egusphere-2026-605 "Temperature dependence of the contribution of soil moisture to soil respiration and the soil respiration temperature threshold in a temperate deciduous forest"

Dear Dr. Timo Plaçais and Reviewers,

We sincerely thank you for your careful evaluation of our manuscript and for your constructive comments. We have carefully addressed all comments and revised the manuscript accordingly. Our detailed responses are provided below.

Summary

This study examines whether the contribution of soil moisture (SMC) to soil respiration (Rs) is temperature-dependent, using two years of continuous automated chamber measurements in a temperate deciduous forest under an Asian monsoon climate. Rs is measured as the total soil CO_2 flux, root and microbial contributions combined, and both Rs and the environmental drivers (Ts, SMC, precipitation) are aggregated to daily means before analysis, so that any sub-daily dynamics fall outside the scope of the study.

Four questions are addressed. Does a significant SMC–Rs relationship exist at the annual scale? Then daily means are considered for the following questions. Does its strength vary across temperature conditions? Does SMC explain additional Rs variability beyond what Ts alone accounts for? And can a formal breakpoint be identified in the Rs–Ts relationship, above which SMC contribution increases markedly? The first three questions are approached by fitting exponential Ts-only and Ts+SMC models within 5°C temperature bins, with ΔAdj. R^2 used to quantify the added contribution of SMC. The fourth uses segmented regression. A consistent breakpoint near 17°C emerges across both years, above which ΔAdj. R^2 rises to 0.21–0.62 depending on year and bin, compared to near-zero values below 15°C. The authors conclude that this threshold marks a reorganization of Rs controls, from temperature-dominated regulation at low Ts to a combined Ts–SMC structure at high Ts, and advocate for incorporating this temperature-dependence into carbon cycle models.

Response: We thank the reviewer for the clear and thoughtful summary of our study. We appreciate the reviewer's recognition of the value of the two year continuous dataset and the ecological relevance of our research question regarding the role of soil moisture in soil respiration. We have carefully considered all of the reviewer's comments and have addressed them in the revised manuscript. Our detailed responses are provided below.

Novelty and methodological concerns

The question is well-motivated and the dataset is genuinely valuable, two years of continuous high-frequency chamber data is not trivial to obtain, and the approach of stratifying by temperature bins to isolate the SMC contribution is sensible. The result that SMC contribution to Rs variability is negligible below ~15°C but substantial above it is ecologically meaningful and reasonably well-supported by the data.

My main concern is with how the breakpoint is identified. The authors define it as the temperature above which SMC contribution to Rs variability increases sharply, that is a statement about the explanatory power of moisture. But the breakpoint itself is estimated through segmented regression on the Rs–Ts curve, which identifies where the slope of Rs with respect to Ts changes. A change in slope in Rs~Ts can reflect nothing more than the curvature expected from a standard Arrhenius-type temperature response, and does not in itself say anything about moisture sensitivity. The variable that actually operationalizes the authors' question is ΔAdj. R^2 as a function of Ts (shown in Fig. 4), and it is on that curve that a breakpoint analysis should be performed. As it stands, the 17°C threshold is borrowed from a different analysis and applied to a question it was not designed to answer. This is a genuine methodological inconsistency, and the conclusions drawn from it are stronger than the framework supports.

Beyond this, the single-site design limits how far the 17°C value can be generalized, and the absence of Rs partitioning makes the mechanistic interpretation difficult to pin down, the breakpoint could reflect a phenological transition in root activity just as well as a moisture threshold for microbial metabolism.

Interpretation

The biological interpretation is largely consistent with established understanding. The invocation of substrate diffusion limitation under dry conditions, oxygen constraint under waterlogged conditions, and temperature-dependent stimulation of microbial and root activity is appropriate and well-referenced. Individual claims do not overreach the data.

Throughout the manuscript, the breakpoint in the Rs–Ts relationship is equated with a threshold in SMC sensitivity, and this equivalence is used to argue for a "reorganization of the dominant control structure governing Rs." This conclusion is repeated in the abstract, results, discussion and conclusions, but the logical bridge between the two analyses is never formally established. A change in slope in Rs~Ts does not imply a change in the variance of Rs explained by SMC, this would require additional assumptions that are neither stated nor tested. The bootstrap test confirms that the segmented model fits Rs~Ts better than an exponential; it says nothing about SMC sensitivity. More cautious phrasing throughout, acknowledging that the two lines of evidence converge suggestively without being formally linked, would substantially strengthen the manuscript.

A further interpretive gap concerns causal attribution. The strengthening of the SMC–Rs relationship above 15–17°C likely coincides with leaf-out and the onset of root activity, both of which covary with Ts and SMC in this monsoon system. Without autotrophic/heterotrophic partitioning, it is not possible to determine whether the breakpoint reflects a moisture threshold for microbial activity, a phenological transition in root respiration, or both. This ambiguity deserves more prominent acknowledgment than it currently receives.

Response: We thank the reviewer for this thoughtful and constructive comment. We agree that,

in the original version, the breakpoint identified from the Rs–Ts relationship and the temperature dependent increase in the contribution of SWC to Rs variability were not sufficiently distinguished. As the reviewer correctly noted, the breakpoint near 17°C was estimated from segmented regression of the Rs–Ts relationship, whereas the temperature dependent contribution of SWC was evaluated separately from model comparisons across temperature bins using ΔAdj. R^2 and ΔAIC. We therefore agree that the breakpoint should not be interpreted as a formal threshold in SWC sensitivity.

In response, we revised the manuscript throughout to clearly separate these two lines of evidence and to moderate our interpretation accordingly. In the revised Methods, we now clarify that the estimated breakpoint was interpreted as a reference temperature indicating a structural change in the Rs response to Ts, while temperature dependent changes in the relative contribution of SWC were evaluated separately. In the revised Discussion, we also explicitly state that the breakpoint in the Rs response to Ts does not directly represent a threshold in SWC sensitivity. We now emphasize that the two patterns occur over a similar temperature range and may together suggest a possible shift in the relative importance of controls on Rs, but that this inference is suggestive rather than formally demonstrated.

We also agree that the ecological interpretation of the breakpoint should be made cautiously. In the revised manuscript, we now state more explicitly that the single site design limits the extent to which the identified breakpoint near 17°C can be generalized. In addition, because Rs was not partitioned into autotrophic and heterotrophic components, mechanistic interpretation remains limited. We therefore explicitly acknowledge that the observed breakpoint may reflect not only moisture related constraints on microbial activity but also seasonal or phenological changes in root activity, or both. We believe that these revisions improve the consistency between our analytical framework and the scope of our interpretation.

Specific comments

27–28 — The authors invoke increasing extreme hydrological events as a motivation for the study, yet daily averaging of SMC and Rs is likely to dampen the very transient responses they allude to — most notably the Birch effect. Could the authors comment on whether rewetting pulses occurred during the study period, and how their representation may have been affected by the temporal aggregation applied?

Response: We thank the reviewer for this helpful comment. We agree that daily averaging can dampen very short lived post rainfall responses, including Birch type pulses. In response, we clarified in the Methods that daily aggregation was used to reduce the influence of these transient responses and to better evaluate the broader effect of SWC on Rs across temperature conditions. We also added to the Results that short term increases in Rs were observed following rainfall related increases in SWC during the study period.

"Because rainfall can induce very brief increases in soil respiration immediately after rewetting, including Birch type pulses (Xu et al., 2004), daily aggregation was used to reduce the influence of these transient responses and to better evaluate the broader effect of SWC on Rs across temperature conditions"

"Additionally, short term increases in Rs were observed following increases in SWC after rainfall during the study period. Specifically, Rs tended to increase on the day of rainfall and on the following day, and a similar increasing pattern was also observed at 0, 1, and 2 h after rainfall at the hourly scale"

"Although short term increases in Rs were observed following rainfall, daily averaged data were used to reduce the influence of these transient responses and to more clearly evaluate the broader effect of SWC on Rs across temperature conditions"

64–65 — The authors acknowledge that SMC effects on Rs depend strongly on timescale, yet daily averaging may itself attenuate the moisture signal they seek to quantify. The manuscript implicitly positions daily resolution as an improvement over annual-scale studies, but does not discuss what temporal resolution would be needed to fully resolve moisture–respiration dynamics near the identified threshold. This point deserves explicit treatment.

Response: We thank the reviewer for this important comment. We agree that the influence of SMC on Rs depends strongly on temporal resolution. In the revised manuscript, we clarified in the Introduction that annual aggregation can mask short term and condition dependent effects of SMC by averaging across heterogeneous seasonal conditions. We also explained that daily resolution was used to evaluate the broader effect of SWC on Rs under comparable temperature conditions, while explicitly acknowledging that daily averaging can still attenuate very short lived post rainfall responses.

"It has been reported that the extent to which SWC explains variability in Rs depends strongly on time scale, phenological state, and temperature conditions(Kim et al., 2019; Podzikowski et al., 2025). Accordingly, analyses based on annual aggregation can mask short term and condition dependent effects of SWC by averaging across heterogeneous seasonal conditions"

185 — The SMC thresholds reported (10.8% in 2022, 13.1% in 2023) lack a methodological basis in the text. Were these derived from the fitted quadratic fonction, from a formal changepoint procedure, or from graphical inspection? A clarification is needed for reproducibility.

Response: We thank the reviewer for this comment. In the revised manuscript, we clarified that the reported SMC values were derived as the SWC values at which the quadratic function reached its minimum in each year.

"Based on the quadratic regression, the SWC value corresponding to the minimum of the quadratic function was estimated at approximately 10.8% in 2022 and 13.1% in

2023 (Fig. 2)"

Figure 5 — A change in slope in Rs~Ts may simply reflect the curvature of an Arrhenius-type temperature response rather than any shift in moisture sensitivity, raising the possibility that the identified breakpoint is an artefact of the functional form rather than an ecological threshold. A more direct test, for instance, examining at what temperature the residual variance of Rs (after Ts removal) begins to increase significantly, would more rigorously operationalize the authors' question. Adding SMC as a color overlay on the Rs–Ts scatterplot would also allow readers to visually assess moisture modulation across the temperature range.

Response: We thank the reviewer for this important comment. We agree that the breakpoint identified from the Rs–Ts relationship should not be interpreted directly as a threshold in moisture sensitivity, because a change in slope may also reflect the curvature of the temperature response itself. In the revised manuscript, we therefore moderated the interpretation throughout the text and clarified that the breakpoint was identified from the Rs response to Ts, whereas the temperature dependent contribution of SWC was evaluated separately using model comparisons across Ts bins. We also added a supplementary figure showing the residuals of the Ts only model plotted against Ts, with SWC indicated by color (Fig. S2). This figure provides a visual assessment of the variation not explained by Ts alone. Residuals were relatively more constrained at lower Ts, but tended to be more widely distributed in the warmer temperature range, including near and above the estimated breakpoint. However, this pattern is only suggestive and does not constitute a formal test of a threshold in SWC sensitivity. Accordingly, we revised the relevant text and now interpret the breakpoint more cautiously as a reference temperature in the Rs response to Ts, rather than as a direct ecological threshold in SWC sensitivity.
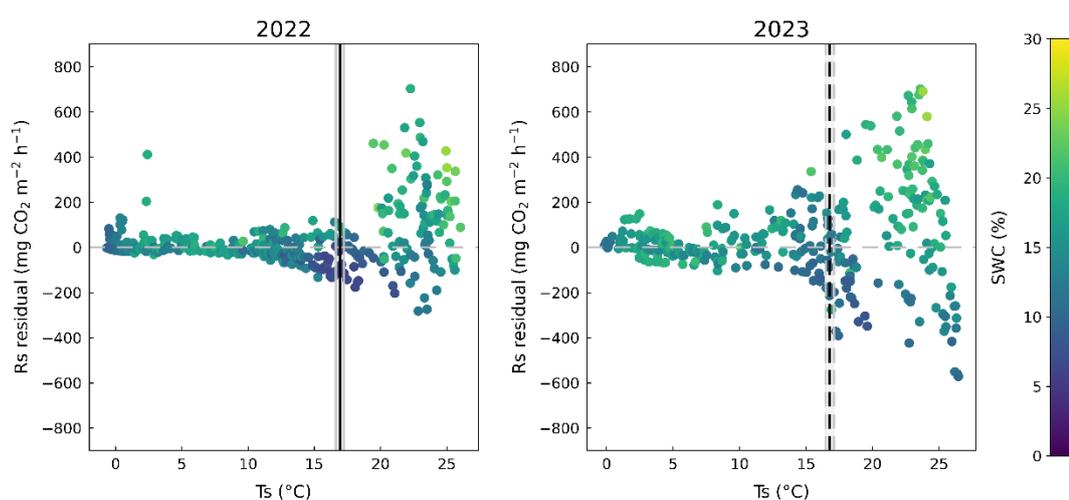

Figure S2: Relationship between Ts and residuals of Rs in 2022 and 2023. Residuals were calculated as observed Rs minus Rs predicted by the Ts only model. Points are colored by SWC. Vertical lines indicate the estimated breakpoint in the Rs response to Ts for each year, and the horizontal line indicates zero residual.