**Authors’ Reply to Editors of**

**“Optimal monitoring design for uncertainty quantification during geologic CO2 sequestration: A machine learning approach”**

**Submitted to Geoenergy Science and Engineering**

**PETROL-37739-R1**

Dear Associate Editor-in-Chief Dr. Silviu Livescu,

We believe we have carefully addressed all the comments in the review from the Editor and technical reviewers, and we are looking forward to seeing our paper published in Geoenergy Science and Engineering.

Sincerely,

Misael M. Morales, *Corresponding author*

The University of Texas at Austin

Austin, TX, 78712, USA

September 14, 2024

**Reviewer #1:**

The manuscript requires a few minor edits, which are as follows:

1. Please revise the schematic of the ANN in Figure 1 because of it appears a bit busy and misleading. The Dropout layer connection (back) to the Linear Layers (FC) suggests to be a product (of matrices?). Perhaps, the authors could show the network structure in the mid section of the figure and show a single block instead, e.g., [FC->BatchNorm->PReLU->Dropout].

Thank you for your comment. We have reworked Figure 1 to simplify and streamline the schematic of the architecture.

2. Figure 3 and 4 (especially) need better quality alternatives.

Thank you for your comment. We have included higher resolution versions of Figure 3 and Figure 4.

3. Permeability units are expressed in m2 and mD. Perhaps, it would be best to have consistent units (either m2 or mD) both in the text and figures.

Thank you for this comment. We have revised all permeability units to mD (and m2 equivalence in parentheses).

4. Results provided in Figure 2 imply overfitting. Please provide more details on the ANN training, such as number of epochs used in total, if early stopping was used, what training and testing metrics were.

Thank you for your comment. Figure 2 shows the true-vs-predicted values of cumulative CO2 leakage for the MARS proxy (blue) and the ANN proxy (orange). These are both results for the testing dataset. The comparison is not between train-test, but rather between two different ROMs, and it shows the increased accuracy and computational efficiency of the ANN ROM.

Furthermore, we have also included more details on the ANN ROM training in the “Reduced-Order Model Development” section (page 4). Details about the validation and testing accuracy are also described in that section.

**Reviewer #3:**

The manuscript proposes a ML workflow to determine the optimal placement of monitoring wells and the type of data to track. Overall, it is a good paper, well written and clear. The approach used is a filtering-based data assimilation solution to the problem.

Authors should better explain how the leakage paths are selected or added to the models and also provide some comments how to handle multiple monitoring wells instead of just focusing on one.  
Another important point is to say a few words on having the monitoring well in the zone of interest outside of the reservoir zone for CO2 injection target or below it.

Thank you for your comment. We have included more details on the placements of the leakage pathways in Section 2.4. We have also included details on how to potentially include multiple monitoring wells to reduce uncertainty instead of using just one in Section 3.2. Finally, we have included the potential for monitoring measurements in other zones beside AZMI in Section 3.2.

Some words on how to deal with more complex subsurface architectures are needed (including those with nearby faults, etc).

Thank you for this insight. We have included details on the fact that our assumed geologic scenario is relatively simple and that faulting or other complex subsurface architectures would make the problem significantly more complicated, and how to possibly deal with this.  
  
Highlights are ok.  
  
Specific comments to the authors:  
  
\*Please review the first sentence of the first complete paragraph on page 2. Something seems missing.

Thank you for this comment. We have revised the first complete paragraph on page 2.

\*Please review the sentence after Equation (1). 'in this case the number of ..' is incomplete.

Thank your for this comment, we apologize for the typo. We have corrected the sentence after Equation (1).

\*It seems that the leakage pathways are via the legacy ways. Are there any other potential leakage paths?

In this particular work, the only potential leakage pathways are through legacy wells. We understand that other potential leakage pathways include leaky faults, leaky caprocks, the injection well itself, etc. We have modified several parts of the manuscripts to say that legacy wells are the only leakage pathways considered but other potential leakage pathways may exist.

\*It is quite surprising that the recommendation for what data to monitor is the pressure. Common sense suggests that once the money is spent to drill the monitoring well, we should try to get as much data as possible. Did you explore situations where more than one parameter is measured?

Thank you for your comment. We did not include results for the combinatorial of the three possible measurements for data assimilation (P+T, P+S, T+S, P+T+S). However, from our experiments, the assimilation of multiple measurements only provided marginal improvements compared to pressure. We have included this in our discussion and conclusion sections.

\*Please provide more details on the assumptions used for the legacy wells. Are these properly abandoned wells?

Thank you for this comment. We have included more details on our assumptions of the legacy wells. These are assumed to be properly abandoned wells, but with potentially slightly higher permeabilities than the reservoir (and caprock), and therefore could provide potential leakage pathways.

\*Did you validate the location of the optimal wells with the FEEM simulator?

Thank you for your comment. We did not validate the final optimal location with the FEHM simulator, although you are right, and this would have been an interesting observation to include. We have included this in our Discussion section.