**Reviewers' and Editors' comments:**

Reviewer #2:

This manuscript discusses some interesting topics for geologic CO2 sequestration. Monitoring is important for long-term security and success of GCS projects, and optimization is a difficulty. Although the overall scope fits the broader scope of Applied Energy, the manuscript should be much improved to become a good quality article, especially for some obvious mistakes. Specific comments and suggestions are listed below:

(1) Page6 Model Description: "Permeability distribution equal to 1 × 10 -1 m2 and 1 × 10 -13 m2, respectively". This is an obvious mistake of this very high permeability for caprock.

(2) Page 7: The pressure at the model top is 0.2 MP, which is equal to about 10 m below the surface. This means that your reservoir is about 100 m below the surface, which is unreasonable for a GCS reservoir (at least 800 m or below). And is the "Aquifer" a USDW or a saline aquifer? The whole model setup is unrealistic.

(3) Page 8: What is the reason for the assignment of data assimilation error tolerance? Is 0.002 MPa equivalent to 0.05 of CO2 saturation and 0.002 C for temperature?

(4) Figure 10: The histograms of "Prior", "posterior\_R1" and "posterior\_R100" cannot be compared in the same figure - the width of each bar is not equal. They should be set to the same interval of each bar.

(5) This manuscript is very similar to Chen et al., (2018) https://www.sciencedirect.com/science/article/pii/S0306261918307372. What is the improvement and what is the novelty of this manuscript?

Reviewer #3:

The manuscript presents an approach to geologic CO2 sequestration using a filtering-based data assimilation coupled with Artificial Neural Networks (ANNs) for developing reduced-order models. These models aim for computational efficiency grounded in full-physics numerical simulations of CO2 injection in saline aquifers. The authors highlight the method's application in two scenarios focusing on CO2 leakage through abandoned wellbores and illustrate the substantial uncertainty reduction in cumulative CO2 leakage at the geologic CO2 sequestration site.  
  
The paper is well-structured and tackles a topic of significant interest. However, several areas require attention and improvement:  
  
1. The manuscript needs to articulate its novel contributions more distinctly. Many aspects of the proposed workflow, such as ANN, reduced-order modeling, and MCMC methods, are well-established in the field. It is important to delineate clearly how this work diverges from or improves upon existing methods cited in the literature, including works by ( see the work of : <<<Specific reference recommendations are being omitted. The authors should make a deep analysis of the specialized literature and use it to improve the paper>>>. The authors need to discuss in more clarity their new contribution to the literature.  
  
2. The manuscript's density of references, particularly in the introduction, is excessive and detracts from its readability and focus. While comprehensive citation is valuable, the current approach borders on overwhelming, with more than 130 references, many of which are not directly relevant to the core contributions of the paper. Streamlining the references to focus on the most relevant works will improve the manuscript's clarity and impact. I suggest reducing the reference by a factor of 2 at least.  
  
3. The authors need to discuss the applicability of their proposed approach for real-field cases. The selected case described in section 2.4 represents a synthetic scenario with given reservoir dimensions and subsurface fluid and rock properties, as well as, a predefined leakage scenario. The presented model is only applicable to the selected model.  
  
4. A comparative discussion against analytical-based methods such as those presented would provide a more comprehensive evaluation of the proposed method's performance and limitations. Such analysis can help in understanding the conditions under which the proposed method might offer significant advantages or face challenges. Some of the proposed analytical-based methods based on pressure transient analysis are :  
<<<Specific reference recommendations are being omitted. The authors should make a deep analysis of the specialized literature and use it to improve the paper>>>  
  
5. The methodological section requires more depth, particularly in explaining the neural network architecture, training process, and how it integrates with the filtering-based data assimilation approach. Specific details on the data used for training, validation, and testing, along with performance metrics, will add substantial credibility and allow for a thorough understanding of the method's robustness.