Adaptive, Risk-Based Monitoring Design for Risk Management

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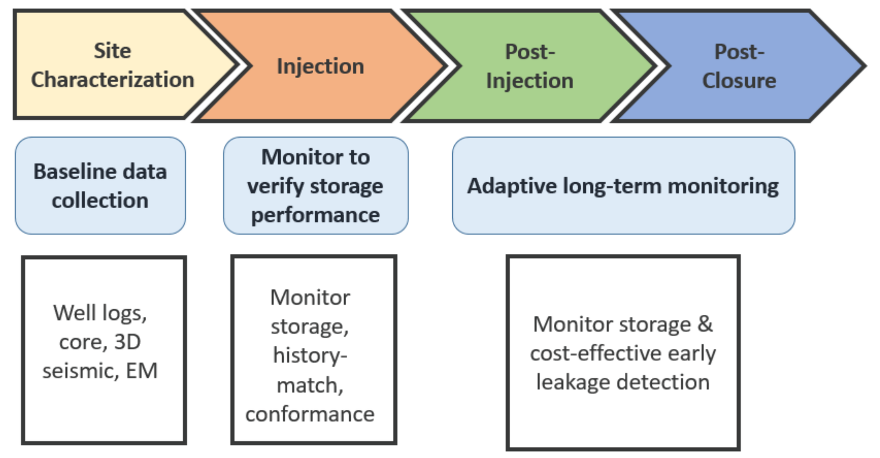
ABSTRACT

Geologic Carbon Storage (GCS) is a viable option for storing unwanted CO_2 in the subsurface. For this process to be widely established, it is necessary to monitor and confirm that the injected CO_2 stays where it was intended. Effective monitoring network design is not a one-size-fits-all problem. The selection of monitoring technologies depends on the monitoring objective. Geophysical methods provide valuable information about subsurface changes, especially when large areas need to be monitored or when direct measurements are impossible or not cost effective. Understanding the techniques' ability to identify unwanted changes in the system is important for choosing appropriate system monitoring to ensure the protection of the environment and inform decision-making about risk acceptability and site closure requirements.

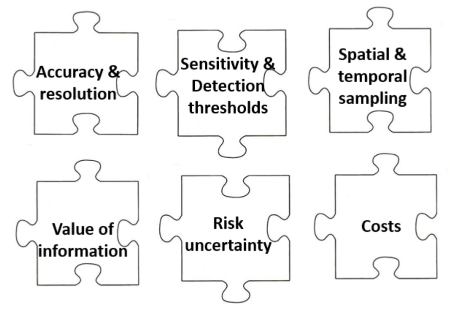
The driving forces in designing and evaluating the optimized geophysical monitoring plan are (1) containment assurance and possible unwanted CO_2 migration outside the main storage reservoir during the injection period, (2) cost-effective detection of possible unwanted CO_2 migration from the storage reservoir in the post-injection and post-closure phase, or both. Understanding the sensitivity and establishing detection thresholds of various geophysical methods is central to designing monitoring schemes. Due to cost considerations, especially for long-term monitoring, less expensive techniques play a role when designing monitoring networks. A site risk assessment would identify areas where monitoring costs would be less than possible mitigation liabilities from an unwanted event or public assurance. We illustrate how complementary techniques could be used in a cost-effective monitoring design using a scenario of GCS in brine-bearing formations and seismic, gravity, and electromagnetic methods.

APPROACH

CCS Site Monitoring

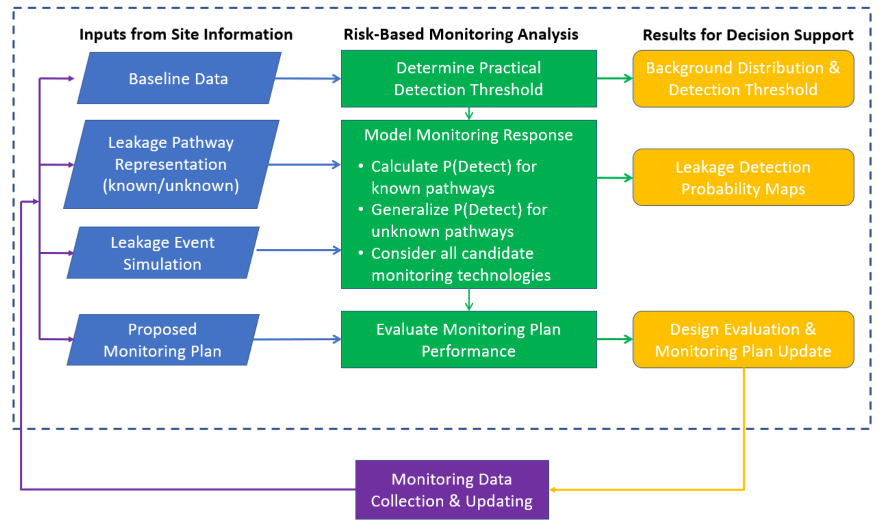


Factors influencing a monitoring design

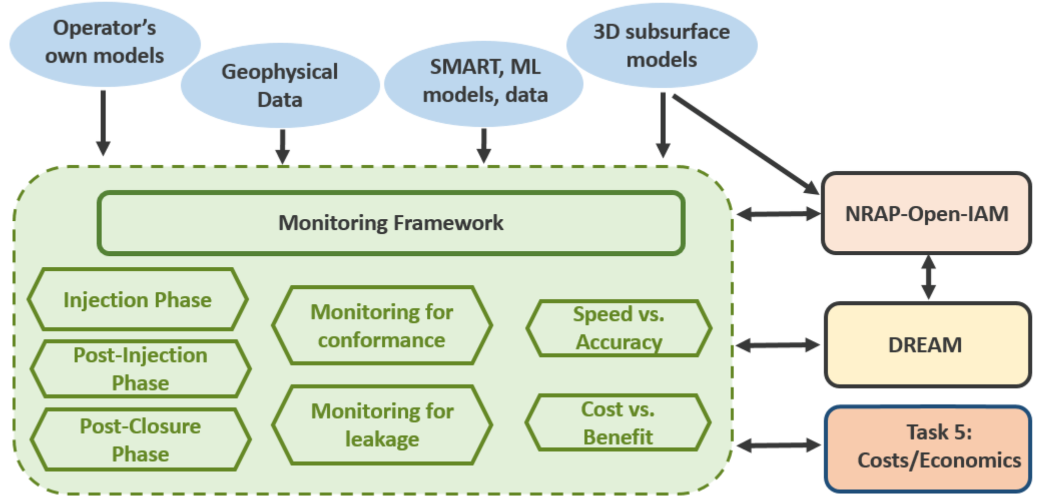


- Explicit computational framework employing a probabilistic workflow for risk-based monitoring design
- Informed decision making regarding the trade-off between detection probability and spatial/temporal network density
- A better understanding of the ability of the monitoring techniques to identify unwanted changes in the system for:
  (1) decision making about appropriate system monitoring to ensure the protection of health and the environment
  (2) decision making about risk acceptability and site closure requirements

NRAP Recommended Practices for Containment Assurance and Leakage Risk Quantification

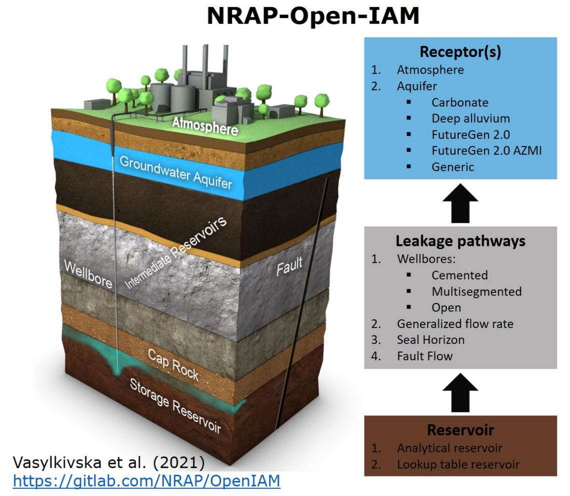


Simplified representation of steps involved in risk-based monitoring design, analysis, design evaluation, and updating (modified from Yang et al., 2018).



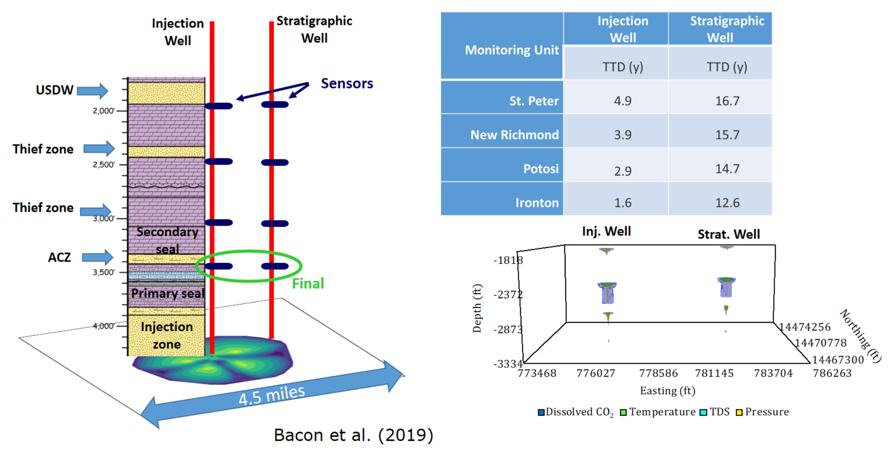
Leveraging NRAP, SMART, and other existing models and computational tools

NRAP-Open-IAM



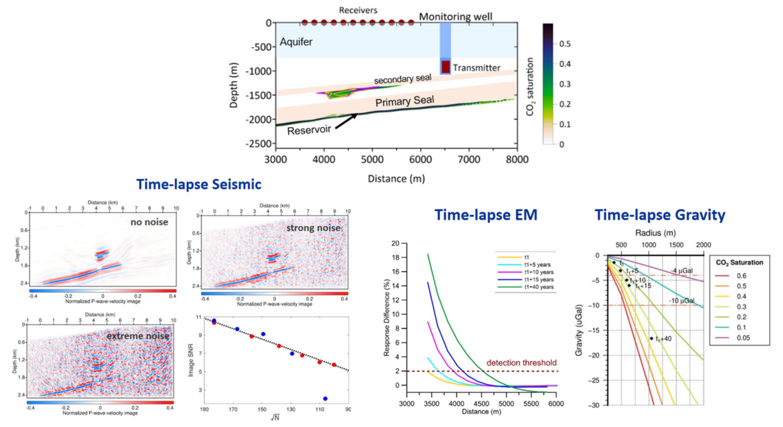
Vasylkivska et al. (2021)
https://gitlab.com/NRAP/OpenIAM

FutureGen 2.0 – DREAM – Time to detection



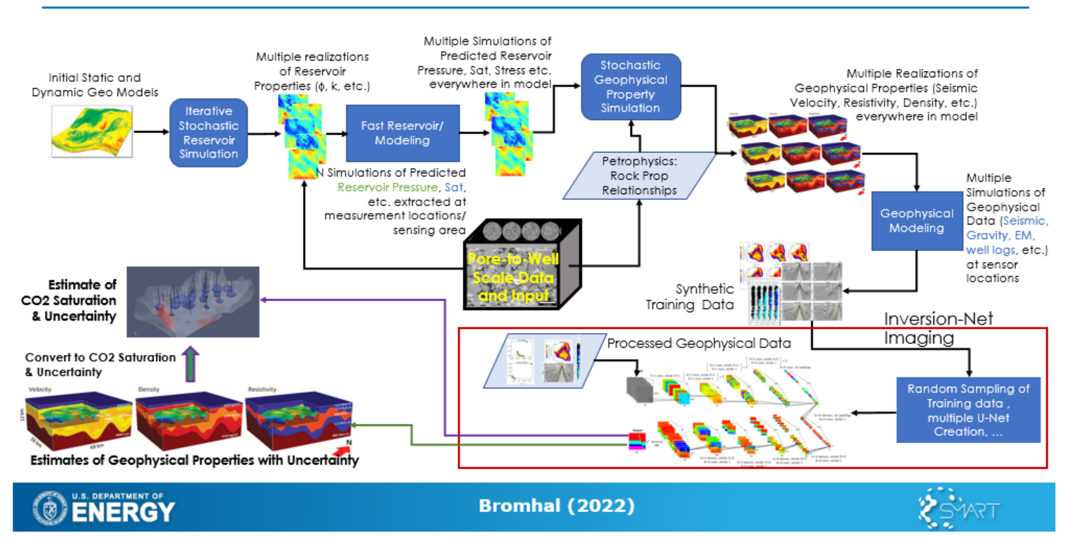
Bacon et al. (2019)

Sensitivity and Detection Thresholds

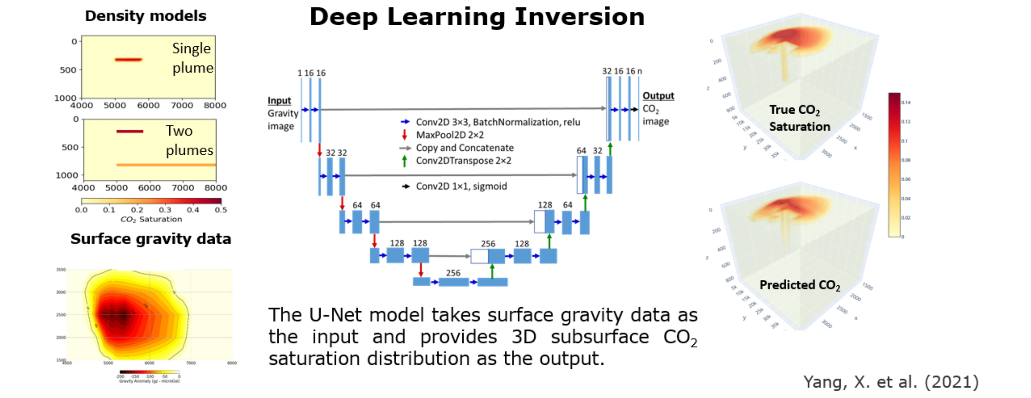


Feng et al. (2022) Gasperikova et al. (2022)

Neural-Net Workflow for Well-to-Field Scale Visualization

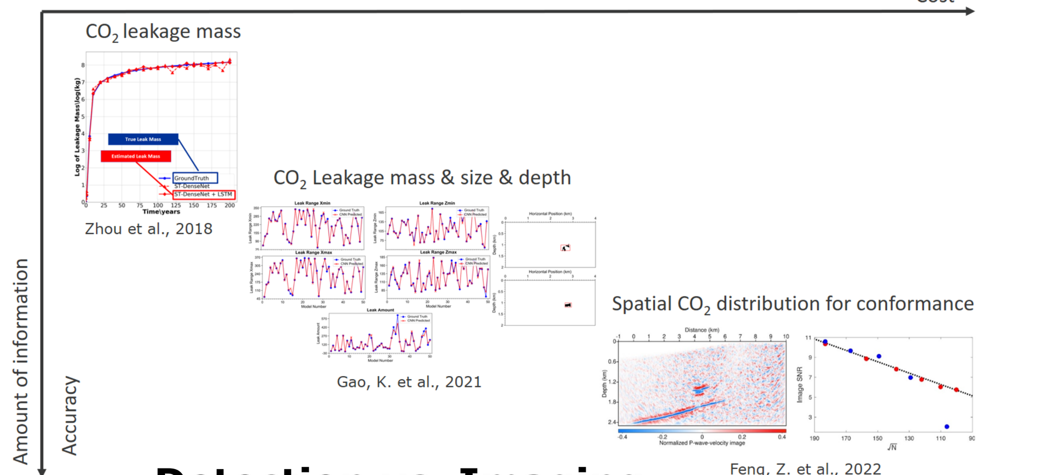


Deep Learning Inversion



The U-Net model takes surface gravity data as the input and provides 3D subsurface CO_2 saturation distribution as the output.

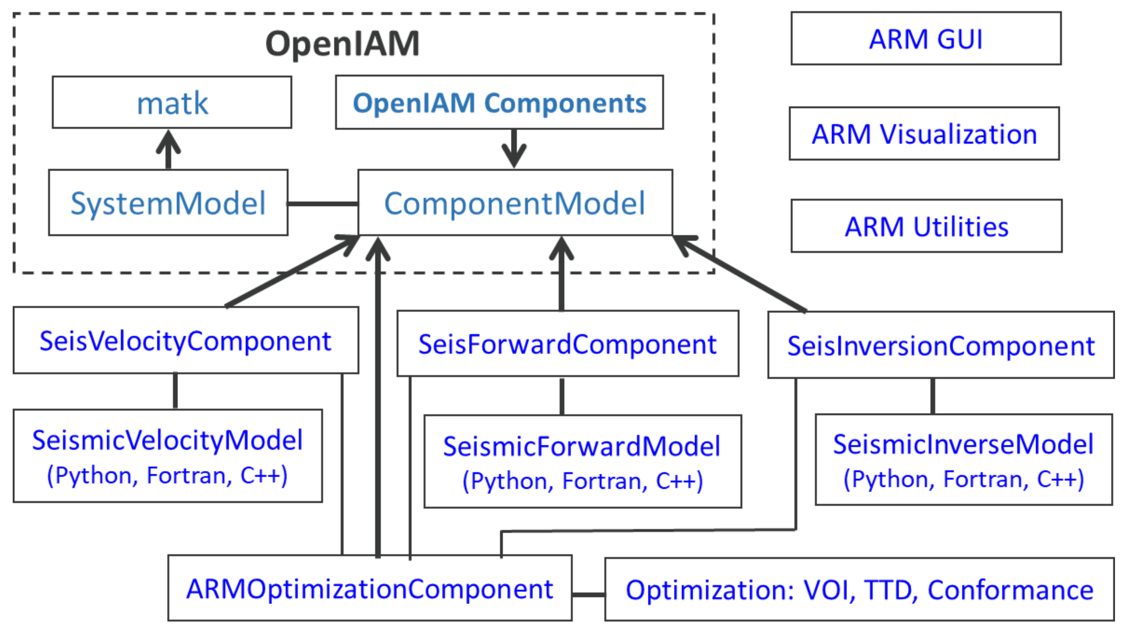
Yang, X. et al. (2021)



Detection vs. Imaging

An adaptive risk-based monitoring (ARM) design workflow

- A modular, open-source, extendable, risk-based monitoring design framework that leverages OpenIAM component model framework
- Accommodating practical considerations for monitoring deployment, data/information of disparate types and dimensionality, and uncertainty
- Accommodating known and unknown leakage pathways
- Adaptive for injection and post-injection periods



- The framework development in Python and support of modeling codes in other languages
- Lightweight GUI in Python tkinter
- Execution control file for custom processing workflow in YAML
- Adapting optimization algorithms from DREAM
- Cost and benefit (liability) data from NRAP Task 5

Monitoring for leak detection:
- Leak detection (Yes/No)
- Leak location (CO_2 plume imaging)
- The likelihood of leak detection for the proposed monitoring design
- Value of information (VOI) for the proposed monitoring design

Monitoring for conformance:
- Image CO_2 plumes in the reservoir
- Data for performance assessment of a CO_2 storage (requirements of all permits, laws and project plans)
- Data for assimilation and model calibration

ACKNOWLEDGMENTS

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