We thank Reviewer 1 for the careful reading of the manuscript and for the constructive comments. Below we respond to each comment individually. Reviewer comments are shown in black, followed by our responses in blue.

Referee #1

The manuscript studies hydrological controls on water-table dynamics in a drained fen peatland. The authors combine long-term field observations with a coupled surface–subsurface hydrological model (HydroGeoSphere). The model is used to quantify the peatland water balance and analyze groundwater dynamics. Results show that strong evapotranspiration in summer lowers groundwater levels and reverses the hydraulic gradient between the peatland and drainage ditches. Peat stratigraphy also plays an important role in controlling water storage and water-table variability. These processes are key to understanding hydrological functioning and challenges for peatland rewetting. The manuscript is generally well written and presents an interesting integration of field observations and modeling. However, several aspects of the methodology and presentation could be improved to strengthen the reproducibility of the model setup and the practical implications for peatland restoration.

Main comments:

1.Although the paper discusses implications for peatland rewetting, the model simulations represent only the current drained conditions. Explicit rewetting scenarios were not tested, which limits the ability to evaluate restoration strategies directly. I suggest including a set of simple scenario simulations (e.g., raising ditch water levels by different amounts or reducing ditch drainage conductivity) to allow the model to directly assess potential rewetting strategies and strengthen the study's practical relevance.

Thank you for the suggestion. The objective of the present study was primarily to establish and validate a robust, process-based hydrological model of the drained fen peatland system using long-term field observations. This baseline simulation under current drainage conditions provides the necessary foundation for reliable scenario analysis. To clarify this point, we have revised the manuscript to better emphasize that the current study focuses on developing and validating the hydrological modeling framework, which can subsequently be applied for testing restoration scenarios. The HydroGeoSphere setup explicitly represents ditch–peatland interactions and water balance components, making it suitable for evaluating management strategies such as raising ditch water levels or modifying drainage controls. A paragraph was added to the Discussion section highlighting that the calibrated model can be used to simulate rewetting scenarios, including ditch water level regulation and water retention measures. These modifications clarify the practical relevance of the modeling framework for peatland restoration planning. Future work will explicitly investigate such scenarios using the validated model configuration.

2.The evapotranspiration parameterization assumes that ET reaches potential evapotranspiration at LAI ≈2.5, even though observed LAI at the site reaches about 7. This assumption effectively removes most vegetation variability from the hydrological response and may underestimate the influence of canopy dynamics on transpiration and groundwater drawdown. The model could be improved by testing alternative ET formulations that account for higher LAI values.

Thank you for pointing this out. We have expanded the Discussion to clarify the implications of the Kristensen–Jensen evapotranspiration formulation used in HydroGeoSphere. The parameterization assumes that transpiration reaches its maximum potential value at LAI values of approximately 2.3–2.5. Consequently, larger observed LAI values do not further increase simulated transpiration demand. We agree that this limits the sensitivity of the model to variations in dense vegetation canopies. However, we do not believe that this simplification is the primary cause of the evapotranspiration overestimation observed during the drought year 2018. During that year, groundwater levels declined unusually deeply and the peat profile experienced substantial drying. Field observations and previous analyses at the site (Dietrich et al., 2021) indicate that actual evapotranspiration became limited by insufficient water availability rather than by vegetation density. We therefore interpret the discrepancy primarily as a limitation in the representation of drought-induced water stress and plant-accessible water rather than as a consequence of the LAI formulation itself. We have revised the Discussion accordingly and now explicitly note that alternative canopy-resistance formulations may improve the representation of vegetation effects under dense canopy conditions and should be explored in future studies.

We added the following paragraph to the discussion:

‘Although the observed LAI of the fen grassland reached values of approximately 7 during peak growing seasons, the Kristensen–Jensen evapotranspiration formulation assumes that transpiration demand reaches its maximum at LAI values of about 2.3–2.5. Consequently, increases in canopy density above this threshold do not lead to further increases in simulated transpiration. This simplification may reduce the sensitivity of the model to interannual variations in vegetation development and canopy structure. However, under the climatic conditions of the study site, evapotranspiration appears to be constrained more strongly by water availability than by canopy density during extreme drought periods. For example, during the summer drought of 2018, groundwater levels declined substantially and the peat profile dried out, limiting root water uptake despite high vegetation productivity. Similar observations were reported by Dietrich et al. (2021), who found that actual evapotranspiration remained below atmospheric demand because of insufficient water availability. Therefore, the overestimation of AET in 2018 is more likely related to limitations in the representation of drought-induced water stress and plant-accessible water than to the LAI parameterization itself. Future studies could investigate alternative canopy-resistance formulations that maintain sensitivity to high LAI values while also improving the representation of drought stress under extreme conditions. This issue may become increasingly important under future climate conditions. While shallow groundwater currently supports high evapotranspiration rates in many fen systems, more frequent and prolonged droughts could result in deeper groundwater tables and stronger soil moisture limitations. Under such conditions, accurate

representation of plant-accessible water and drought-induced transpiration reduction may become more important than the representation of canopy density alone. Consequently, future rewetting and climate-change scenario analyses would benefit from improved coupling between vegetation dynamics, root water uptake, and evolving peat hydraulic properties.'

3.The paper reports good model performance metrics. Still, it does not clearly describe the calibration procedure or identify which parameters were calibrated, making it difficult to assess parameter sensitivity or reproduce the model setup.

We agree that the calibration procedure was not sufficiently described in the original manuscript. We have added a dedicated paragraph in the Methods section explaining the calibration and validation strategy. Due to the high computational demand of multi-year HydroGeoSphere simulations, a formal automatic calibration was not feasible. Therefore, we employed an iterative manual calibration procedure using groundwater levels and eddy covariance evapotranspiration observations. During calibration, peat porosity and the van Genuchten parameters α and β were found to be the most sensitive parameters affecting groundwater dynamics and water storage, while saturated hydraulic conductivity had a secondary influence. The revised manuscript now clearly identifies the calibrated parameters, the calibration period (2016–2020), and the independent validation period (2021–2023).

We added the following to the Methods:

'Model calibration and validation

The HydroGeoSphere model was calibrated against observed groundwater levels and eddy covariance evapotranspiration measurements using an iterative manual calibration procedure. Model parameters were adjusted manually within physically realistic ranges reported in the literature for degraded and less degraded peat soils (Wallor et al., 2018a, 2018b; Liu and Lennartz, 2019; Menberu et al., 2021; Renaud et al., 2025) until satisfactory agreement with the observed groundwater dynamics and evapotranspiration was achieved. The calibration focused primarily on peat hydraulic properties and evapotranspiration parameters. During the calibration process, peat porosity (ϑs) and the van Genuchten parameters α and β were identified as the most sensitive parameters controlling groundwater fluctuations and water-storage dynamics. These parameters strongly influence soil water-retention characteristics and therefore determine the availability of water for evapotranspiration and the response of groundwater levels to climatic forcing. Saturated hydraulic conductivity also influenced model results, particularly the timing of groundwater-level responses and lateral exchanges between the peatland and the surrounding ditch system. Model performance was evaluated using both groundwater-level observations and actual evapotranspiration estimates derived from eddy covariance measurements. The period 2016–2020 was used for calibration because it encompassed a broad range of hydrological conditions, including both wet (2017) and dry years (2018), thereby providing a robust basis for parameter evaluation. The period 2021–2023 was subsequently used for model validation. Model performance was assessed using the Nash–Sutcliffe efficiency (NSE), Kling–Gupta efficiency (KGE), and root mean square error (RMSE).'

Minor comments:

1.Figure 8 attempts to show seasonal and interannual variability using a heatmap, but the color gradients make the evapotranspiration patterns difficult to interpret. A line plot showing monthly values across years would likely communicate the seasonal cycle and year-to-year differences more clearly.

Thank you for this suggestion. Figure 8 was specifically designed to simultaneously visualize both seasonal and interannual variability of evapotranspiration components over the entire simulation period. While line plots can effectively illustrate seasonal dynamics, representing monthly values for all years and for both evapotranspiration components would require a large number of overlapping lines or multiple separate figures, making the results more difficult to interpret and compare. For this reason, we keep the heatmap format, which provides a compact overview of temporal patterns across years.

2.Figure 10 uses a 3D perspective to illustrate surface flooding, but the visualization makes it difficult to interpret actual water depths and spatial patterns. A top-down map or cross-sectional slices would likely provide clearer quantitative information about flooding dynamics.

The 3D visualization in Figure 10 was intended to illustrate the spatial evolution of surface inundation across the peatland domain. The figure caption was expanded to explain the spatial patterns more explicitly to improve the interpretability of inundation dynamics. However, we agree that readability can be improved by adding explanation in the text and caption.

3.Why was NSE not reported for the evapotranspiration comparison in Fig. 11b while it was included for groundwater in Fig. 11c? Including the same performance metrics (e.g., NSE, KGE, RMSE) for both variables, or explaining why different metrics were used, would improve consistency and help readers evaluate model performance.

NSE has now been calculated and reported for the evapotranspiration comparison to ensure consistency with the groundwater evaluation. The revised manuscript now presents the same performance metrics (NSE, KGE, and RMSE) for both evapotranspiration and groundwater simulations.

4.The tables mainly summarize model parameters, but they are rarely referenced explicitly in the text, which makes it harder for readers to connect the discussion to the parameter values used in the simulations. Explicitly referring to the tables in the text (e.g., “soil hydraulic parameters are summarized in Table X”) would help guide readers and improve the clarity of the model description.

We agree. In the revised manuscript, references to Tables 1–3 have been added throughout the Methods section where, hydraulic properties and evapotranspiration parameters are introduced.