	kg/m^3	1020	1100
2	Injection Rate	Q	MT/year	0.25	2
3	Depth to bottom of USDW	z_u	m	100	350
4	Depth to the top of the reservoir	z_i	m	800	1800
5	Reservoir thickness	h	m	50	200
6	Reservoir permeability	k	mD	50	1000

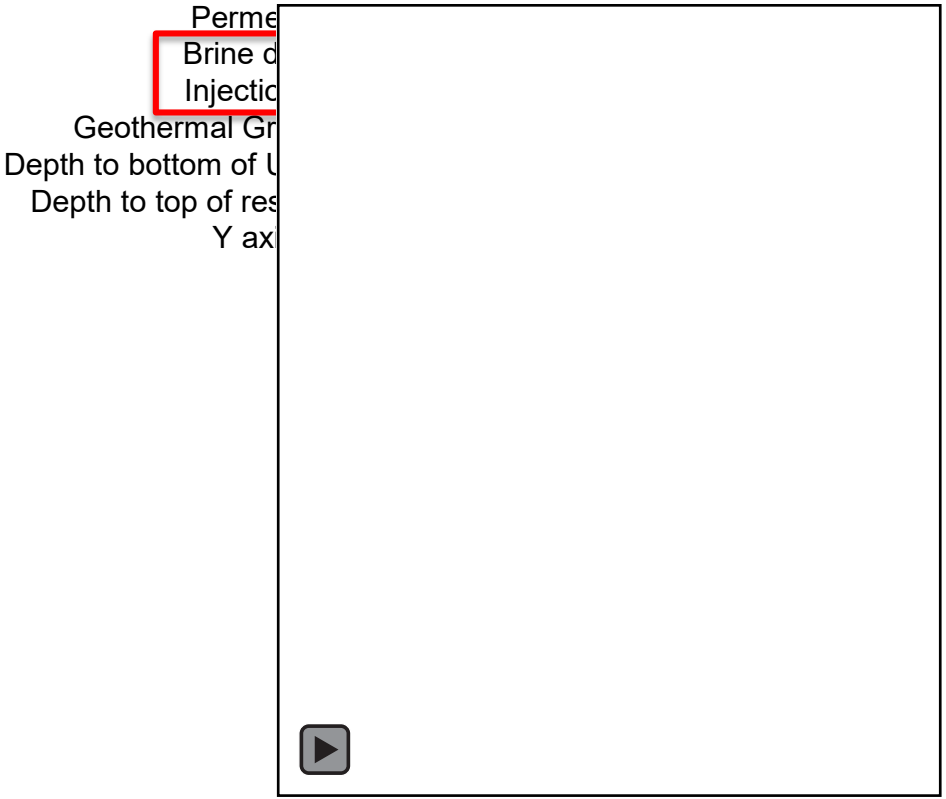
Extraction of plume and pressure radii

- Plume radius extracted from the gas saturation output and critical pressure radius extracted from the pressure buildup output



- AoR = max(CO_2 plume radius, critical pressure radius) = max(2942, 8446) = 8446 m
- The AoR is hence pressure-dominated in this case.

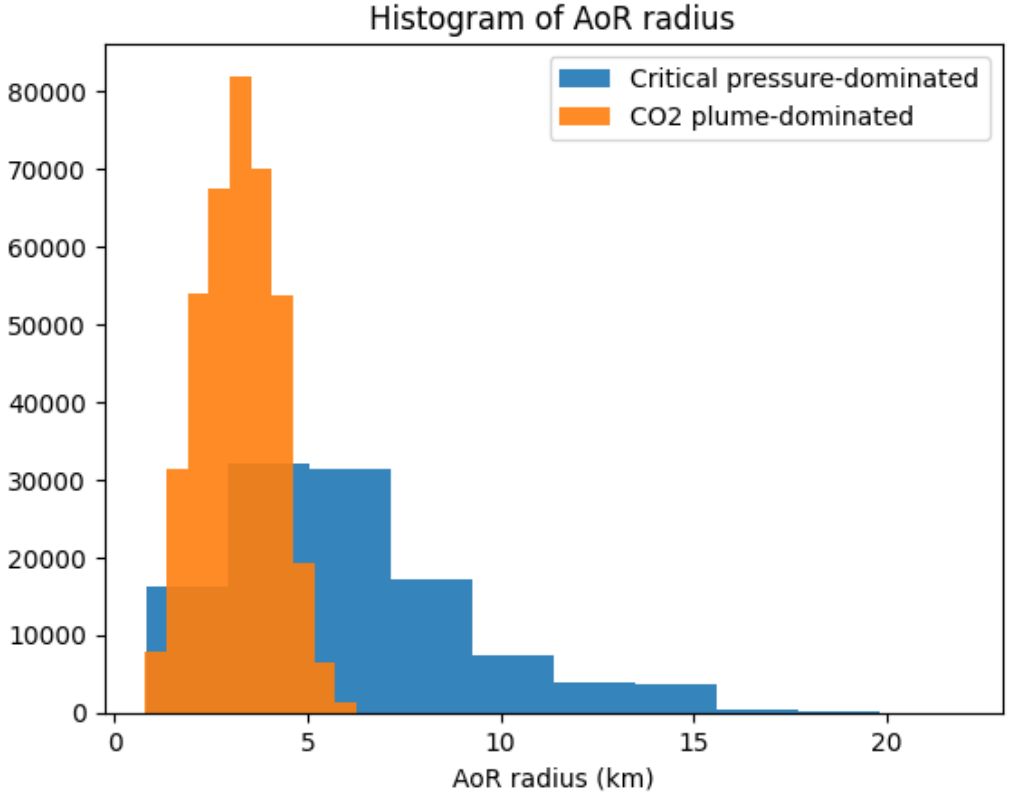
Results – parametric tool

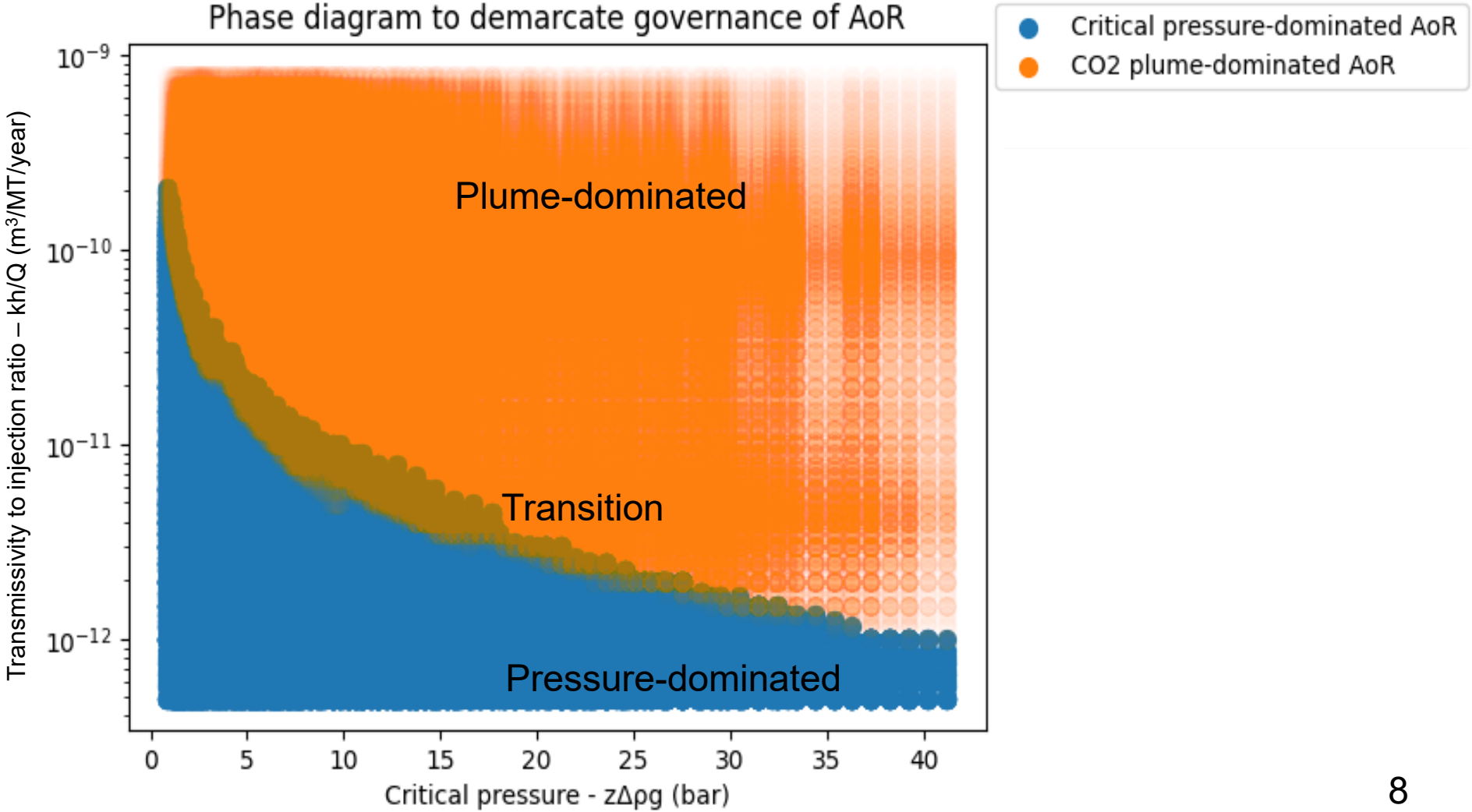


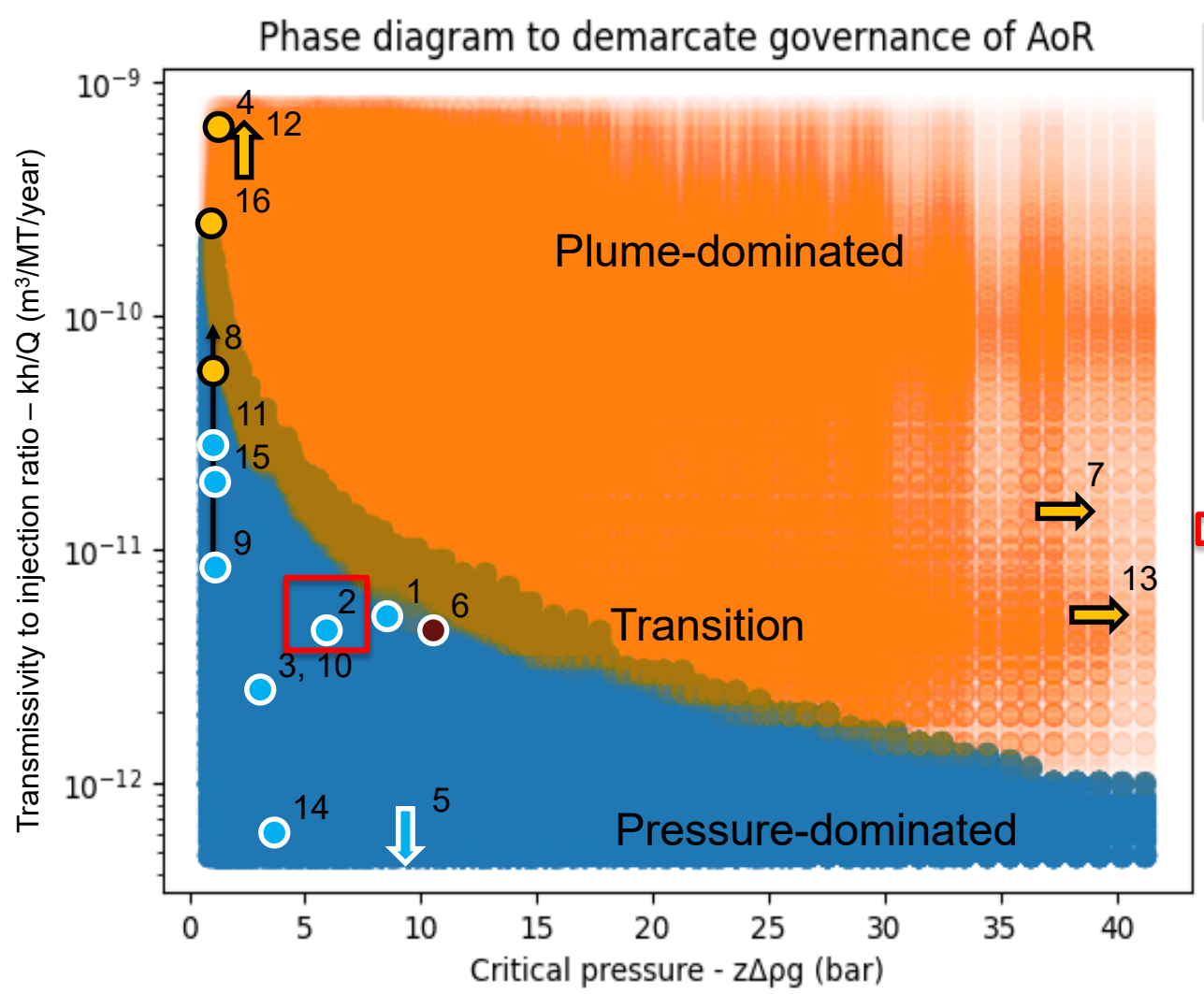
To minimize the radius of AoR, the following are preferred:

- Low injection rates
- Thick reservoirs
- Highly permeable reservoirs
- Highly saline aquifers
- A large vertical separation between the USDW and reservoir

Pressure-dominated AoR projects affect larger land areas!




Phase diagram to demarcate governance of AoR
Critical pressure-dominated AoR
CO2 plume-dominated AoR
Plume-dominated
Transition
Pressure-dominated
Transmissivity to injection ratio – kh/Q (m³/MT/year)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
0
5
10
15
20
25
30
35
40
Critical pressure - zΔρg (bar)



Critical pressure-dominated AoR
CO2 plume-dominated AoR

Critical pressure-dominated, as per permit

CO2 plume-dominated, as per permit

Combination, as per permit

Lies outside phase diagram

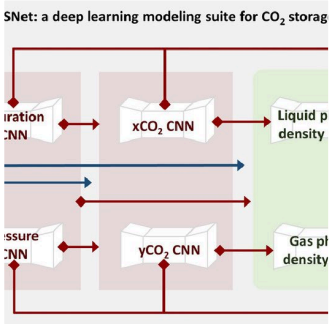
Projects:
1 HGCS LLC, Vervain
2 Archer Daniel Midland Decatur Campus
3 Lorain Carbon Zero Solutions LLC
4 Wabash Carbon Services
5 HGCS LLC, Christian County
6 Oxy Low Carbon Ventures LLC, Brown Pelican
7 CTV I LLC: Elk Hills A1-A2
8 CTV I LLC: Elk Hills 26R
9 CTV Holdings: CTV III
10 Aera Energy LLC: CarbonFrontier
11 Montezuma NorCal CarbonSequestration Hub
12 Chevron USA Inc, Kern River Eastridge CCS
13 Tallgrass: Eastern Wyoming Sequestration Hub
14 Frontier Carbon Solutions
15 Casper Carbon Storage
16 Red Trail Energy, LLC

HGCS – Heartland Greenway Carbon Storage
CTV – Carbon TerraVault

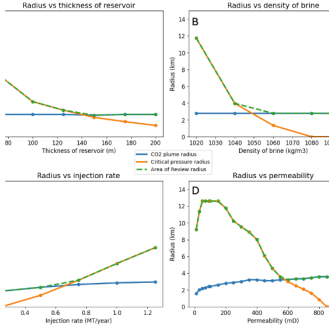
Summary

Backend API of deep-learning based modeling tool used to run ~500k trials

CCSNet



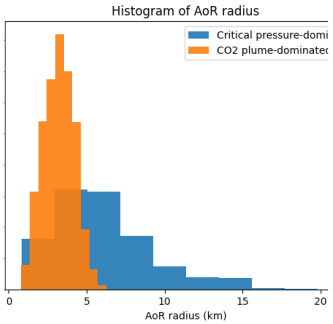
Parametric Tool



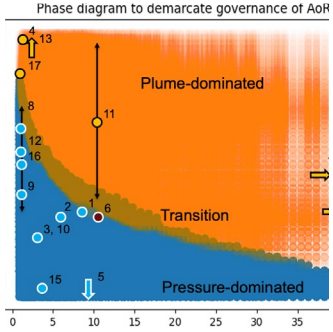
Parametric slider-based tool developed to plot AoR radius versus thickness, brine density, injection rate, permeability etc.

Histogram shows range of AoR radii for both CO_2 plume and pressure-dominated cases

AoR Histogram



Phase Diagram



Phase diagram developed for rapid determination of governance of AoR