Task 4: Adaptive, Risk-Based Monitoring of Geologic Carbon Storage

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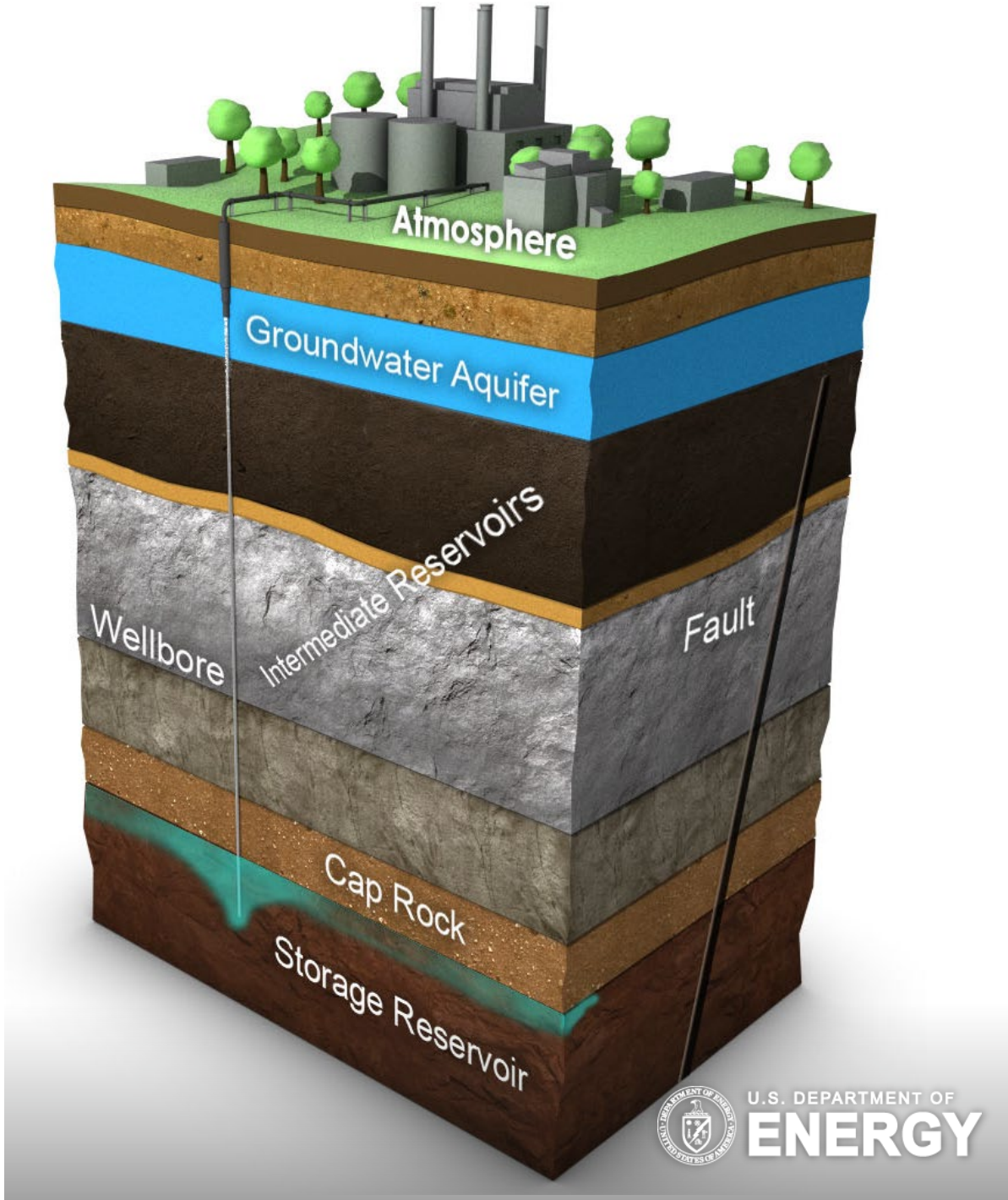
2023 FECM/NETL Carbon Management Research Project Review Meeting
August 28- September 1, 2023

NRAP
National Risk Assessment Partnership



NATIONAL ENERGY TECHNOLOGY LABORATORY
BERKELEY LAB
Lawrence Livermore National Laboratory
Los Alamos NATIONAL LABORATORY
Pacific Northwest NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY

Research Team

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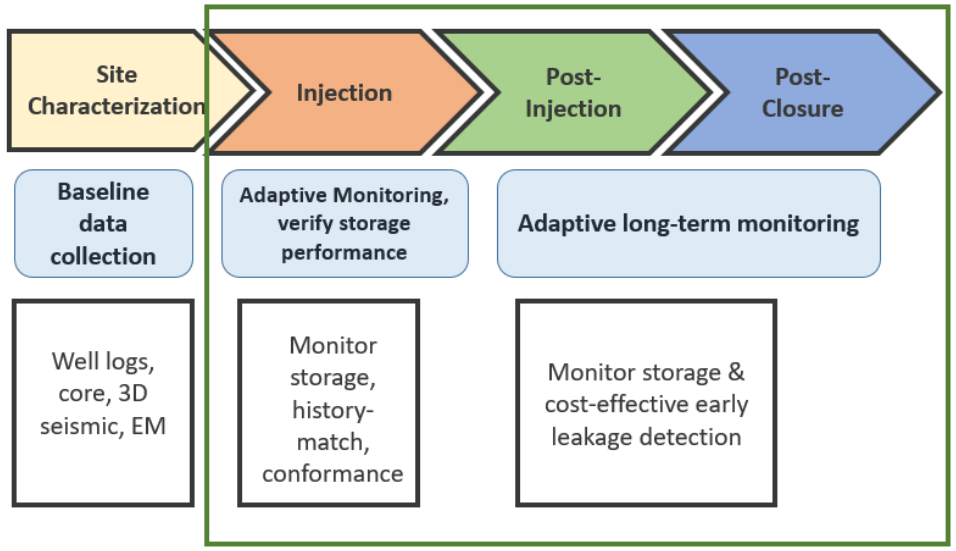
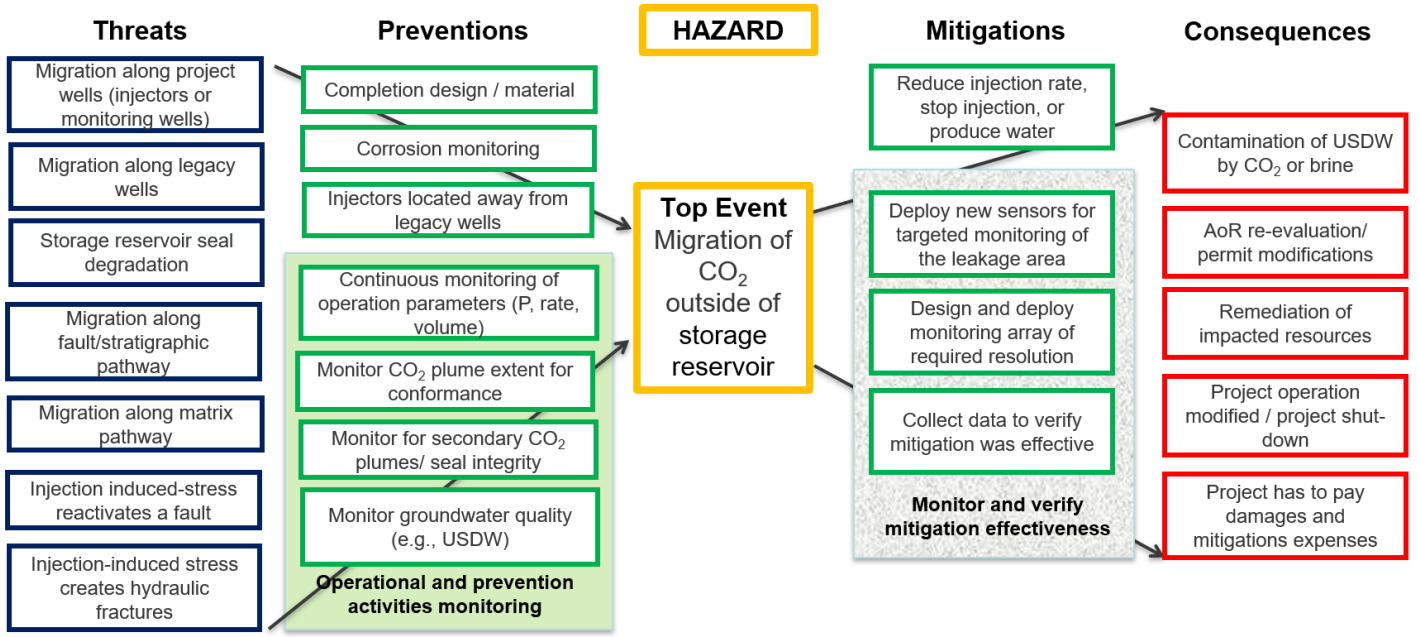
CCS Site Monitoring

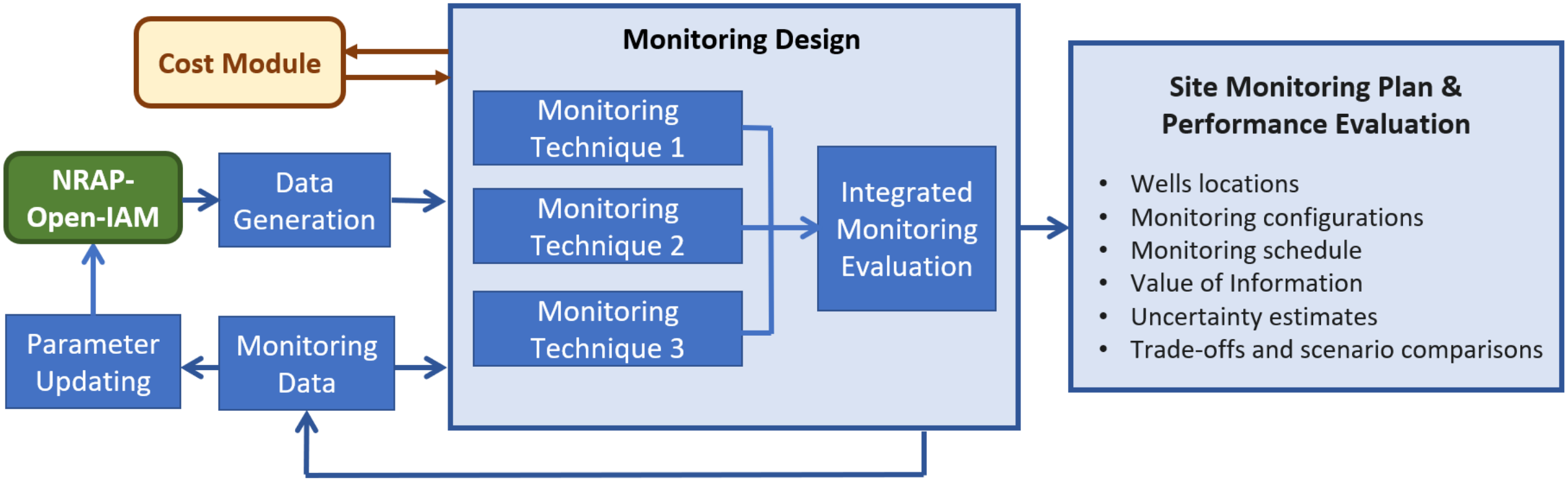


Focus on monitoring objectives in injection and post-injection phases



Value of monitoring within a bowtie risk assessment framework

Risk-based Adaptive Monitoring Plan (RAMP)

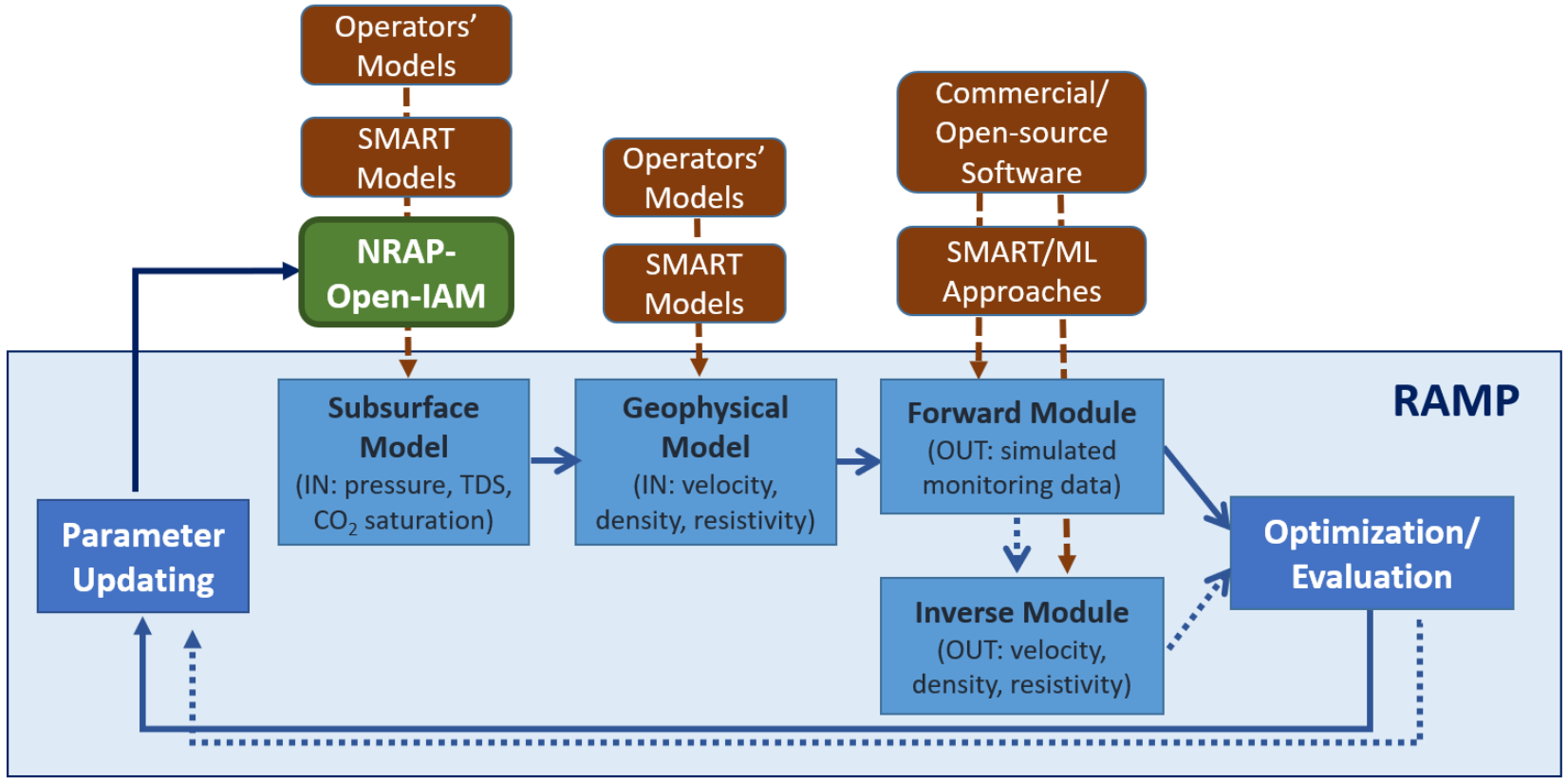


RAMP will allow the user **to assess multiple monitoring technologies** (downhole pressure, fluid geochemical sampling, indirect methods – seismic, gravity, electrical/electromagnetic) and their **combination**, **sensor configurations, monitoring intervals**, and select an **optimal site monitoring plan** based on the **main project objectives**.

RAMP

Goals:

- Reduce risk
- Improve confidence



What is unique and complementary to other CS-BIL programs:

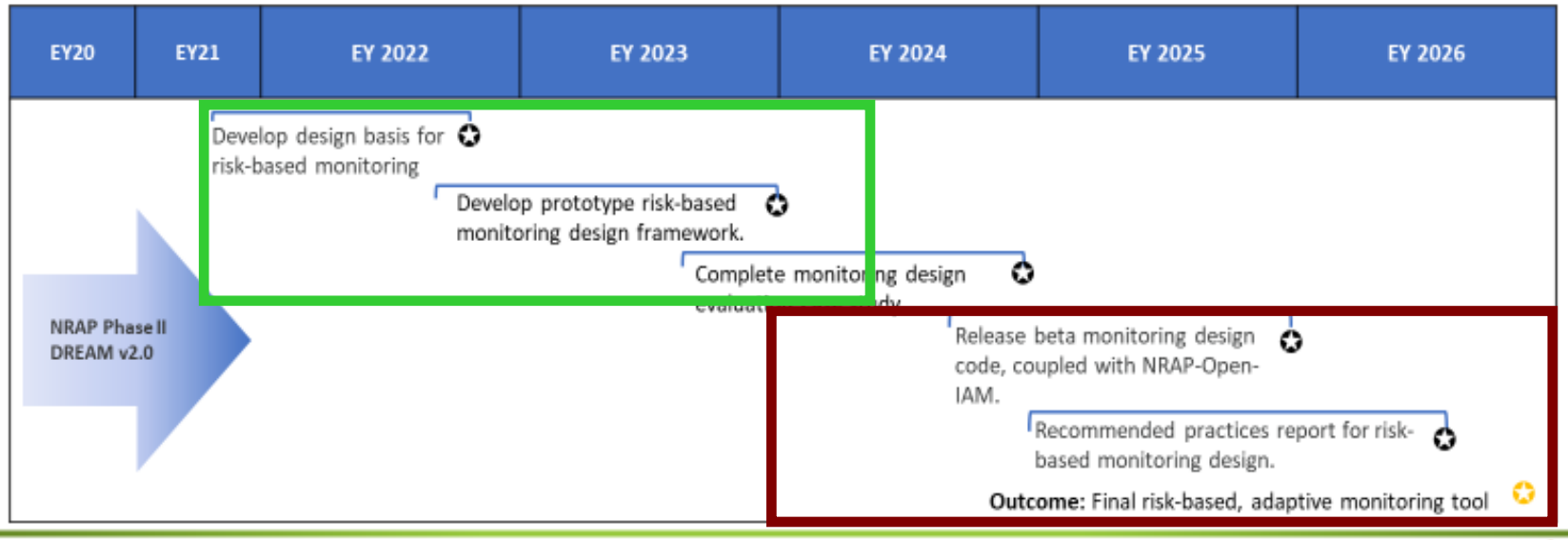
- Risk-based and adaptive with time
- Optimize monitoring configurations for NRAP Task 3 or SMART approaches
- Monitoring can detect features/issues not captured in AI/ML training
- Trade-offs between different monitoring scenarios

NRAP Phase III Plan

Technical Approaches & Prototype Framework

Task 4 Adaptive, Risk-Based Monitoring Design for Risk Management

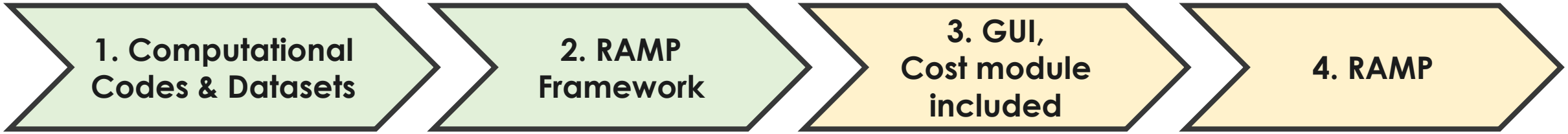
Objective To develop and demonstrate a practical computational framework and recommended practices for risk-based monitoring design at geologic-storage sites.



GUI, Case Studies & Final Tool

RAMP - Timeline

- Year 1 – Identify and collect codes and data sets required for RAMP development. Milestone: Design Basis Document - done
- Year 2 – Implement prototype RAMP framework and modify back-end codes – this presentation. Milestone: Beta version in April 2024
- Year 3 – Add GUI (use SMART visualization platform), link to Cost module (Task 5)
- Year 4 – Complete RAMP tool

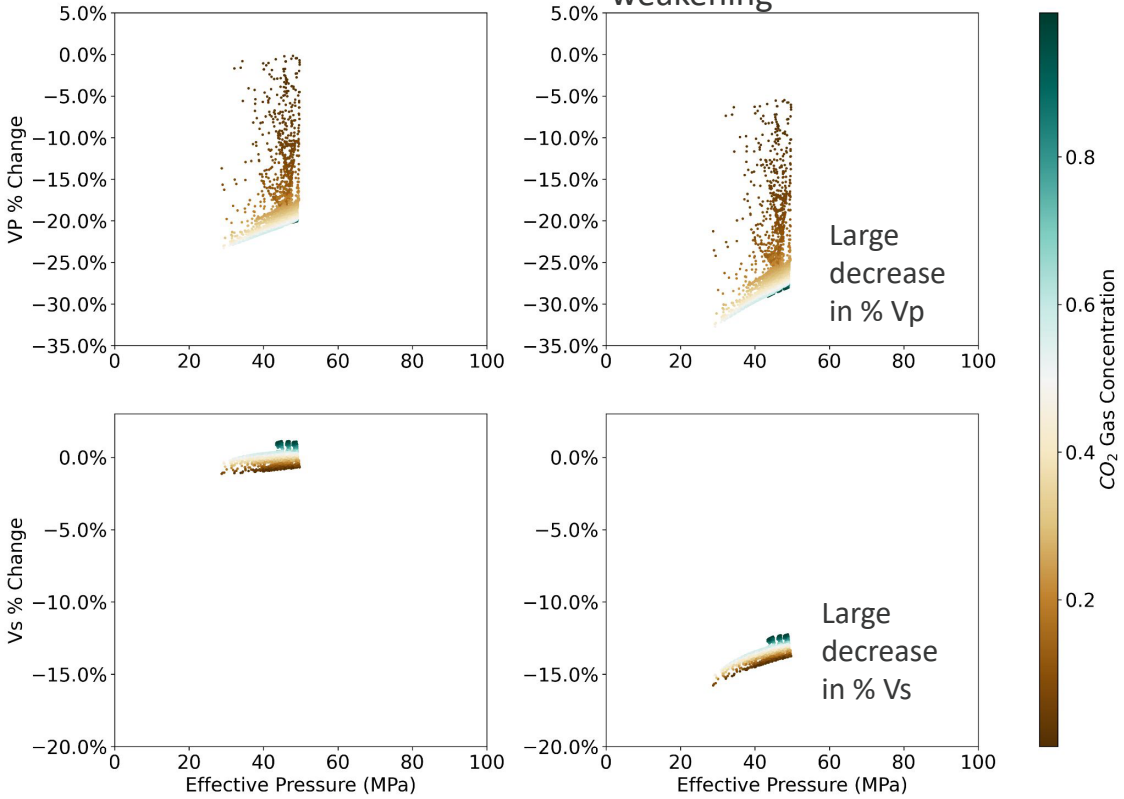


New addition to Back-end Codes

Improved rock-physics model
(Creasy et al., 2023, in review)

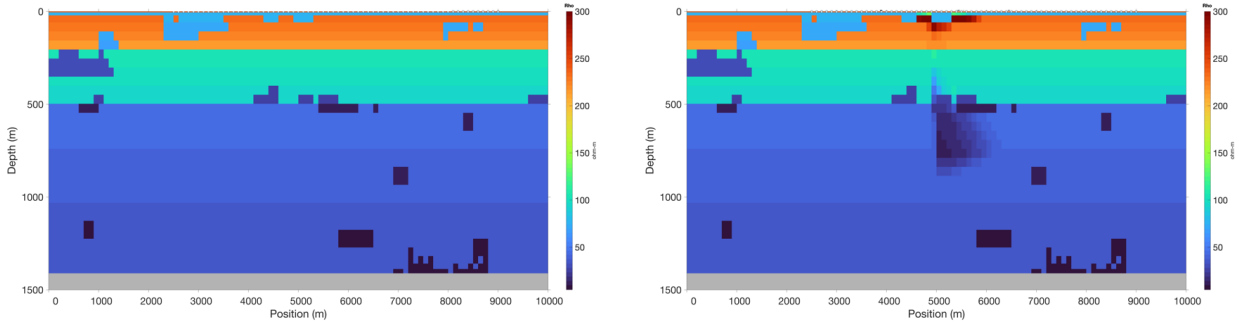
Hashin-Shtrikman, Hertz-Mindlin Model

Model with compliant porosity with CO_2 weakening

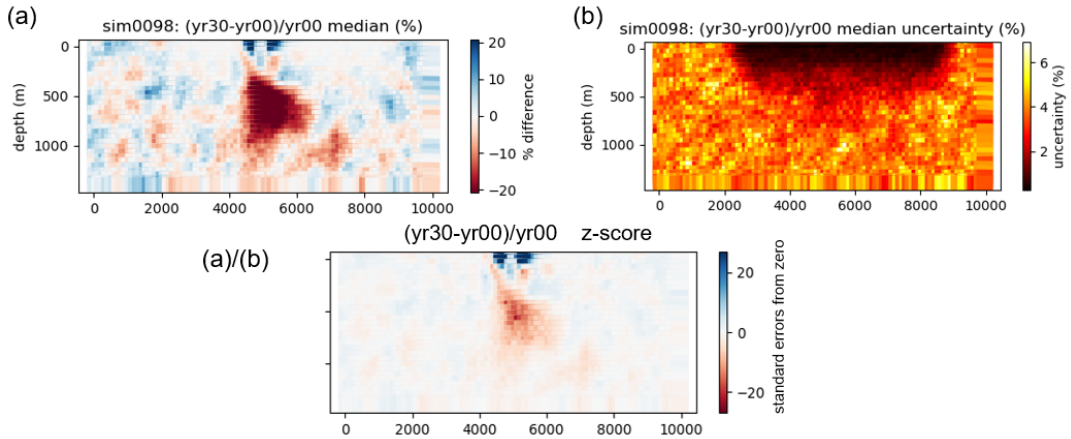


Model uncertainty quantification
(Blatter et al., 2023, in progress)

Ground truth: Kimberlina 1.2 resistivity models

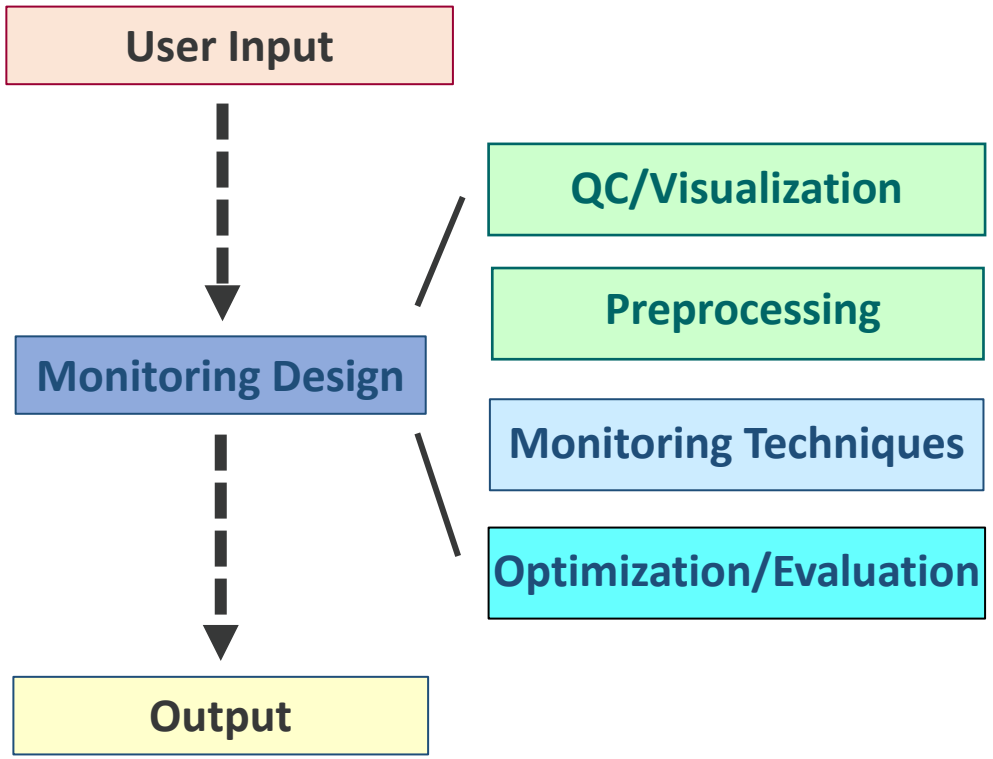


Recovered change & uncertainty from ERT monitoring data

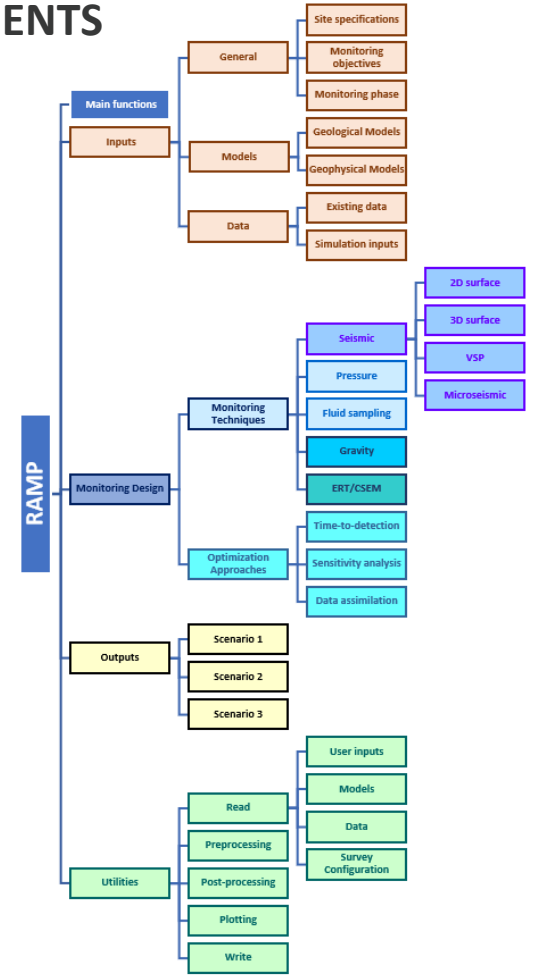


RAMP Framework

WORKFLOW

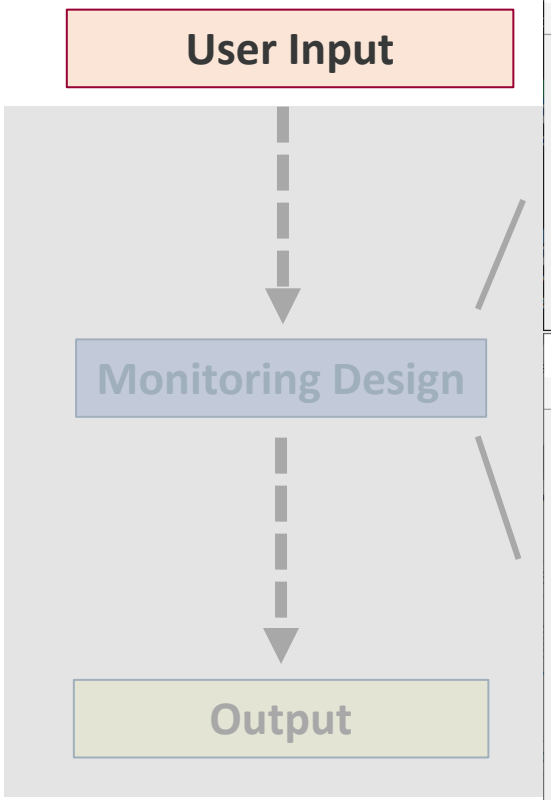


COMPONENTS

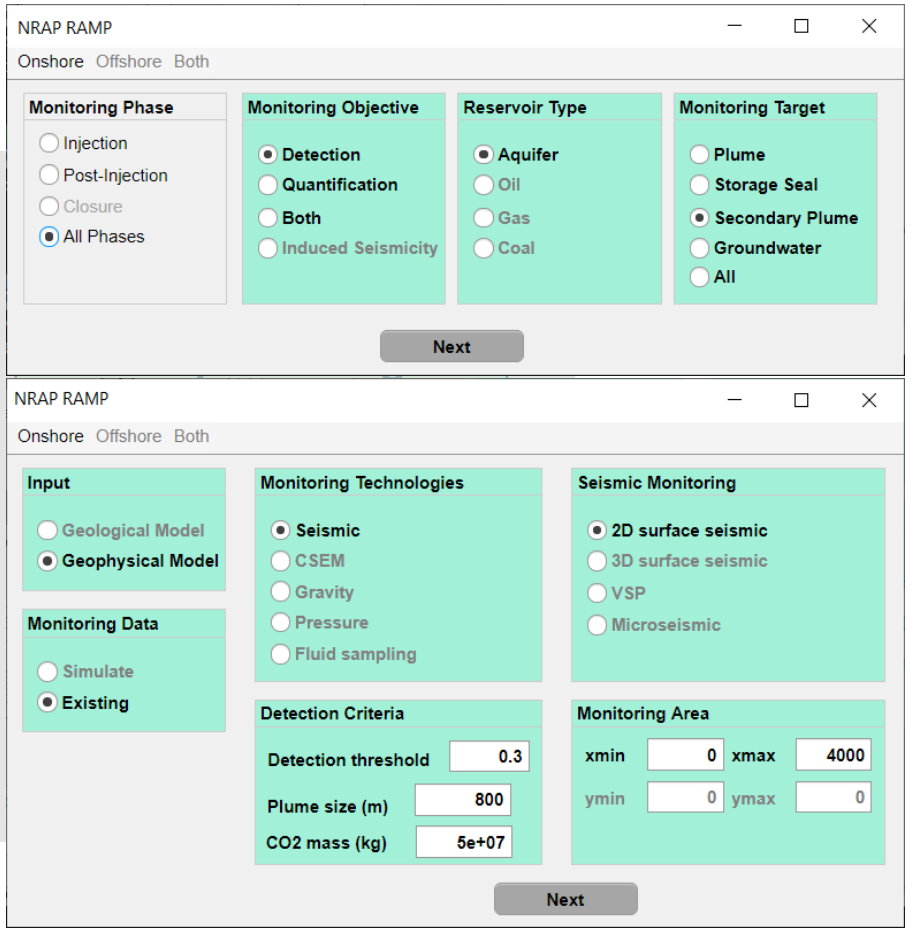


RAMP Framework

WORKFLOW



Final version: GUI

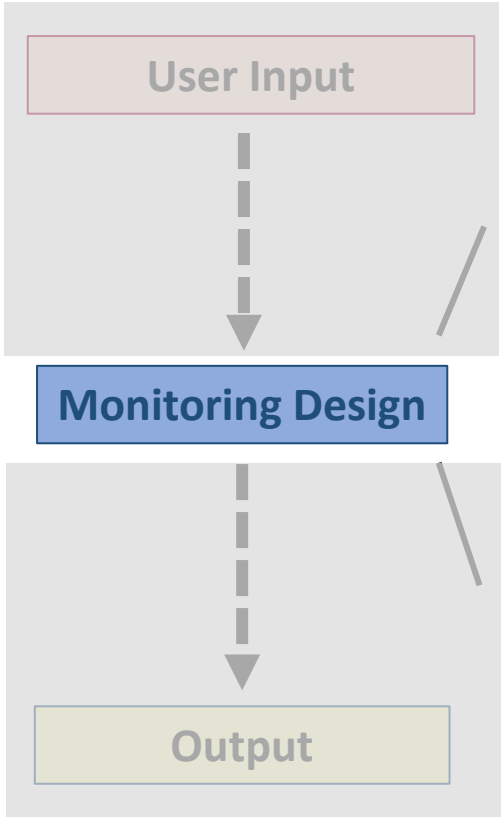


Current version: YAML file

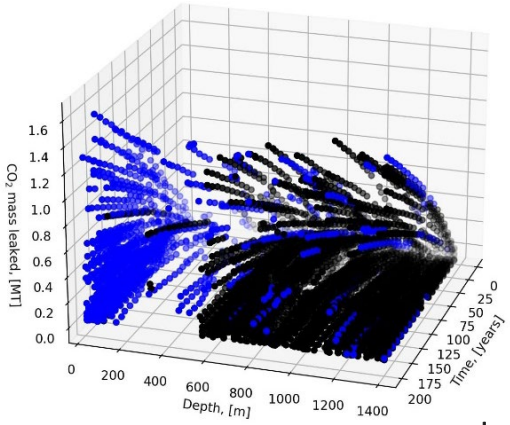
```
# NRAP RAMP Demo Use Case 1 YAML input file
# Last Modified: August 17, 2023
# Xianjin Yang, LLNL
#-----------------------------------------------
MonitoringScope:
  StorageLocation: Onshore
  MonitoringPhase: All Phases
  MonitoringObjective: Detection
  ReservoirType: Aquifer
  MonitoringTarget: Secondary Plume
MonitoringTechnology:
  Input: Geophysical Model
  MonitoringData: Existing
  MonitoringTechnology: Seismic
  SeismicMonitoring: 2D surface Seismic
  DetectionCriteria:
    detection_threshold: 0.3
    plume_size: 800 ;  size_unit: m
    CO2_mass: 5e+07 ;  mass_unit: kg
  MonitoringArea:
    xmin: 0
    xmax: 4000
    ymin: 0
    ymax: 0
```

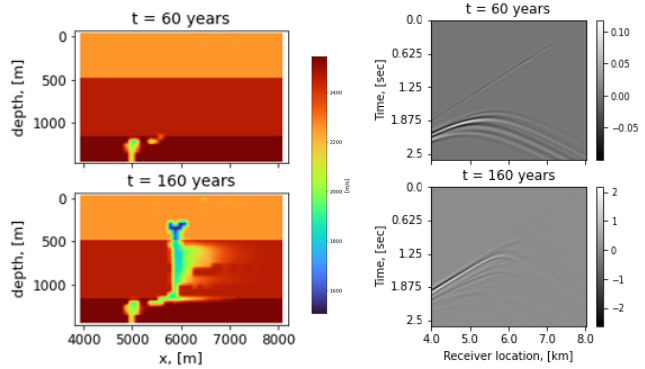
RAMP Framework

WORKFLOW

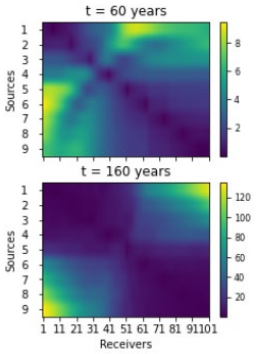


- QC/Visualization
- Preprocessing
- Monitoring Techniques
- Optimization/Evaluation

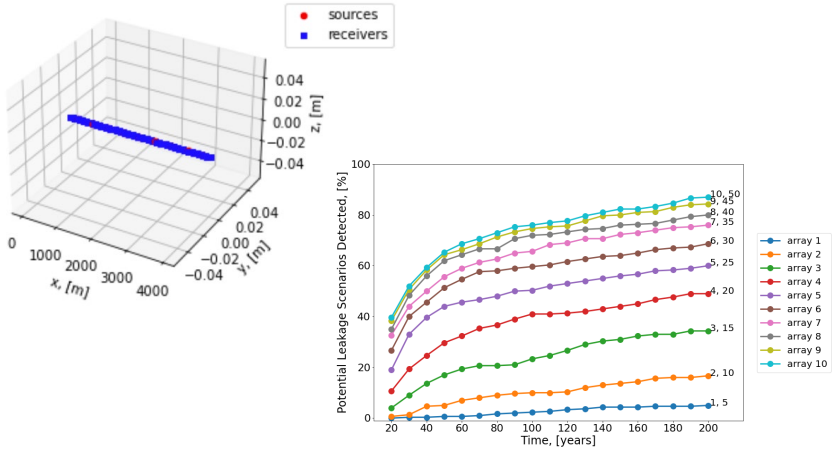




Input models and data QC



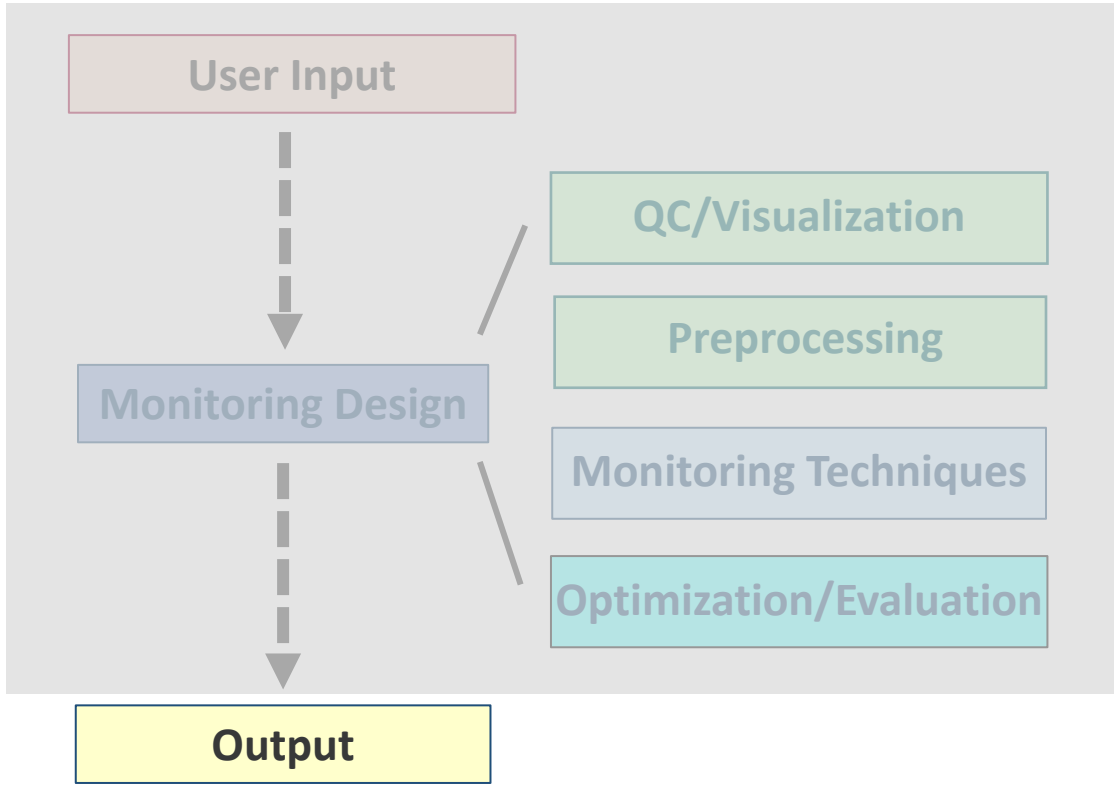
Pre-processing

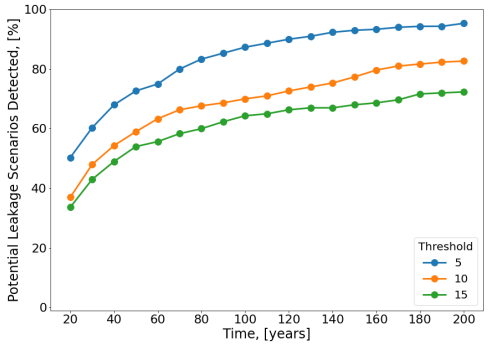


Monitoring Configurations Evaluation

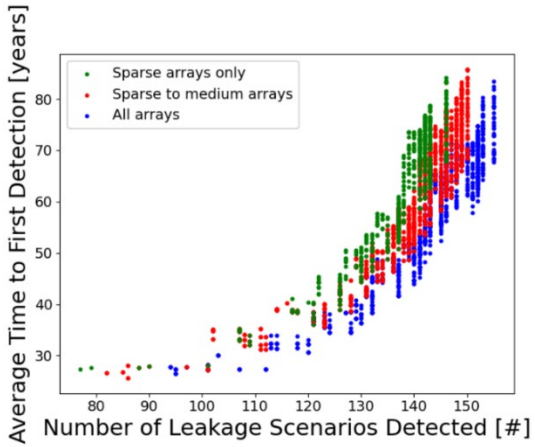
RAMP Framework

WORKFLOW

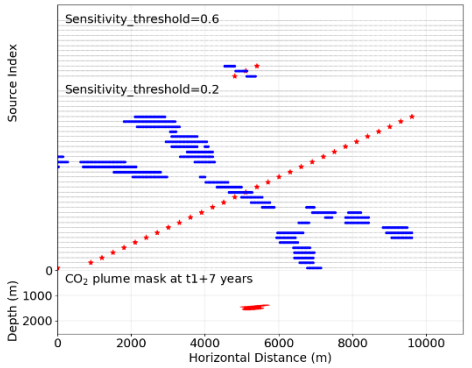


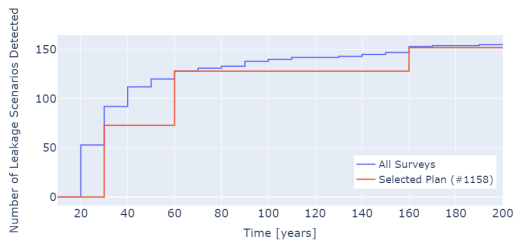


Monitoring performance tradeoffs



Scenario's comparison





Detection and Characterization

Detection

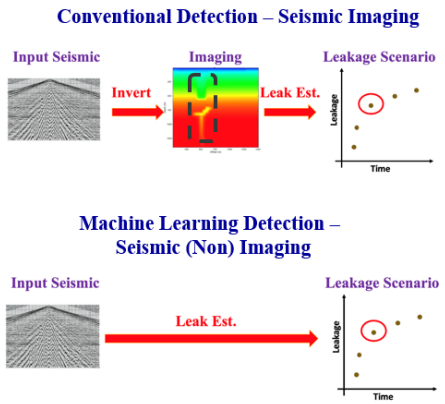
Characterization/ Imaging

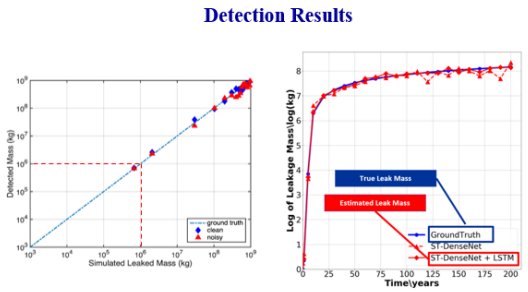
Amount of information

Accuracy

Time-to-detection

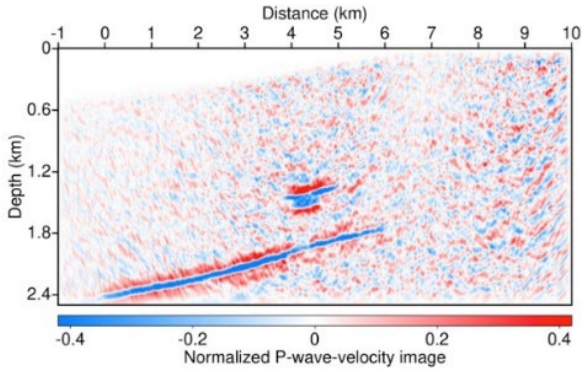
Cost

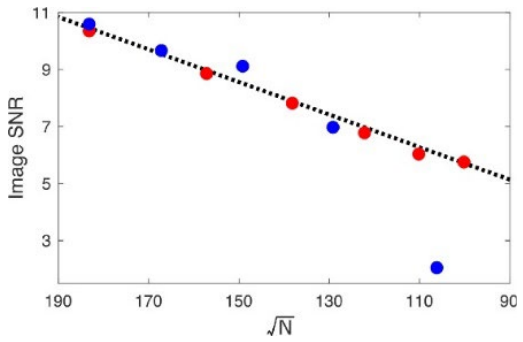




Zhou et al. (2019)

Spatial CO_2 distribution for plume imaging/conformance

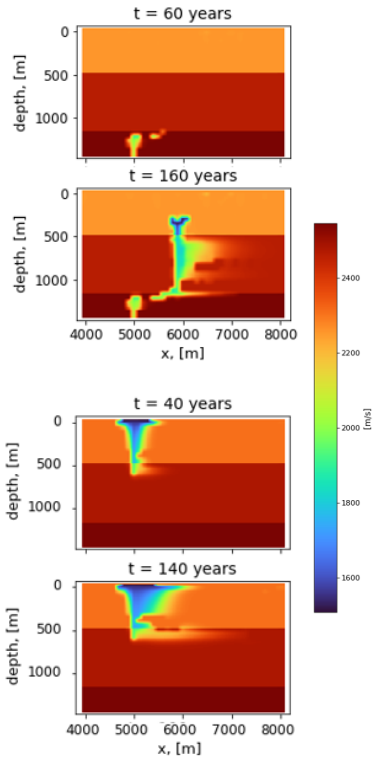




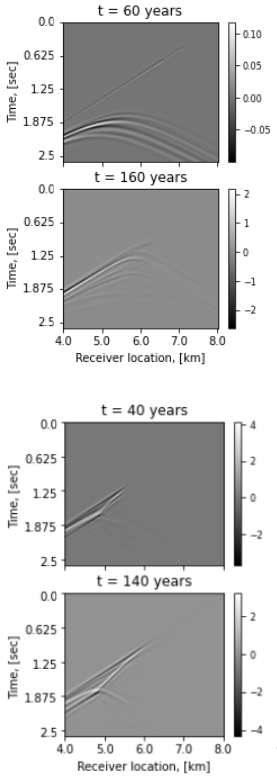
Feng et al. (2022)

Example 1 - Detection

User Input

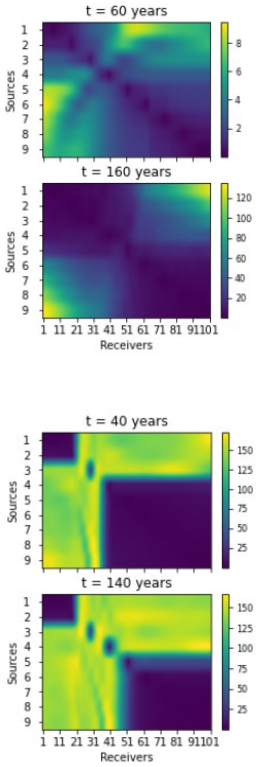


Velocity models



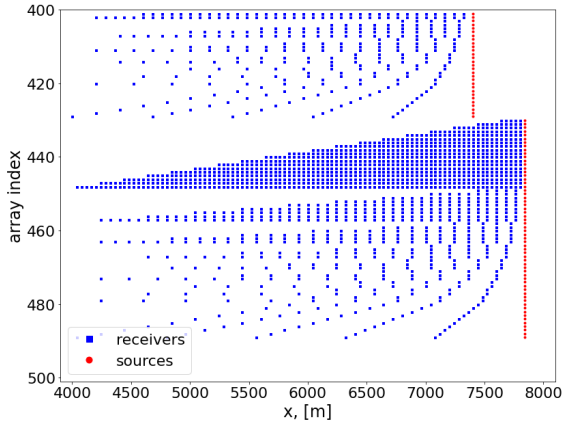
Seismic data

Monitoring Design

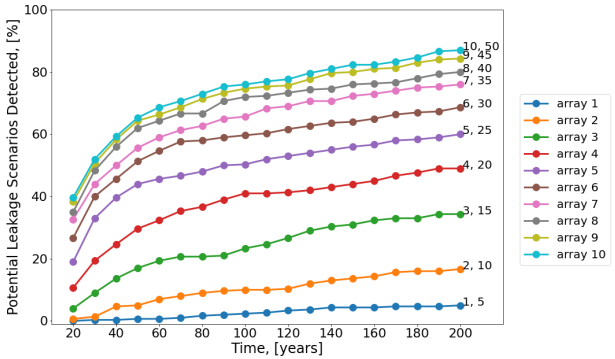


nRMS

Pre-processing

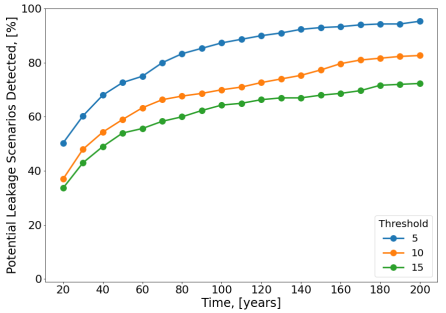


Array construction: sparse–to-dense

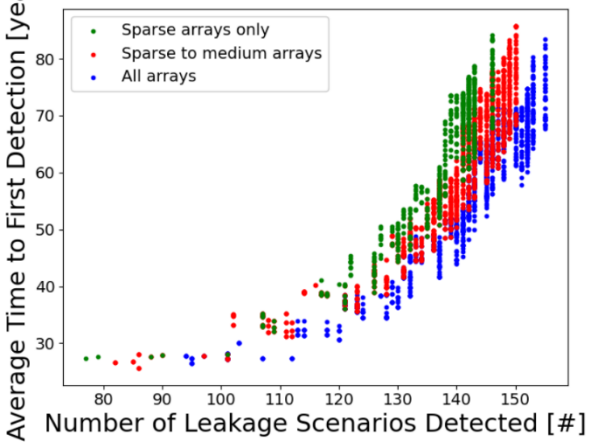


Array evaluations

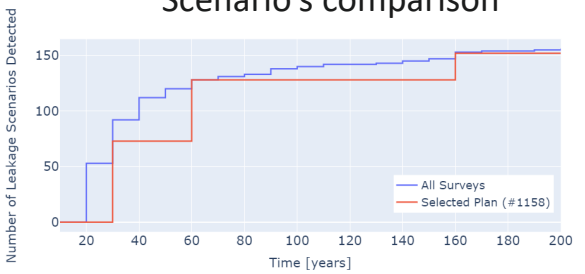
Possible Outputs



Monitoring performance tradeoffs



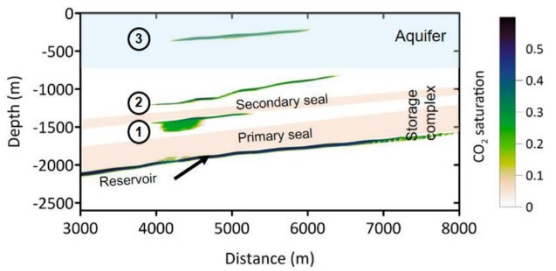
Scenario's comparison



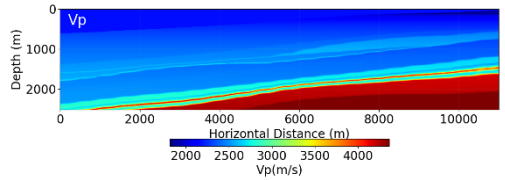
Example 2 - Characterization

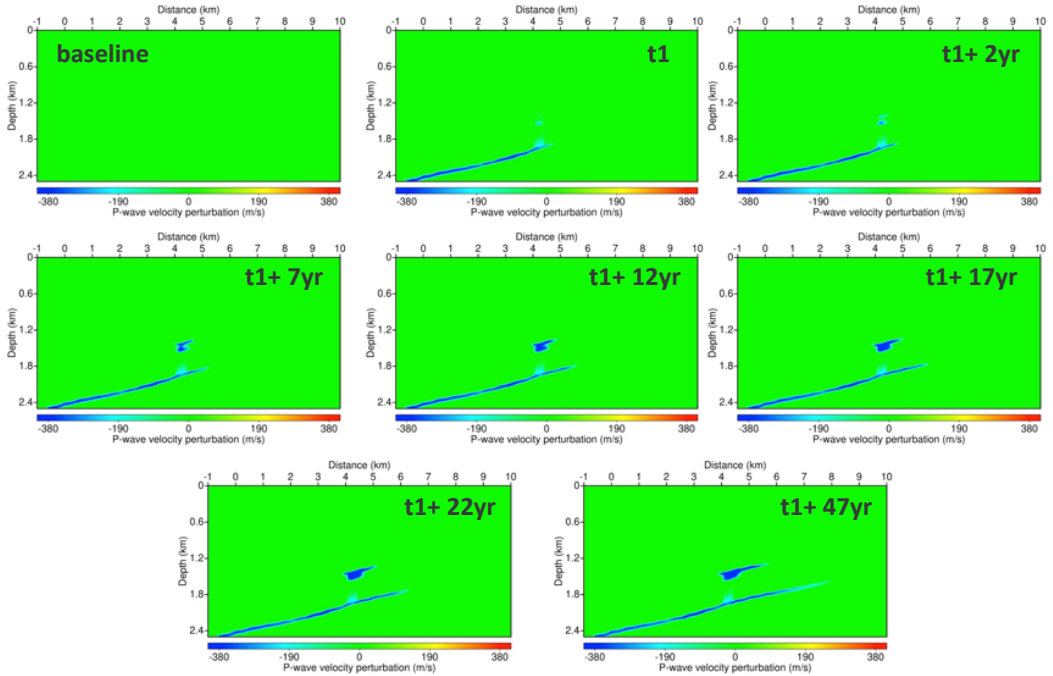
User Input

Subsurface model



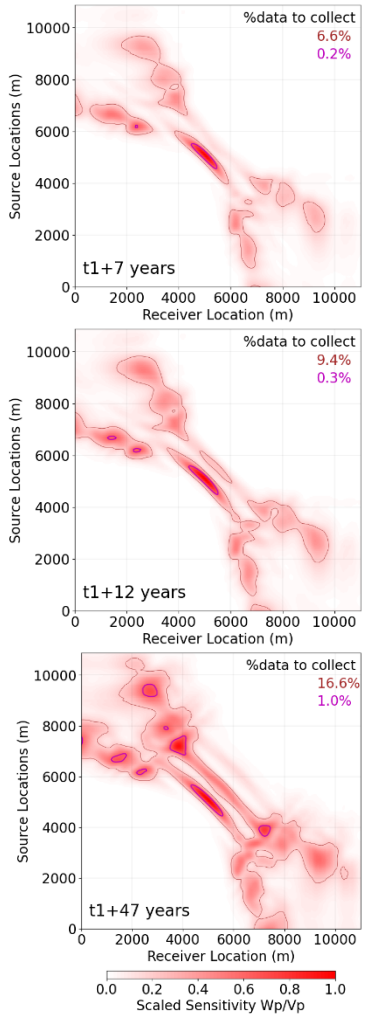
Background velocity model





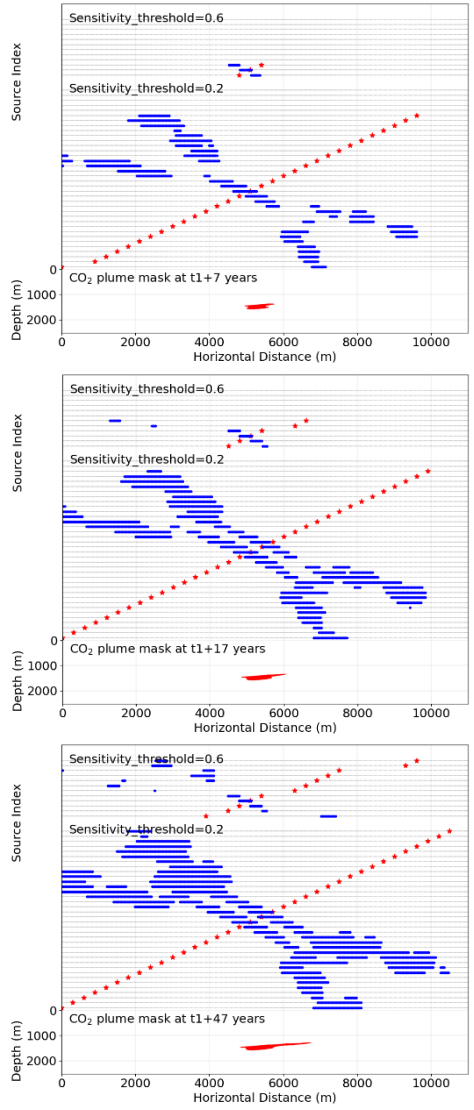
Time-lapse changes in velocity models

Monitoring Design



Sensitivities

Possible Outputs



Array configurations

Thank you!

Comments and Questions:

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NRAP
National Risk Assessment Partnership

NRAP Website: https://edx.netl.doe.gov/nrap/