Illinois Storage Corridor – Enhanced Framework for Monitoring and History Matching

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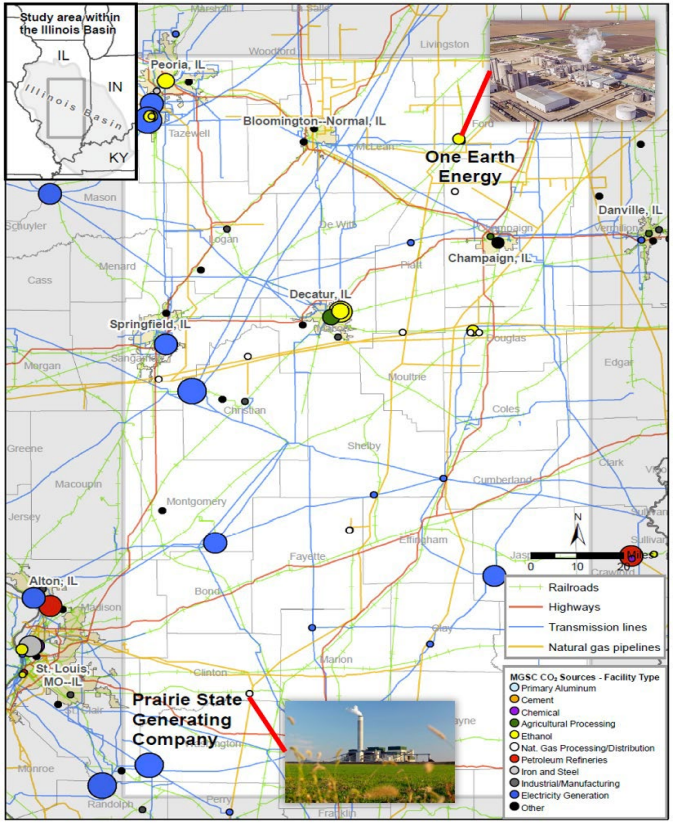
Stanford | Doerr School of Sustainability | Stanford Center for Carbon Storage

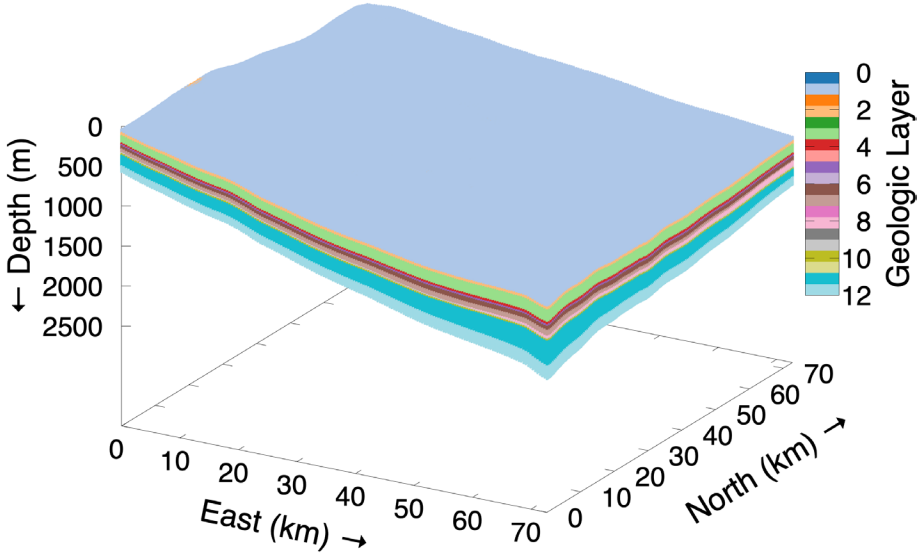
Illinois Storage Corridor: ISC



- ISC project:
  - Mitigate CO_2 emissions in Illinois
  - Acceleration of commercial CCUS
  - Region with proven storage performance
- Prairie State Generating Company (PSGC)
  - Coal-fired power plant
- One Earth Energy (OEE)
  - Ethanol production plant
- Acquire Class VI injection permits for both sites
  - Through submission to the EPA

Geology of Prairie State Site

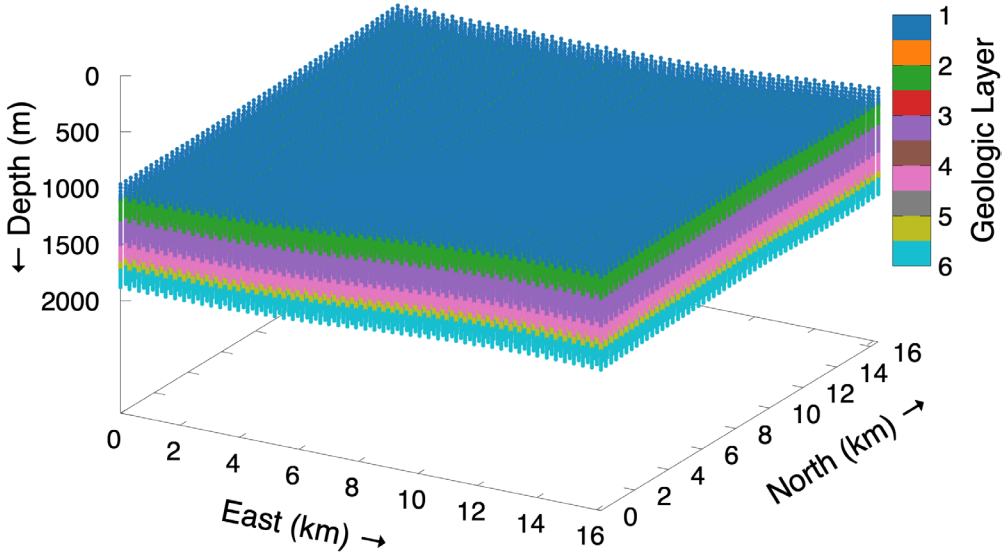
Prairie State Reservoir Model



Layer Number	Geologic Unit
1	**Maqueketa Shale**
2	**Trenton**
3	**Platteville**
4	**Upper Joachim**
5	**Lower Joachim**
6*	**St. Peter**
7	**Everton Dolomite**
8*	**Everton Sandstone**
9	**Upper Shakopee**
10	**Middle Shakopee**
11	**Lower Shakopee**
12	**Oneota**

Geology of One Earth Energy Site

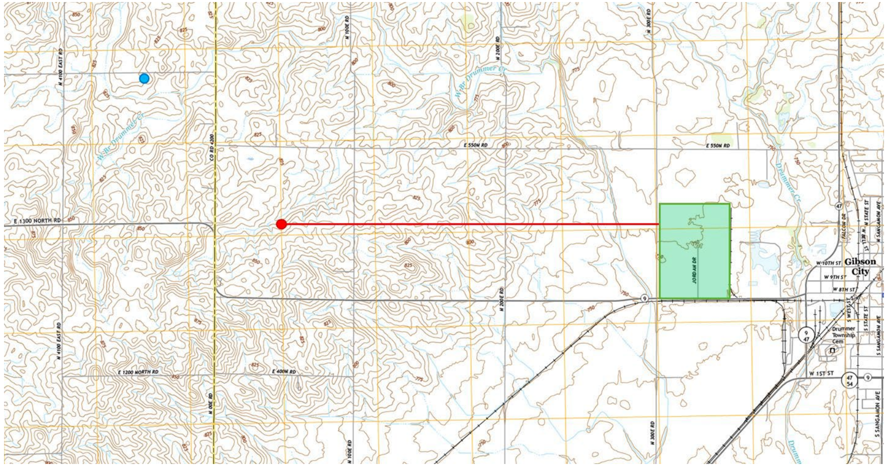
One Earth Energy Reservoir Model



Layer Number	Geologic Unit
1	Eau Clair Shale
2	Upper Mt. Simon
3	Middle Mt. Simon
4	Lower Mt. Simon
5*	Arkosic Zone
6	Argenta

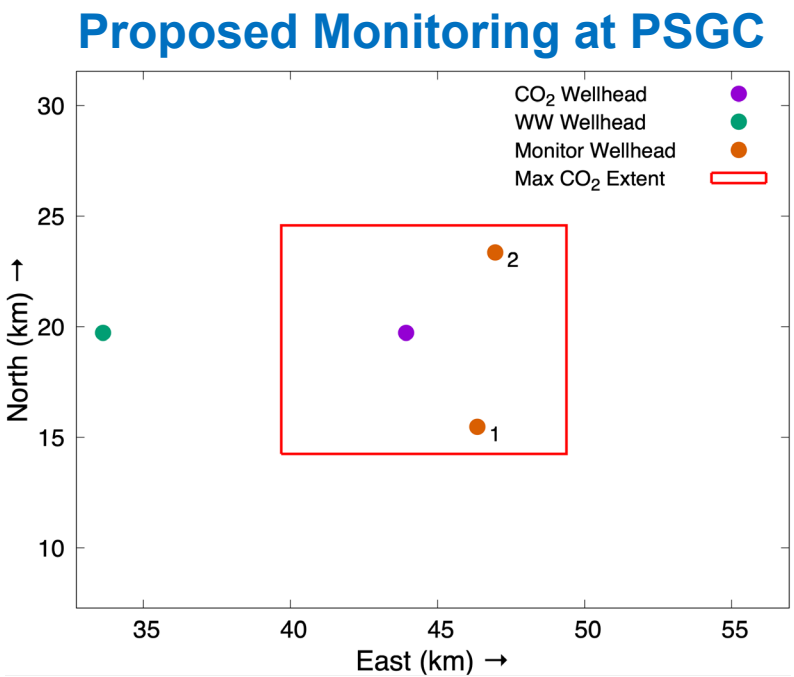
CO_2 Injection Plan

Pipeline for PSGC Site



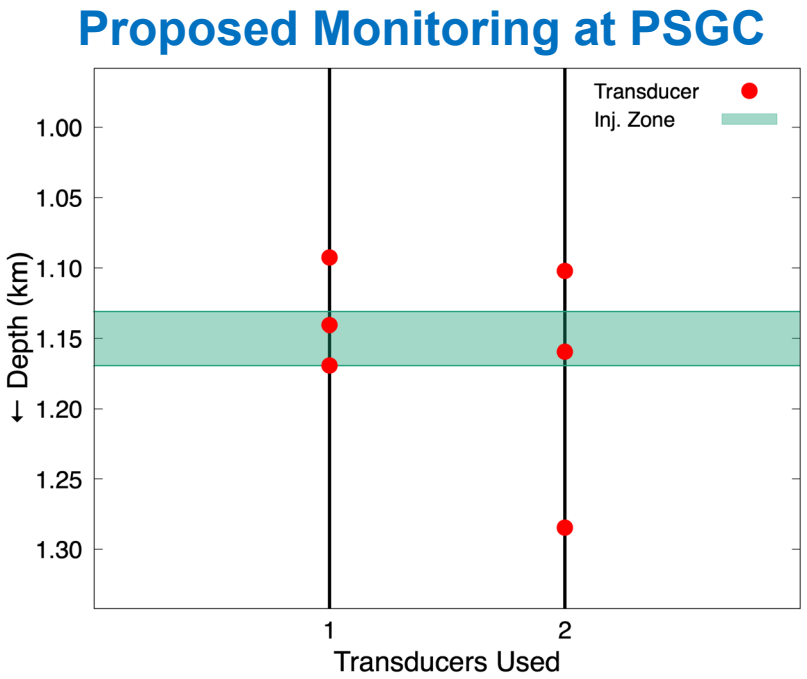
- PSGC injection
  - Inject around 1 Mt/year
  - Two horizontal injection wells
  - Single wellhead
- OEE injection
  - Initially ~0.5 Mt/year
  - Goal is to be a hub: 4.5 Mt/year
  - Multiple planned injection wells
- CO_2 transportation
  - Both sites will utilize pipelines
  - Buried 5 ft below the surface

Monitoring Plan



- Time-lapse 2D seismic
- Above-zone wells (AZM)
  - Above confinement shale
  - Fluid sampling
  - Temperature sensing
- In-zone wells (IZM)
  - Yearly saturation logging
  - Pressure transducers
- OEE will begin with one IZM
  - Expand after 5 years

Monitoring Plan



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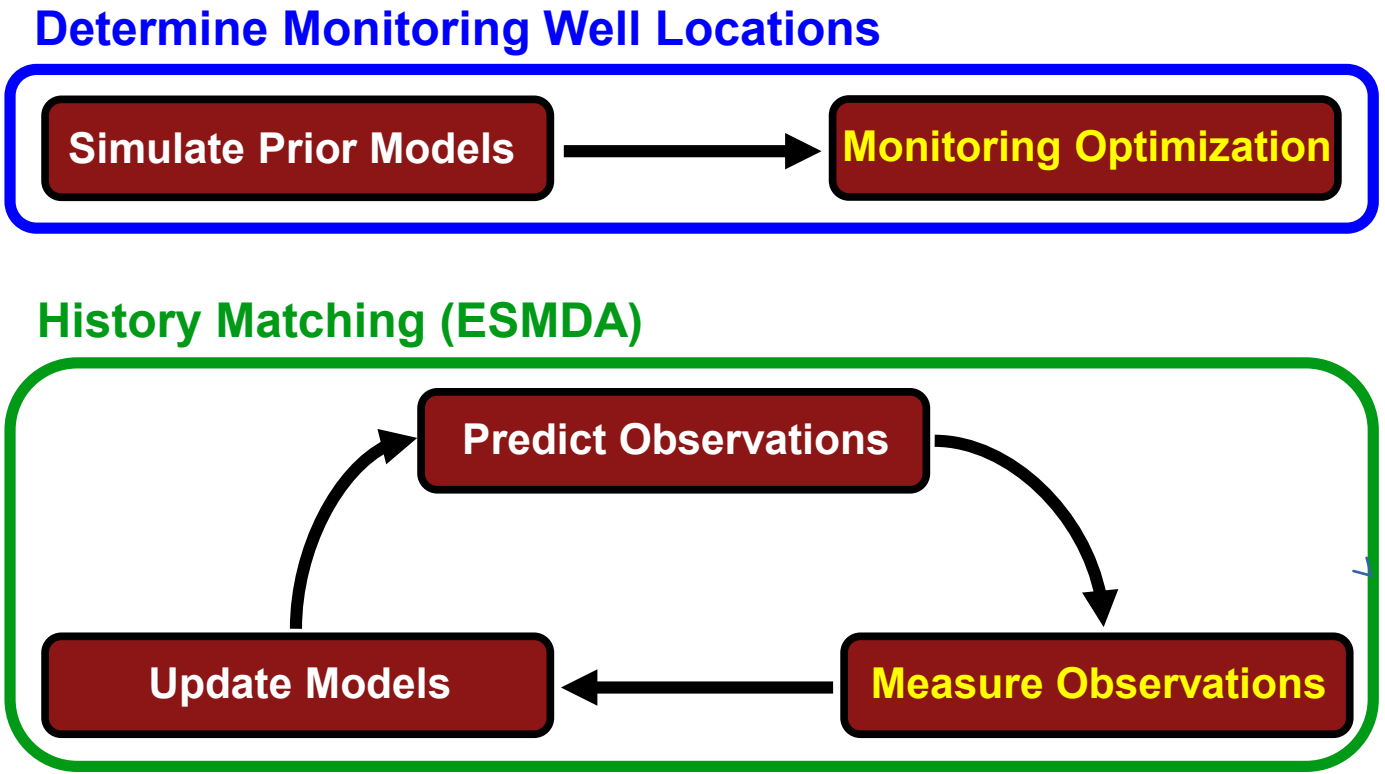
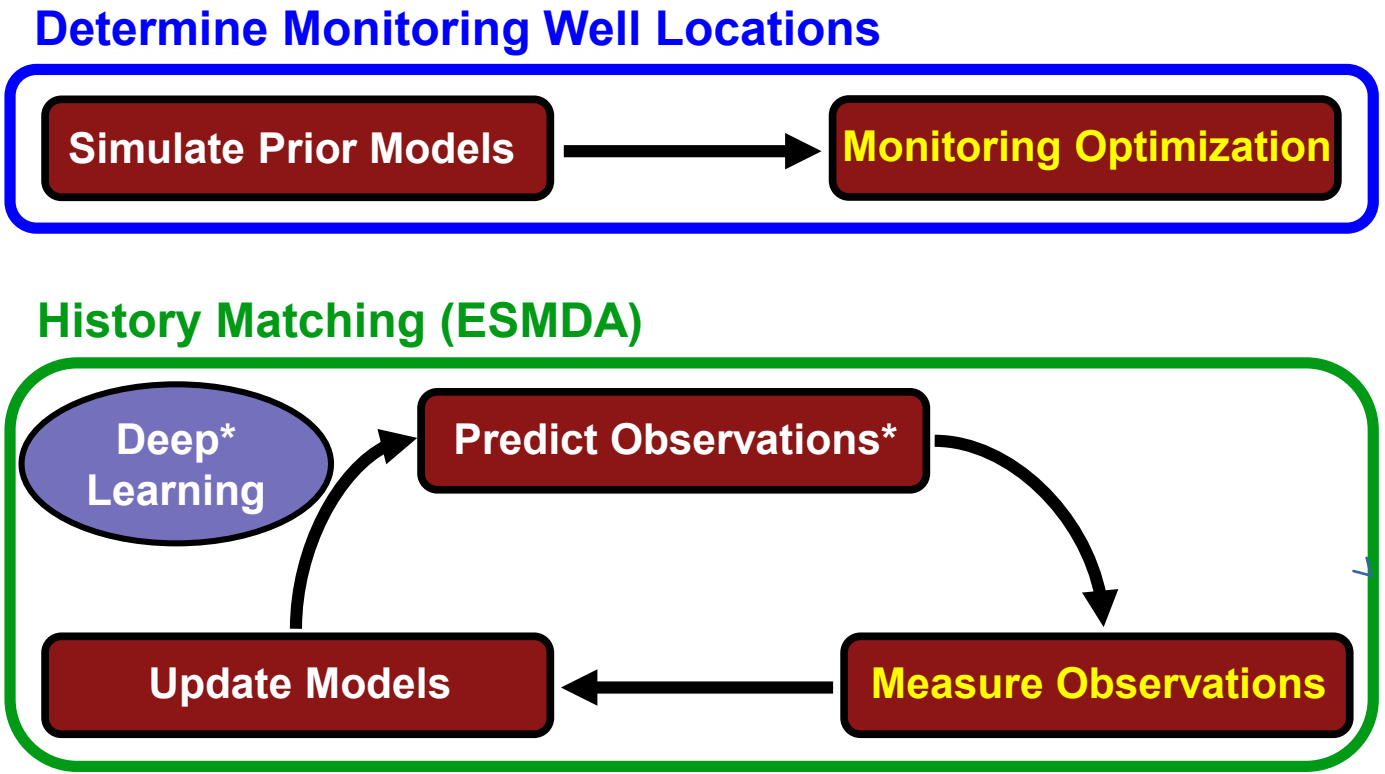
Framework Workflow

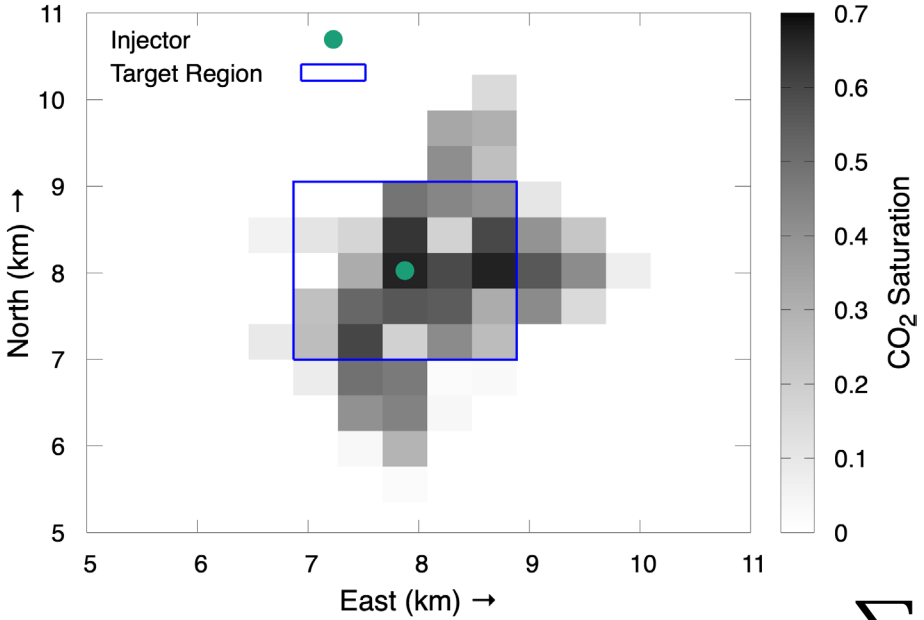


Framework Workflow

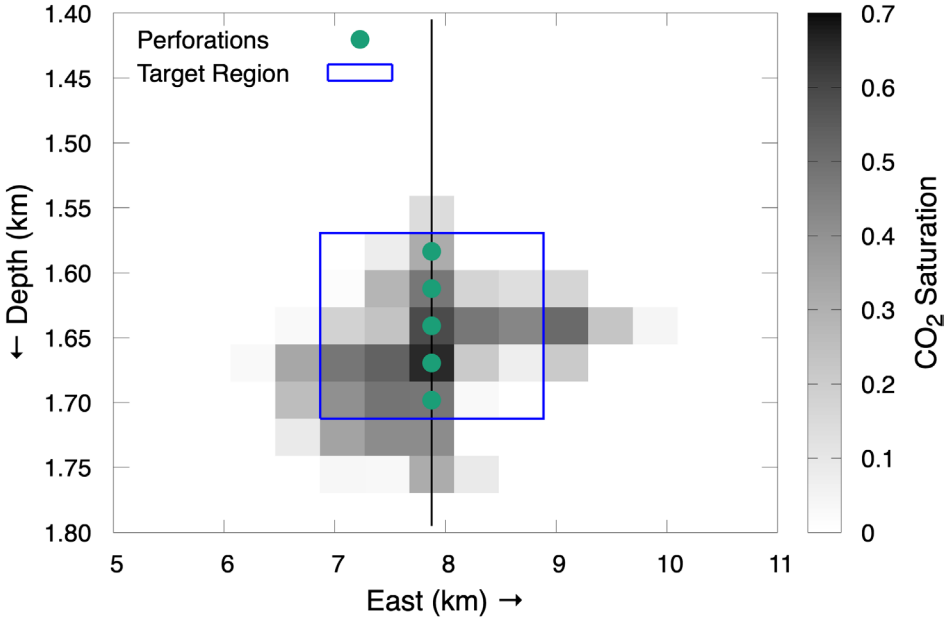


Quantity of Interest: J

Overhead View



Side View

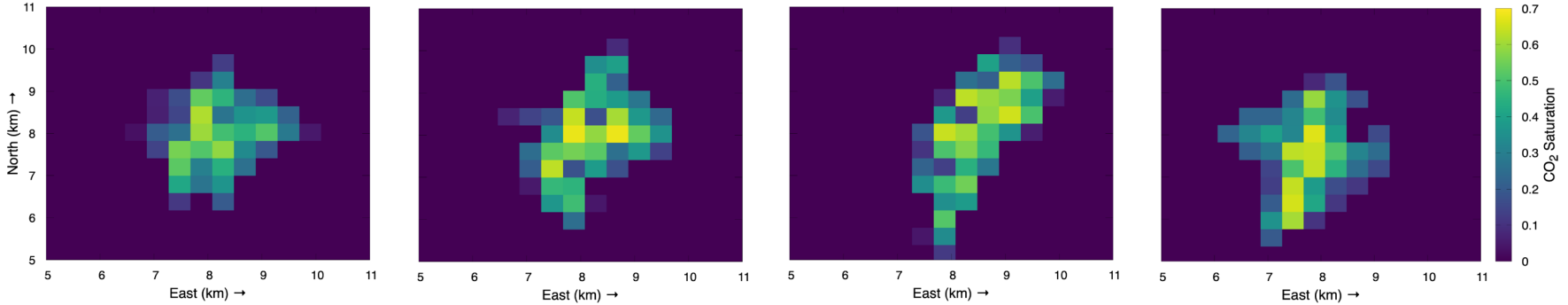


$$J = \sum_{i \notin TR} v_i \, \phi_i S_i$$

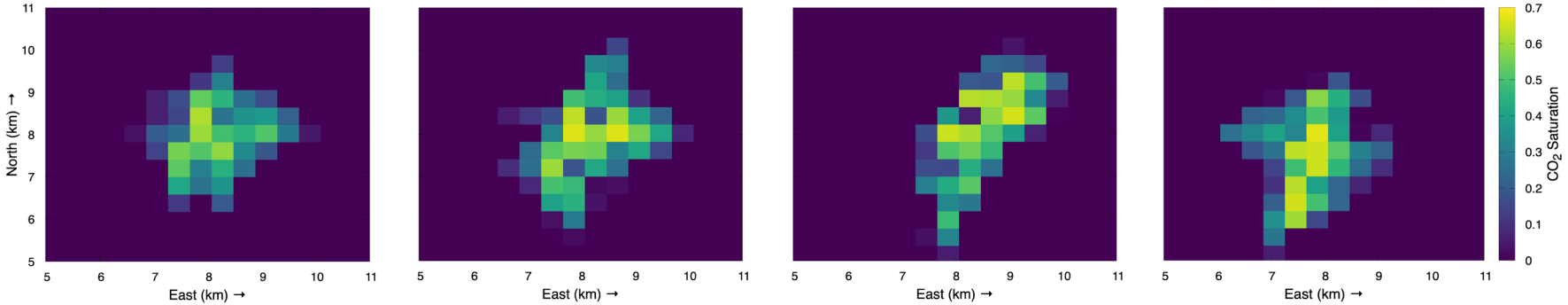
Deep Learning Enhancement: Overhead View

DL Predictions

*DL model by Yifu Han



Simulation Results



History Matching with Localization

ESMDA Algorithm

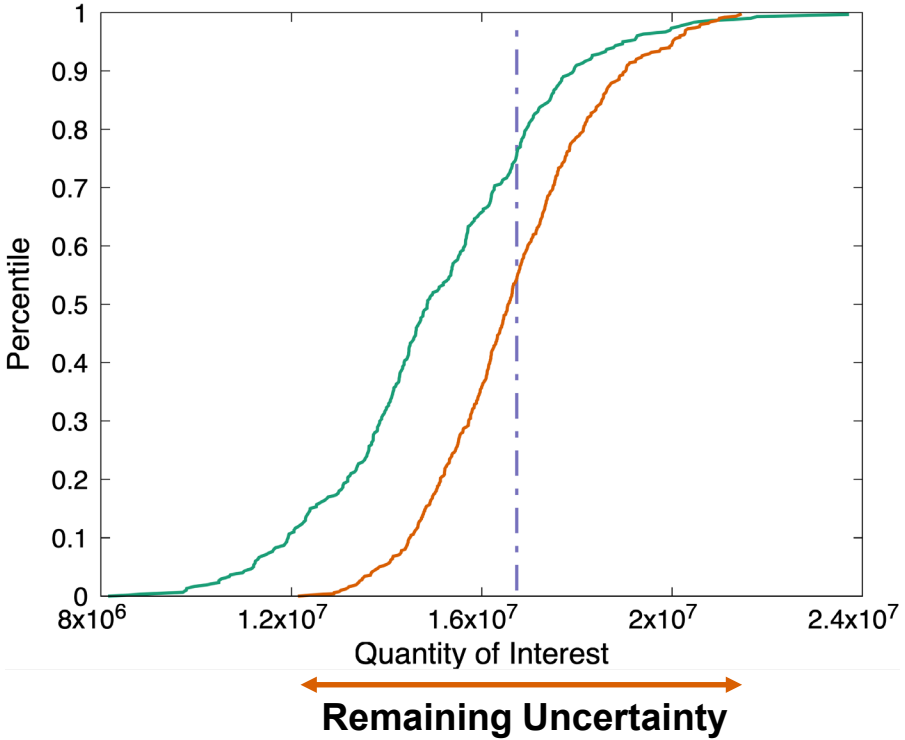
1. Define number of assimilation steps N_a & coefficients α_i
2. For $i = 1 \ldots N_a$
   a) Simulate the ensemble
   b) Perturb observations: $\mathbf{d}'_{obs} = \mathbf{d}_{obs} + \sqrt{\alpha_i} C_D^{1/2} \mathbf{z_d}$
   c) Update model parameters: $m_f^j + C_{md_h}^f \left(C_{d_h d_h}^f - \alpha_j C_D \right)^{-1} \left(\mathbf{d}'_{obs,j} - \mathbf{d_{h,j}} \right)$

Localization

- Anomalous behavior occurs in some cases (small ensemble size, low errors)
- Can be prevented using localization (here with the Gaspari-Cohn function)
- Update only geomodel properties that are “close” to observations

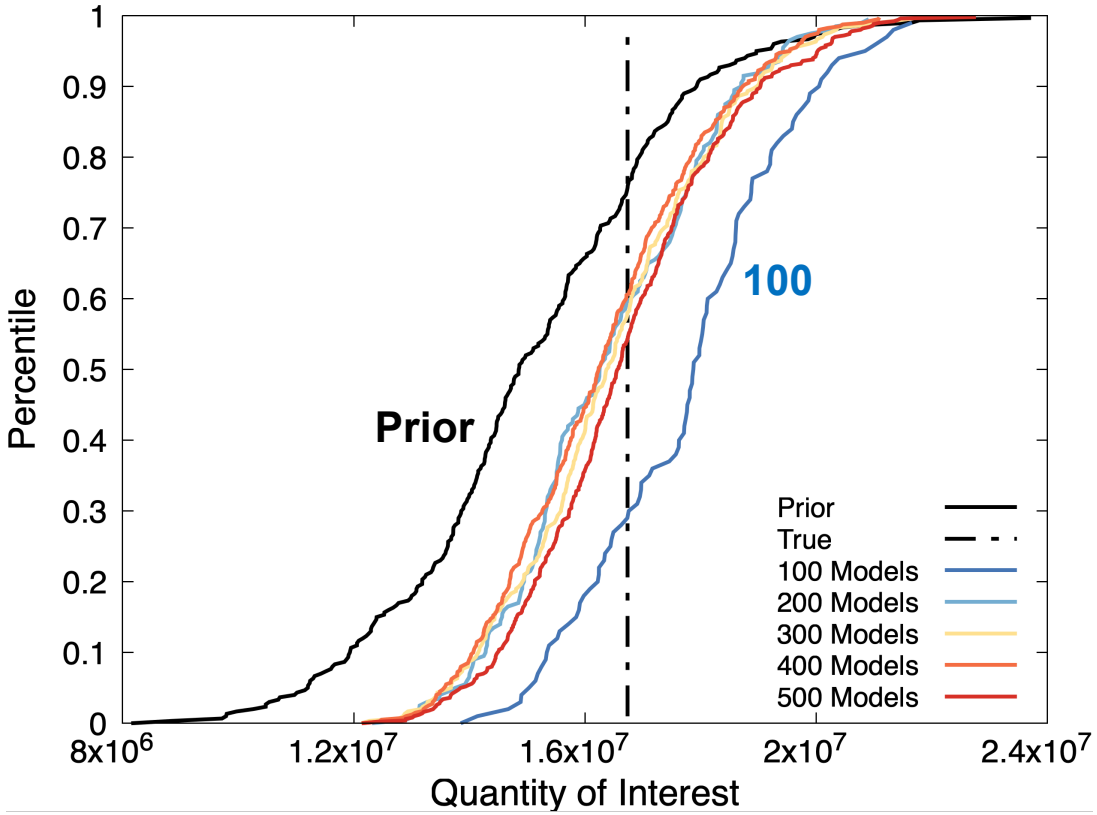
Posterior Uncertainty Reduction

History Matching for Optimal Monitoring

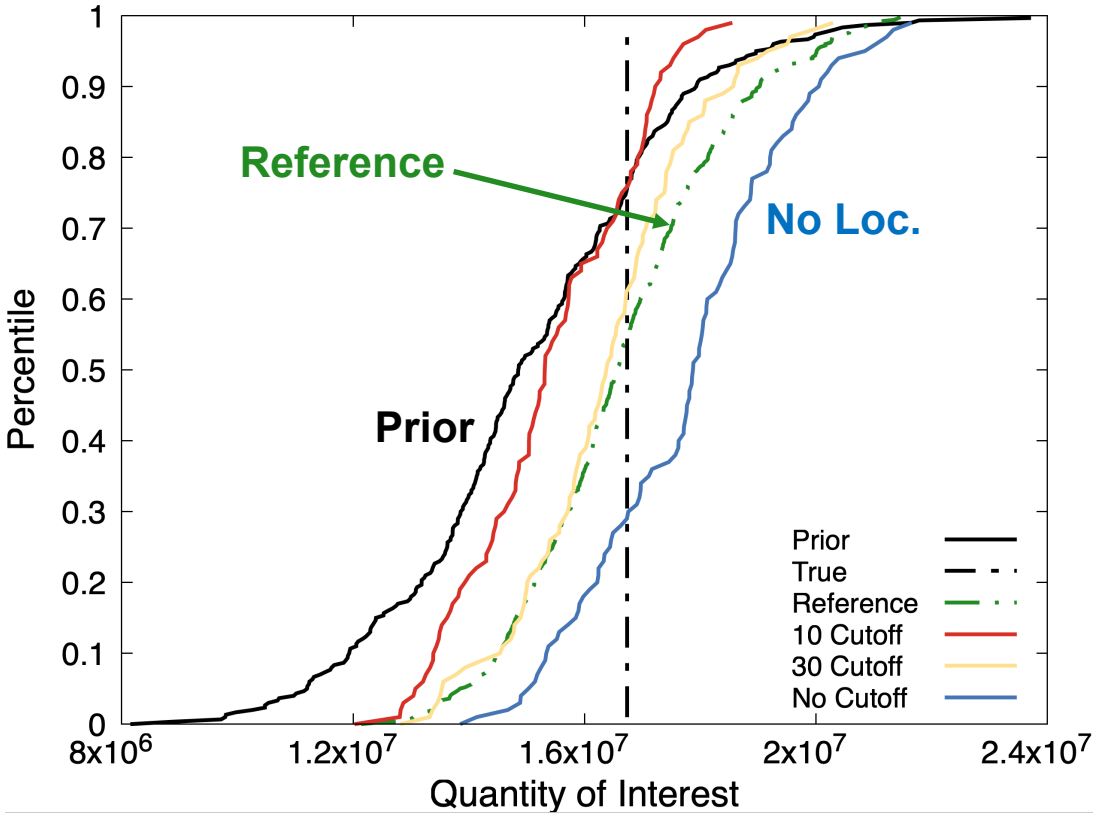


- **Green curve**:
  - Prior distribution (CDF)
- **Orange curve**:
  - History matched posterior
  - Determined from optimization
  - ESMDA used for history matching
- **Purple line**:
  - True model value for J
  - Source of data for monitoring

Varying Ensemble Size



Varying Localization Cutoffs with 100 Models



Summary and Future Work

Summary

- Framework developed to optimally monitor and history match CCUS fields
- Provided recommendations for in-zone monitoring wells in ISC project
- Extended the framework with a deep learning architecture
- Enhanced ESMDA through parameter exploration (using DL model)

Future work

- Continue to investigate ESMDA with differing localization techniques
- Assess treatments to avoid ensemble collapse

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