Incorporating Feedback between Risk Assessment and Monitoring Strategies: Optimizing Monitoring and Minimizing Uncertainty in Risk Assessment

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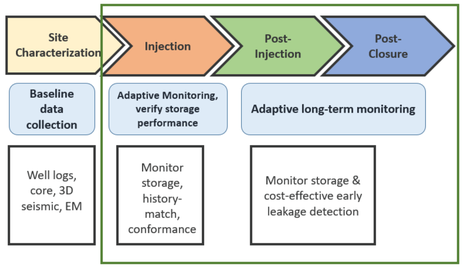
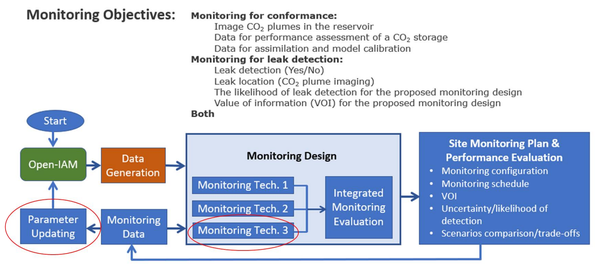
The NRAP Task 4 Team is developing a Risk-Based Adaptive Monitoring Planning (RAMP) tool, a monitoring design framework that will support efforts of GCS site operators/project developers and regulators to design and/or evaluate monitoring plans related to CO_2 injection permit applications and monitoring activities throughout the site operation phases of a GCS project, including injection and post-injection phases.

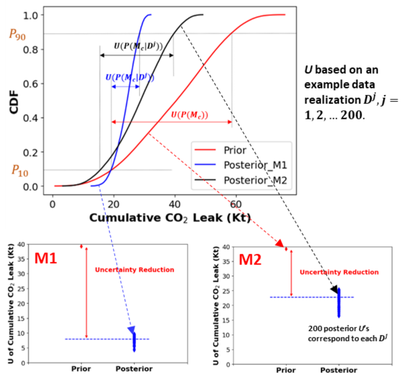


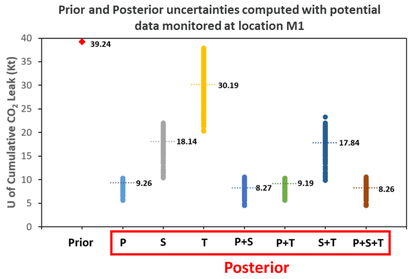
CCS site monitoring phases and their primary monitoring objectives (Yang et al., RAMP Software Design Basis Document)



Adaptive monitoring design flowchart for development of a site monitoring plan (Yang et al., RAMP Software Design Basis Document)

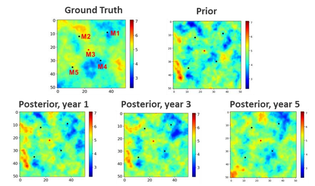
Based on the simulation, we quantify the uncertain reduction (*UR*) due to the simulated data obtained from two monitoring locations (M1 and M2)



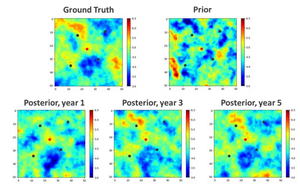


- Find optimal monitoring strategy based on a set of alternative monitoring designs (M1, M2, …).
- The goal of monitoring design is to evaluate the value of data, where the value of data is quantified by the amount of uncertainty that is reduced in the prediction of CO_2 leakage.
- Higher uncertainty reduction corresponds to higher value of data or value of information (VOI).
- Higher VOI is an indication of more accurate detection of CO_2 leakage!
- Pressure data (P) have more value of information (VOI) than CO_2 saturation (S) and temperature (T) data, while the temperature data have the least VOI.
- The combination of P and S can address more uncertainty than individual P or S data set, while adding T to the combination of P and S cannot further reduce the uncertainty.

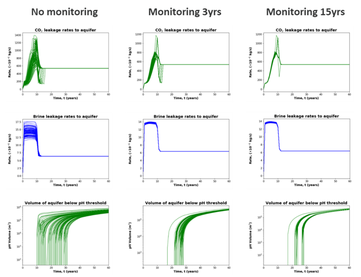
- **Point data assimilation and model update**



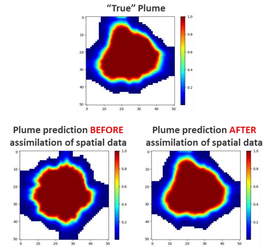
- **Spatial data assimilation and model update**



- **Point data assimilation and leakage risk predictions**

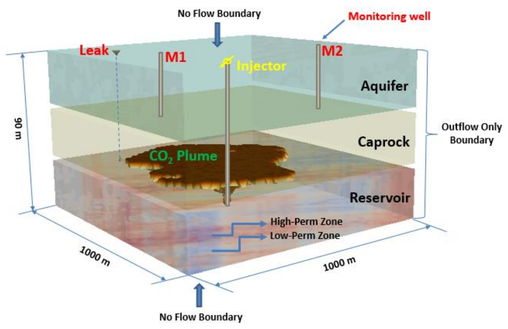


- **Spatial data assimilation and plume predictions**

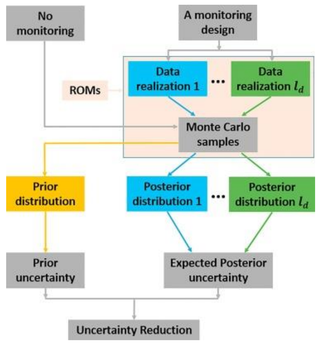


- Increased similarity between the updated model and the ground truth model with the increased number of monitoring data from monitoring wells or seismic surveys.
- Spatial data have more VOI than point data regarding to model updating.
- Significant uncertainty reduction in the predictions of risk quantities based on the updated models.

UQ based monitoring design



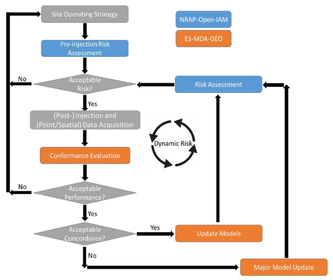
Schematic of the model



UQ based workflow for CO_2 monitoring design (B. Chen et al., Applied Energy, 2018)

Model updating and dynamic risk assessment

- **Objective:**
  - Develop a dynamic workflow to assimilate point/spatial data to calibrate model and reduce uncertainty in the predictions of CO_2 and brine leakage, pH volume, plume size, etc.
- **Methodology:**
  - State-of-the-art data assimilation approach, ES-MDA-GEO, for assimilating monitoring data and spatial images
  - Integrate NRAP-Open-IAM into the workflow for dynamic risk assessment
- **Highlight:**
  - Demonstrated the effectiveness of the workflow for model updating and dynamic risk assessment (B. Chen et al., IJGGC 2020, Gondwana Research 2022, SPE Journal, 2023)



Workflow for dynamic risk assessment

Conclusions:

- By providing a user-friendly interface for generating and assessing risk-based monitoring plans, the RAMP tool intends to help decision-makers identify, prioritize, and optimize monitoring activities based on the potential risks associated with a given carbon storage site.
- UQ based approach was demonstrated to be one of the effective methods in RAMP for monitoring design.
- A novel approach based on dynamic risk assessment was developed to effectively reduce the uncertainty in the predicted risk-related system properties and risk metrics.

Acknowledgement:

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