The reviewer's comment is written in bold. The reply of the authors is written in non-bold.

This manuscript presents a novel data-driven approach for calibrating scaling parameters used in cosmic-ray neutron sensing (CRNS) for soil moisture measurements. The work makes a meaningful contribution to improving CRNS methodology, though there are some aspects that would benefit from revision. For example, more detailed discussion of the practical implementation of the new approach can be made, what the implications of the new methods for CRNS users can be discussed.

Thank you for the positive overall evaluation of the manuscript and for agreeing with us on the novelty of the calibration approach. We appreciate your time and effort in reviewing the manuscript. In the forthcoming revision we will consider each of your suggestions and implement the necessary changes.

With regard to the comment on practical implementation of the new approach, we suggest the addition of a new discussion subsection that seamlessly integrates the last paragraph of the discussion:

"4.3 Implementation and implications of the new approach
A data-driven approach may offer a viable alternative to semi-analytical models and offers practical benefits for CRNS users. For instance, it allows for the selection of NMDB monitors that are more suitable for specific CRNS sites than the commonly used Jungfraujoch station. This flexibility allows for improved scaling accuracy by incorporating NMDB monitors that are geographically closer or better suited to the environmental conditions of a given CRNS site (Bogena et al., 2022; Zreda et al., 2012). Additionally, our method can be seamlessly integrated into existing CRNS workflows, complementing traditional methods to improve calibration reliability. By improving calibration accuracy, our approach supports robust soil moisture estimates, enabling better-informed decisions in agriculture, hydrology, and climate monitoring."

The manuscript is well-structured and generally well-written, though some sections could be more concise and clear. The abstract could better highlight the quantitative improvements achieved over existing methods, the current version of abstract lacks detailed descriptions using some values. In the methods section, I think it would benefit from a general paragraph summarizing what it takes to complete the calibration using the new method, maybe a flowchart can be added.

Thank you for highlighting the need of a summarizing paragraph of what is required to complete the calibration. We therefore add a brief paragraph at the beginning of Section 2, in order to allow the reader more easily to access the new scaling approach:

"This study introduces a data-driven method for estimating the scaling parameters beta, psi, and omega in cosmic ray neutron sensing (CRNS) to improve soil moisture measurement accuracy. Section 2.1 outlines the scaling parameters, which correct for atmospheric pressure, incoming neutron intensity, and absolute air humidity. The forward model, detailed in Section 2.2, combines these scaling functions to estimate neutron flux by applying the corrections to the observed flux from the previous time step. Uncertainty estimates, described in Section 2.3, are calculated using bootstrapping techniques to evaluate the robustness and reliability of scaling functions. Together, this integrated approach provides a systematic and flexible framework for site- and sensor-specific calibration."

We further present a more complete description of the objective function for the inversion routine which is also in line with the comment by Todd Caldwell:

"The forward model used for estimating the parameters beta, omega, and psi is based on the combination of scaling functions for atmospheric pressure, absolute air humidity, and incoming neutron intensity, as detailed in Equations (1), (2), and (3). The forward model computes the neutron flux N at time t by applying these scaling factors to the observed neutron flux $N_{t-1,obs}$ of the previous time step (t-1). This previous time step essentially serves as reference condition:

$$N_{t,est} = N_{t-1,obs} \times exp\{beta(P_t - P_{t-1})\} \times \{1 + omega \times (abs_t - abs_{t-1})\} \times \{1 + psi \times (Inc_t - Inc_{t-1})\} \quad (4)$$

Parameters beta, omega and psi are the free parameters to be optimized. N, P, abs and Inc represent vectors of n days, and $N_{t,est}$ is the neutron flux estimated by using the corrections.

To optimize the three parameters, we use an inversion approach that minimizes the root mean square error (RMSE) between the observed neutron flux $N_{t,obs}$ and the estimated neutron flux $N_{t,est}$:

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(N_{t,obs} - N_{t,est}\right)^2} \quad (5)$$

where n represents the total number of days."

In all, this paper represents a valuable contribution to the field and is suitable for publication in HESS after moderate revision.

Thank you. We will implement the suggested changes accordingly.

Specific line-by-line comments:

Lines 87-93: The objectives should be stated more explicitly here. Consider put specific research questions and objectives at the beginning.

We thank the reviewer for this constructive suggestion. We will rephrase the last paragraph to:

"This study aims to address these limitations by presenting a novel data-driven, empirical approach for calibrating scaling parameters (i.e., beta, psi, and omega) used in CRNS. Specifically, this study has three objectives: (1) to develop an inverse method that directly calculates correction parameters from measurement signals while treating soil moisture dynamics as a noise term, (2) to evaluate the accuracy of current scaling functions, and (3) to quantify the impact of local environmental factors on calibration parameters. The hypothesis is that this approach, by accounting for site-specific and sensor-specific conditions, will improve the accuracy and reliability of CRNS soil moisture measurements. By improving the accuracy of soil moisture determination, this study contributes to better informed decisions in agriculture, hydrology, and climate monitoring."

Lines 315-324: The sensitivity analysis results could be more quantitative when describing impact of parameter variations on soil moisture estimates. Consider refer to specific values (sometimes can be in brackets after your statements) in this section.

We agree and will be more quantitative in the description. We will add specific values accordingly.

Grammar Issues:

Line 74: “effect” to “affect”

Thank you. We changes this.

Line 142: Missing space after absref

Thank you. We changes this.

Line 330: “Contour lines show soil moisture differences of 0.00 and 0.02 m^3/m^3 to reference values.” Consider rephrasing to avoid ambiguity

Thank you. We clarified:
“Contour lines show soil moisture differences of 0.02 m^3/m^3 (curved) and 0.00 m^3/m^3 (straight) to reference values.“