June 4, 2025

Major Comments: This study examined watershed modeling of water and nutrient exports during complex freeze-thaw periods. I believe this research is novel and would be pertinent to an international readership. I thought the introduction did a good job summarizing prior research, identifying knowledge gaps, stating the contribution, and setting the stage for the modeling. The discussion was also invigorating. For the methods, I have some concerns with the clarity and robustness of the calibration approach, the clarity of the potential influence of rain-on-snow melt on the simulations, and the poor quality of the NO3-N simulation at the daily time step. I provide some suggestions to hopefully help alleviate these concerns.

Response: We sincerely thank the reviewer for the insightful and constructive comments, which have been invaluable in refining the manuscript and strengthening the rigor of our research. Each comment was carefully analyzed, and we have implemented corresponding revisions to address the concerns raised. For suggestions that could not be directly incorporated, we have provided detailed explanations in the response section to clarify our approach. We are committed to ensuring the manuscript meets the highest standards of clarity and scientific integrity, and we hope these revisions will satisfy your expectations. Below is a detailed summary of the main corrections and our responses to each of the reviewer's comments:

Comment 1: Page 2, lines 37-38. Rain-on-snow melt events are mentioned here (and in the discussion) as being pertinent to snowmelt and nitrogen exports from the watershed. I could see this being important when simulating at the daily time step. However, I believe the SWAT model used in this study simulates snowpack temperature-based melt only, omitting the energy transfer to snowpack during rain events and rain-on-snow melt simulation. This was confusing for me, so I suggest clarifying the snowmelt simulation in this study, for instance after the SWAT model is introduced on Line 67 and/or in Section 2.3. Alternately, if rain-on-snow melt events are common in the watershed, you could consider using a model that simulates rain-on-snow melt to solidify this (e.g., Zare et al. 2022).

Zare, M., Azam, S., and Sauchyn, D: A modified SWAT model to simulate soil water content and soil temperature in cold regions: a case study of the south saskatchewan river basin in Canada. Sustainability 14.17 (2022): 10804. https://doi.org/10.3390/su141710804.

Response: We greatly appreciate the reviewer's reminder. The authors' description of "rain on snowmelt" indeed caused ambiguity. What we intended to convey by "rain on snowmelt" in this paper is not rainfall during the snowmelt period (when significant snow cover remains), but rather rainfall during the runoff period induced by snowmelt (when most snow has melted). The specific reasons are as follows:

Statistics show that the average precipitation in the study area during the freeze-thaw period is 31.8 mm, including an average snowfall of 17.3 mm during the stable freezing period and 18.9 mm during the unstable spring freeze-thaw period. Part of this precipitation falls as snow, which undergoes processes like volatilization and melting. Low-lying and shady areas retain more snow (about 10–20 cm), while most regions have only a few centimeters or no snow cover. Snowmelt in the basin typically concludes within 1–2 days, with minimal overlap between snowmelt and rainfall processes, as snowmelt usually occurs during warming periods, whereas rainfall occurs during cooling periods. However, due to the region's low winter temperatures (average -10.5°C) and sparse snow cover, the frozen depth of soil averages ~1 meter, which drastically reduces the infiltration of snowmelt water . Snowmelt water remains in surface depressions for extended periods, functioning as depression storage. Before the permafrost thaw depth reaches 10 cm after snowmelt, rainfall can significantly increase runoff coefficients and volumes (Zhao et al., 2016). The SWAT model accounts for this process via the freezing parameter S_{frz}, which modifies direct runoff parameters.

To avoid further ambiguity in the "rain-on-snowmelt" description, the authors have revised the relevant content in Section 4.2 (following the response to the first reviewer's comments) and added a brief introduction to the SWAT model's snow simulation process in Section 2.3, as detailed below:

Section 4.2:

On this basis, runoff and runoff coefficient would be quite high if rainfaill events occurred during the snowmelt period (Fig. 9a–9d).

Section 2.3:

For modeling purposes, the SWAT model partitions a watershed into a number of sub-watersheds or sub-basins, which are further partitioned into a series of hydrologic response units (HRU) with unique land cover, soil, and agricultural management practice combinations. The generation of surface runoff, soil water, groundwater, sediment, and nutrients is calculated in every HRU and then routed through the river channel. Snow melt in SWAT model is controlled by the air and snow pack temperature, the melting rate, and the areal coverage of snow. Snow melt is calculated using a linear function of the difference between the average snow pack temperature, maximum air temperature and the base or threshold temperature for snow melt.

Reference: Zhao Q., Chang D., Wang K., Huang J.: Patterns of nitrogen export from a seasonal freezing agricultural watershed during the thawing period. Sci. Total Environ. 599, 442-450, doi.org/10.1016/j.scitotenv.2017.04.174, 2017.

Comment 2： Page 7, line 158. I think more clarity is needed here. If the simulations were only evaluated during the snowmelt period, do you need to account for changes during the rest of the year to variables dependent on states, such as groundwater levels, that could affect runoff model performance at the start of each annual snowmelt period? Was there a model warm-up period to help with this? I may simply not be understanding this right, so more clarity here would be helpful.

Response: We appreciate the reviewer's suggestion. This study used only freeze-thaw period data for model calibration and validation for three reasons:

(1) Data limitations: The authors' prior research focused on water and nitrogen dynamics during seasonal freeze-thaw periods. Due to a lack of automated hydrological and water quality monitoring stations in the studied watershed, as well as constraints in manpower and equipment, only manual flow measurements and water sampling were conducted during the freeze-thaw period, with no data collected for non-freeze-thaw periods.

(2) Anthropogenic interference: The study area is located in a typical agricultural region—a tributary of Heidingzi River (a third-order tributary of the Songhua River). The main channel has four sluice gates, and large rice fields are distributed along both banks. From May to September (irrigation period), the gates are closed to store upstream reservoir releases and rainfall runoff for irrigation, causing backwater effects that disrupt natural flow

conditions in both the main and tributary channels, making hydrological and water quality monitoring unreliable.

(3) Groundwater dynamics: In 2016, two groundwater wells were installed near the riverbank and in distant farmlands. Monitoring data showed that during the freezing period, groundwater received no precipitation recharge due to soil freezing. Instead, it migrated upward under thermal potential and topographic gradients (from higher to lower elevations). Consequently, groundwater levels across the study area remained significantly below the river channel before and during early snowmelt (Fig. 1), preventing groundwater discharge into the river. Thick frozen layers in early snowmelt periods forced meltwater to flow overland as "flow over ice," with river heat gradually thawing adjacent soils and recharging groundwater, leading to faster water table rises near the riverbanks (Fig. 2). Thus, key factors controlling runoff during freeze-thaw periods were soil frost depth, snowpack, initial thawing temperatures, and rainfall, while groundwater played a negligible role.

Soil water and nitrogen contents were monitored in October 2014 and October 2015, corresponding to the initial stages of the calibration and validation periods. Due to the absence of groundwater data for 2014–2015, data from the 2015–2016 period were used instead. Owing to data limitations, a model warm-up period was not implemented. The authors added a new section (4.4 Limitations and Perspectives), which includes an explanation of the uncertainties arising from relying solely on freeze-thaw period data for calibration and validation, as follows:

This study identified the combinations of climatic factors favored by snowmelt runoff and NO_3^--N export. Statistical data revealed that the precipitation during the freeze-thaw periods in 2015 and 2016 was 78.4 mm and 92.3 mm, ranking 14th and 10th respectively among the precipitation totals during the freeze-thaw periods within the 65-year span from 1952 to 2016, both of which can be categorized as relatively wet years. The calibration and validation of the SWAT model were solely based on snowmelt period data from two wet hydrological years. Although this approach aligns with the study's focus on significant water and nitrogen export dynamics, the absence of data from dry/average hydrological years and non-freeze-thaw periods could potentially introduce uncertainties in parameter estimation and model robustness. To address this, long-term annual monitoring in the region is essential to ensure that model calibration and validation encompass diverse hydrological conditions (e.g., wet, dry, and average years) and account for the influence of precipitation during non-freeze-thaw periods on water and nitrogen export processes during freeze-thaw periods, making the research results more representative. Additionally, although the small watersheds typified by the study area in this paper are major contributors to water and nitrogen output in this region, and identifying the combinations of climatic factors facilitating water and nitrogen output in such small watersheds can substantially ascertain those beneficial for regional water and nitrogen output, it must be acknowledged that the size of the studied watershed is inherently limited. As a result, the full applicability of the derived conclusions to large basins with a wider spectrum of land uses and soil types remains uncertain. Therefore, future research should focus on multi-scale analyses across watersheds with varying topographies, soil characteristics, and agricultural practices to verify the transferability of identified climate drivers.

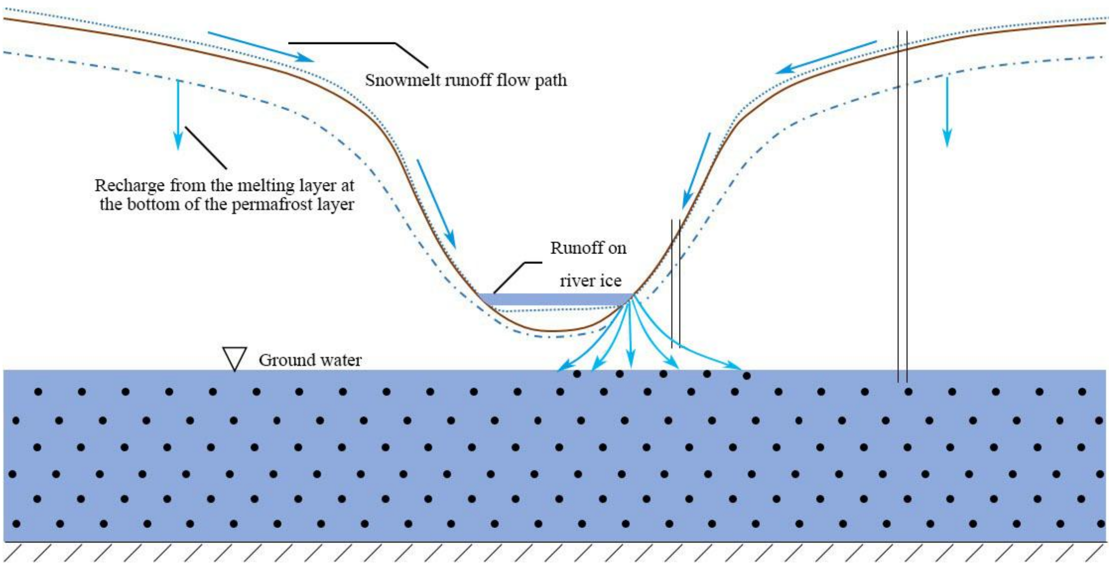

Fig 1 Hydrological processes during initial snowmelt period in the study watershed

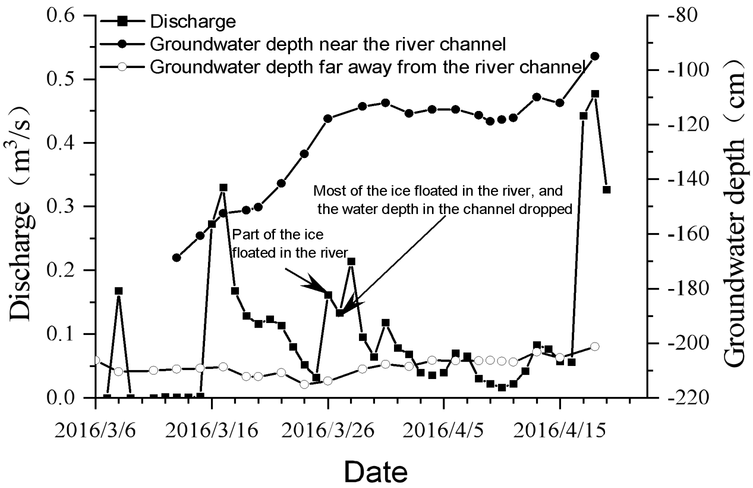

Fig. 2 Discharge and ground water depth during snowmelt period of 2016

Comment 3: Page 7, lines 158-164. I think you should add a few sentences to explain the reproducibility of the manual calibration approach used here. Are there other similar studies using manual calibrations you could cite to document the reasons for choosing this approach? Or, could you provide more details about the parameter combinations that were attempted and how optimal values were reached? I feel that calibrating 15 parameters for both discharge and NO3-N export would have a very large number of potential "optimal" parameter combinations to consider, so it would be helpful to expand on how this was achieved with this calibration approach, and what the limitations are. Also, an automated approach such as using R-SWAT (Nguyen et al., 2022) may help make the calibration more reproduceable.

Nguyen, T. V, Dietrich, J., Dang, T. D., Tran, D. A., Van Doan, B., Sarrazin, F. J., Abbaspour, K., and Srinivasan, R.: An interactive graphical interface tool for parameter calibration, sensitivity analysis, uncertainty analysis, and visualization for the Soil and Water Assessment Tool, Environ. Modell. Softw., 156, 105497, https://doi.org/10.1016/j.envsoft.2022.105497, 2022.

Response: We appreciate the reviewer's suggestion.. During the research, we attempted to use automated calibration and validation tools (e.g., SWAT-CUP) for calibrating and validating the SWAT model. However, we encountered critical limitations: the dataset was incomplete for a full annual cycle, and the start/end dates of the freeze-thaw periods in calibration and validation years were inconsistent, leading to the inapplicability of these tools.

Additionally, considering the limited data available for model calibration and validation, previous studies have demonstrated that automatic calibration of SWAT may bias parameter values toward optimization objectives (Zhang et al., 2009, 2011; Shi et al., 2011), potentially leading to unreliable performance in uncalibrated hydrologic variables. These factors necessitated our choice of manual calibration for SWAT parameters.

We recognize that the explanation of the manual calibration process and the citation of supporting literature were not fully elaborated in the manuscript. In response to your suggestion, we have supplemented Section 2.4.3 with relevant content to refine this part of the discussion, as follows:

This study only simulated snowmelt runoff during the snowmelt period. Therefore, the observed datasets of water discharge and NO_3^--N export during the snowmelt periods of 2014–2015 and 2015–2016 were used for calibration and validation, respectively. Considering that the data available for model calibration and validation were limited, and previous studies showed that calibrating SWAT using automatic methods may bias parameter values towards optimization objectives, leading to unintended model performance in other hydrologic variables that are not used for calibration (Zhang et al., 2009; Zhang et al.,2011; Shi et al., 2011). Therefore, in this study, we chose a manual calibration of SWAT parameters. Parameters were selected based on previous studies that used SWAT to simulate hydrology and non-point source pollution in cold regions (Ouyang et al., 2013; Grusson et al., 2015; Wang et al., 2016). Manual calibration was then performed by evaluating parameter sensitivity using the sensitivity analysis factor (SAF), calculated as follows:

$$S_{AF} = \frac{\Delta A / A}{\Delta F / F} \quad (5)$$

Where S_{AF} represents the sensitivity analysis factor; $\Delta F / F$ is the fractional change of the uncertain factor F; $\Delta A / A$ is the corresponding fractional change in the model output A.

A positive S_{AF} indicates a positive correlation between A and F, while a negative S_{AF} indicates an inverse relationship. The magnitude of S_{AF} reflects the degree of influence: larger values signify stronger impacts of F on A. The top 15 parameters most sensitive to streamflow and nitrate-nitrogen (NO_3-N) load were prioritized for calibration, as listed in Tables A1 and A2. Calibration followed a sequential two-step process: First, streamflow-related parameters were calibrated, proceeding from the highest to lowest sensitivity (Table A1). Subsequently, NO_3^--N related parameters were adjusted using the same sensitivity ranking while keeping streamflow-related parameters unchanged (Table A2). Each parameter was calibrated iteratively: after adjusting a parameter, model performance metrics were evaluated. If no significant improvement was observed, the next parameter was adjusted. This cycle repeated until all parameters were calibrated, and further iterations yielded negligible improvements in model performance.

References

Grusson Y., Sun X., Gascoin S., Sauvage S., Raghavan S., Anctil F., Sáchez-Pérez J.: Assessing the capability of the swat model to simulate snow, snow melt and streamflow dynamics over an alpine watershed. J. Hydrol. 531, 574-588, doi.org/10.1016/j.jhydrol.2015.10.070, 2015.

Ouyang W., Huang H., Hao F., Guo B.: Synergistic impacts of land-use change and soil property variation on non-point source nitrogen pollution in a freeze-thaw area. J. Hydrol. 495, 126-134, doi.org/10.1016/j.jhydrol.2013.04.037, 2013.

Shi, P., Chen, C., Srinivasan, R. et al.: Evaluating the SWAT Model for Hydrological Modeling in the Xixian Watershed and a Comparison with the XAJ Model. Water Resour. Manage. 25, 2595–2612, doi.org/10.1007/s11269-011-9828-8, 2011.

Wang Y., Bian J. M., Wang S. N., Tang J., Ding F.: Evaluating SWAT snowmelt parameters and simulating spring snowmelt nonpoint source pollution in the source area of the Liao River. Pol. J. Environ. Stud.;25(5):2177-2185, doi.org/10.15244/pjoes/63174, 2016.

Zhang X., Srinivasan R., Bosch D.: Calibration and uncertainty analysis of the SWAT model using Genetic Algorithms and Bayesian Model Averaging. J. Hydrol. 374(3–4):307–317, 10.1016/j.jhydrol.2009.06.023, 2009.

Zhang X., Srinivasan R., Arnold J., Izaurralde R. C., Bosch D.: Simultaneous calibration of surface flow and baseflow simulations: a revisit of the SWAT model calibration framework. Hydrol. Process. 25, 2313-2320, 10.1002/hyp.8058, 2011.

Comment 4: Page 8, line 168. I think more details about the principal components regression would be useful here. For instance, were data transformed? Was multicollinearity considered? Are there any references for the method you used?

Response: According to the co-relationship analysis between precipitation (P), starting day (SD), number of day (ND), and average temperature (T) of the unstable freezing period (USFP), stable freezing period (SFP), and snowmelt period (SMP) (Fig 6), significant multicollinearity exists among these climatic factors. Utilizing principal component regression (PCR) to mitigate this issue(Liu et al., 2003), we calculated the regression coefficients between climatic variables and runoff, runoff coefficients, and NO_3^--N export during different freeze-thaw periods to identify the major influencing factors. During the principal component regression analysis, both independent and dependent variables were standardized.

We appreciate the reviewer's suggestion, and add more information about the principal components in section 2.5, as follows:

Because there are multicollinear among climatic factors, the coefficients of principal component regression between climate factors and runoff, runoff coefficient, and NO_3^--N export were calculated using SPSS17 to identify the major affecting factors (Liu et al., 2003). The Mann-Kendall (MK) test method was used to analyze the variation trend of climate factors, snowmelt runoff and NO_3^--N export. A detailed calculation process of MK test method has been reported by Shi et al. (2019).

Reference:

Liu R. X., Kuang J., Gong Q., Hou X. L.: Principal component regression analysis with SPSS. Comput Methods Programs Biomed. 71(2):141-7, doi: 10.1016/s0169-2607(02)00058-5, 2003.

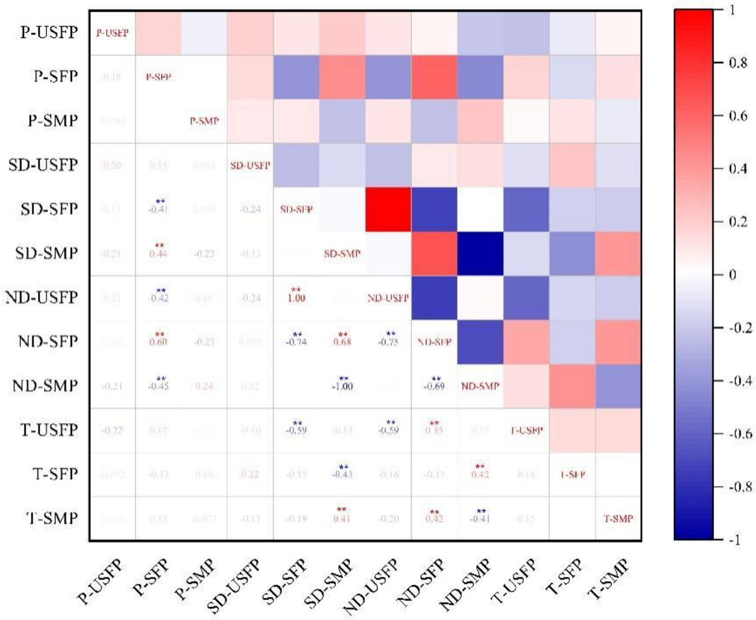

Fig. 6. Co-relationships between precipitation (P), starting day (SD), number of day (ND), and average temperature (T) of the unstable freezing period (USFP), stable freezing period (SFP), and snowmelt period (SMP).

Comment 5: Page 8, line 182. Simulating nitrate nitrogen export at the daily time step can certainly be difficult, but the NSE of -0.19 and Fig. 4 c-d suggest it is often not being simulated well, with lags in particular. However, it appears that the simulation could be alright at the weekly time step. Would it be better to aggregate results to a weekly time step for nitrate-nitrogen instead of daily, note that the higher temporal resolution was not achievable, and then continue using the weekly time step for nitrate-nitrogen model throughout the results section (e.g., the long term 1951-2014 model)? This could potentially lead to a better performing NO3-N model and also alleviate the need for the "NSE and R2 values when simulated values during the initial snowmelt period were put off a day" results and footnote of Table 2.

Response: We sincerely appreciate your constructive feedback. After aggregating the NO_3^--N export simulation results to the weekly scale, the model performance improved significantly. In line with your suggestion, we have revised the manuscript by converting all daily-scale

NO_3^--N export simulations to weekly-scale throughout the text and figures. The specific modifications are detailed as follows:.

Section 3.1: The performance of SWAT in modelling daily NO_3^--N export was not as good as that in modelling daily runoff. The *NSE*, R^2, and R_e values were -0.19, 0.44, and 2.7% for daily NO_3^--N export calibration and 0.35, 0.28, and -13.79% for validation, respectively. If NO_3^--N export results were aggregated to a weekly time step, the *NSE*, R^2, and R_e values were 0.28, 0.90, and 2.7% for NO_3^--N export calibration and 0.44, 0.46, and -13.79% for validation, respectively.

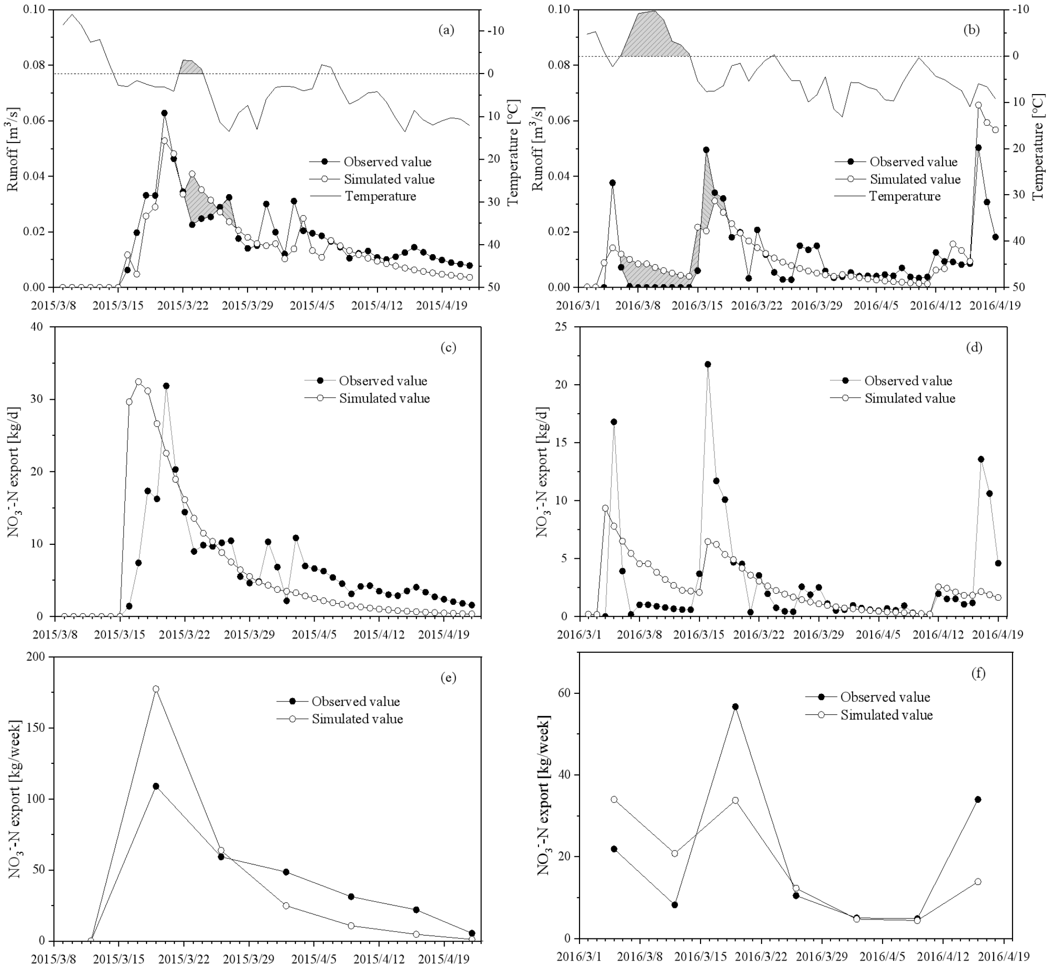

Fig. 4. Calibration and validation result of snowmelt runoff and NO_3^- -N export (a-d: daily; e-f: weekly). Shadow areas denote the differences induced by temperature variation.

Table 2. Performance evaluation of SWAT model

Model evaluation statistics	Calibration （2014–2015）		Validation（2015–2016）	
	Runoff	NO_3^--N Export	Runoff	NO_3^--N Export
NSE	0.75	-0.19 (0.28)[a]	0.54	0.35 (0.44)[a]
R^2	0.78	0.44 (0.90)[a]	0.51	0.28 (0.46)[a]
R_e	-12.76%	2.7%	15.65%	-13.79%

[a] *NSE* and R^2 values when simulated values during the initial snowmelt period were aggregated to a weekly step

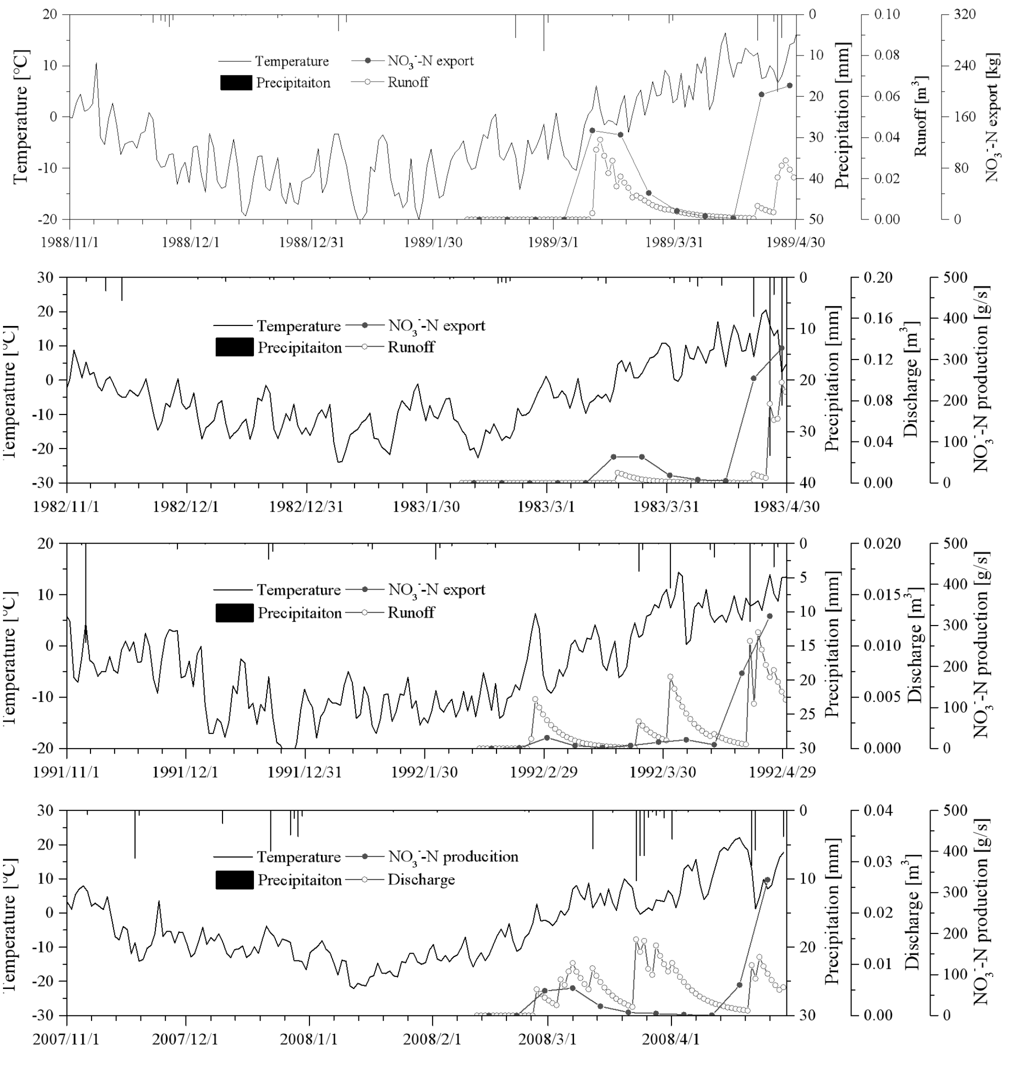

Fig. 11. Variation of climate factors, daily snowmelt runoff, and daily NO_3^--N export during the freezing-thawing period of years with highest NO_3^--N export.

Comment 6: Page 15, lines 261-265. This text basically states that the model did not simulate nitrate-nitrogen well, but in a hypothetical situation with better lags, in would have. I don't believe that supports the statement "Hence, the SWAT model is considered suitable for simulating daily NO_3^--N export during the snowmelt period." If the model is not simulating NO3-N well at the daily time step, I suggest as an alternative, aggregating to the weekly time step for NO3-N may potentially help alleviate this and lead to better performance.

Response: We sincerely appreciate your constructive feedback, and have aggregated the NO_3^--N export simulation results to the weekly scale. Relevant content has been revised, as follows:

NSE, and R^2 values of daily NO_3^--N export simulation are -0.19 and 0.44 for calibration, and 0.35 and 0.28 for validation, respectively, which are lower than those of daily snowmelt runoff simulation (Table 2). R_e values were 2.7% and -13.79% for daily NO_3^--N export calibration and validation, respectively. The lower *NSE* and R^2 values were mainly attributed to two reasons. As discussed above, the SWAT model does not consider the refrozen snowmelt water, which results in over- and underestimated NO_3^--N export during temperature drop and rise days during the initial snowmelt period (Bengtsson, 1982; Nie et al., 2017). The beginning of water and NO_3^--N export was earlier and higher in modeling value (Fig. 3) because the SWAT model did not involve the hysteresis effect of snow cover in the river channel on snowmelt runoff (Ouyang et al., 2013; Nie et al., 2017). However, if we aggregate results to a weekly time step for NO_3^--N export (Fig. 4e and 4f), the *NSE* and R^2 could reach 0.28 and 0.90 for calibration, and 0.44 and 0.46 for validation (Table 3), respectively. Therefore, the SWAT model showed certain deviations in simulating daily-scale nitrogen export during the snowmelt runoff period, yet it performed acceptably for weekly-scale simulations. In subsequent analyses, the nitrogen simulation results will be presented at the weekly scale. Fortunately, the model exhibited minimal bias in total nitrogen export over the entire freeze-thaw cycle (< 20%), validating its applicability for quantifying nitrogen fluxes during this period.

Comment 7: Page 15, line 286 to page 16, line 287. This statement could use clarification. Minorly, the "runoff and runoff" may be a typo? But more importantly, I believe that clarity is needed because the rain-on-snow melt was not simulated in the SWAT model of this study, only snowpack temperature-based melt, so it is confusing to me. Since rain-on-snow melt is mentioned as pertinent to the findings, I think it would be beneficial to clarify that it wasn't simulated here and mention any potential limitations. You may also discuss how simulating rain-on-snow melt (such as by using an energy balance approach; e.g., Zare et al., 2022) could provide further insights about these relationships.

Response: Thanks to the reviewer for pointing out the issues. We have revised "runoff and runoff" to "runoff and runoff coefficient". As response for comment 1, we may misunderstand the meaning of "Rain on snow." What we intended to convey by "rain on snowmelt" in this paper is not rainfall during the snowmelt period (when significant snow cover remains), but rather rainfall during the runoff period induced by snowmelt (when most snow has melted). In this paper, the events of "rain-on-snowmelt" is not involved, thus it is not discussed in detail. Instead, "rain-on-snowmelt" has been replaced with "rainfall". As follow:

To verify this conjecture, the variation in climate factors during the freezing-thawing period and daily snowmelt runoff during the snowmelt period for years with the highest runoff coefficient are shown in Fig. 9 of which four years had the highest runoff (Fig. 9a–9d). The average ND-SFP and SD-SMP of these 8 years was 112.62 and 73.25 days, which were 17.20 days longer and 8.95 days later, respectively, than the average value of the same in 1951–2014. In addition, the average PR-SFP of these eight years was 41.34%, which was 1.48 times of the average value for 1951–2014. On this basis, runoff and runoff coefficient would be quite high if rainfaill events occurred during the snowmelt period (Fig. 9a–9d). Therefore, based on the analysis of runoff and climate factor data from long series and typical years, it can be concluded that the years with a longer stable freezing period, later snowmelt period starting day, and higher rainfall during snowmelt are more likely to generate high snowmelt runoff.

Comment 8: Page 4, lines 101-102. For reproducibility, could you give a more specific description of the fertilizer and manure application rates you used based on the survey with farmers? Perhaps a couple sentences describing the application timings and rates that were used would help clarify this.

Response:Thank you for your suggestions. We have supplemented the relevant content, as follows:

The basic datasets required to set the model input files were the topography, land use, soil, and climatic data. The digital elevation model (DEM) used in the study area was obtained from the International Scientific Data Service Platform (wist.echo.nasa.gov) with a resolution of 30 × 30 m. Land use data (30 × 30 m) were obtained from the Landsat thematic mapper image data acquired in 2012. Soil data were obtained from the second soil survey conducted in Jilin Province. Daily climatic data (including precipitation, minimum and maximum temperatures, solar radiation, wind speed, and relative humidity) were obtained from the Shuangyang weather station which is 12 km away from the study area. The recording period was 1961–2016. Daily streamflow and NO_3^--N load datasets during the thawing period of 2014–2015 and 2015–2016 were obtained by flow discharge measurements and water sample collection and analysis at the watershed outlet. There was no point source pollution in the study watershed, and primary pollution loads were from rural domestic sewage and livestock farming. Domestic TN inputs [0.051 kg/(ha·day)] were calculated using per capita water consumption (150 L/d), sewage TN concentration (34 mg/L), and emission factors [0.6 kg/(man·a)], based on a population of 516 and area of 684 ha. Livestock contributions [0.226 kg/(ha·day)] were derived from animal counts and annual TN equivalents. Nitrogen fertilizer (375 kg/ha) was applied during the late snowmelt period (April 5 - 20).

Comment 9: Fig. 1. The font size for labels on the legend and scale bar is small and difficult for me to read. I suggest making it larger.

Response: Thank you for your suggestions. We have revised Fig. 1, as follows:

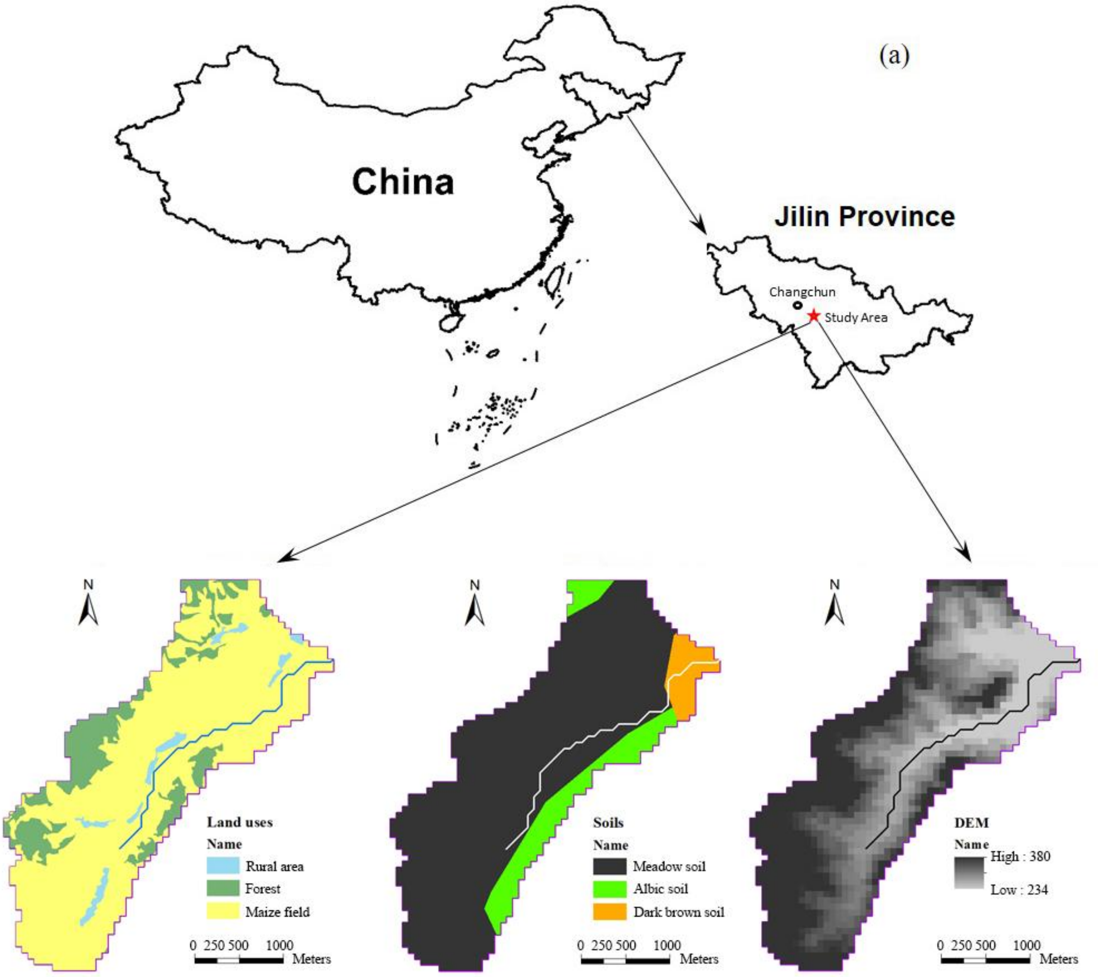

Fig. 1 Study site description. (a) Location of the watershed in China; (b) land uses, (c) soil, and (d) topography of the study watershed

Comment 10: Fig. 7. I really like the insights gained from this visualization.

Response: Thank you for your positive feedback on Fig. 7. Your appreciation motivates us to maintain rigorous standards in data presentation.

Comment 11: Page 17, line 319 to page 18, line 329. For the conclusions section, I think it would benefit readers to not use the acronyms (ND-SFP, etc.), or at least redefine them, so readers can understand the summary of the findings without having to find the all the definitions in the paper.

Response: Thanks for your suggestions. We have replaced these acronyms to full forms, as follows:

This study evaluated the application of the SWAT model to simulate the daily water and NO_3^--N export during the snowmelt period, identified the controlling climate factors, and confirmed their suitable combination to facilitate snowmelt water and NO_3^--N export. We found that the SWAT model performed well for *Re* values in simulating the daily snowmelt runoff and NO_3^--N export, but poorly for *NSE* and R^2 values in simulating NO_3^--N export. Number of days in the stable freezing period and precipitation during the stable freezing period controlled daily snowmelt runoff, while daily NO_3^--N export was mostly affected by precipitation during the snowmelt period. The combinations of climatic factors favored by snowmelt runoff and NO_3^--N export were different. Years with longer number of days in the stable freezing period and later starting days of snowmelt period were always accompanied by higher precipitation during the stable freezing period and lower negative cumulative temperature, which increased the amount of surface water available for runoff generation and the runoff coefficient. These combined effects increased the snowmelt runoff. Later appeared rainfall and higher temperature favored the formation of NO_3^--N during snowmelt period. High and concentrated rainfall events during the late snowmelt period provided a driving force for the export of these NO_3^--N. This research provides new insights into the effects of climate change on snowmelt runoff and accompanying NO_3^--N generation.