

Authors' reply to the reviewer's comments:

Dear Referee,

Thank you for your careful review of the manuscript and for your constructive comments and suggestions. We have carefully considered each comment and revised the manuscript accordingly. Our detailed point-by-point responses are provided below, with the referee's original comments presented in bold.

Comments from the Referee #1:

This manuscript presents a grain-size-informed framework for constructing and extending turbidity—SSC relationships in the Kuoqiongqangri Glacier Basin on the Tibetan Plateau. The study combines continuous turbidity monitoring, paired SSC sampling, suspended sediment grain-size analysis, and controlled laboratory mixing experiments at the glacier terminus and basin outlet. The authors show that turbidity—SSC relationships differ among snowmelt-, glacier melt-, and rainfall-dominated periods and attribute much of this variability to changes in suspended-sediment grain-size composition. They further demonstrate that direct extrapolation of conventional turbidity—SSC curves perform poorly, whereas extrapolation based on grain-size composition substantially improves SSC estimates.

Overall, I think the manuscript addresses an important observational problem in glacier-fed rivers, where high turbidity events are difficult to sample directly. The combination of field observations and laboratory experiments is interesting, and the proposed framework has potential value for sediment monitoring in remote glacier basins. The manuscript is generally well structured, the overall logic is clear, and the main results are convincing. I believe the manuscript has the potential for

publication, but the following issues should be addressed before it is suitable for publication.

1. **Methods and materials:** The overall workflow of the study is not immediately clear from the Methods section. My understanding is that the authors first establish relationships between turbidity and grain-size composition using field samples, extrapolate the proportions of individual grain-size fractions to higher turbidity levels, prepare laboratory sediment mixtures according to these extrapolated compositions, establish a corresponding turbidity—SSC curve for each composition, and finally determine the SSC corresponding to a target turbidity. I suggest that the authors provide a simple workflow diagram at the end of Sect. 2.5 to summarize the complete methodological framework. This would be helpful for readers, although it is not essential.

Response: Thank you for this helpful suggestion. To improve the clarity of the Methods section, a simple workflow diagram (Fig. 2) has been added at the end of Sect. 2.5 to summarize the overall methodological framework of the study. Because the new figure has been inserted as Fig. 2, the original figures have been renumbered accordingly: the original Fig. 2, Fig. 3, Fig. 4, and Fig. 5 are now Fig. 3, Fig. 4, Fig. 5, and Fig. 6, respectively, and all corresponding citations in the manuscript have been updated (Lines 324, 334, 350, 373, 388, 460, 461, 490, 498, 505, 507, 530, 537).

The new schematic explicitly presents the main steps of the approach, including: (1) continuous turbidity monitoring and paired SSC sampling; (2) classification of observations into snowmelt-, glacier melt-, and rainfall-dominated periods; (3) analysis of the main controls on turbidity—SSC relationships, with particular evaluation of particle size and organic matter through laboratory experiments; (4) establishment of relationships between turbidity and the proportional composition of individual grain-size fractions using field samples; (5) extrapolation of grain-size proportions to higher turbidity levels; (6) preparation of laboratory sediment mixtures according to the

extrapolated grain-size compositions and construction of the corresponding turbidity–SSC curves; and (7) determination of SSC for each target turbidity, thereby extending the field-derived turbidity–SSC relationships beyond the range constrained by paired field samples.

In addition, a short paragraph has been added at the end of Sect. 2.5 to introduce this workflow and to guide the reader through the logic of the framework. We agree that this addition improves the readability of the Methods section and clarifies how the field observations and laboratory experiments were integrated in the study: “The overall workflow diagram is summarized in Fig. 2. (Line 288)”.

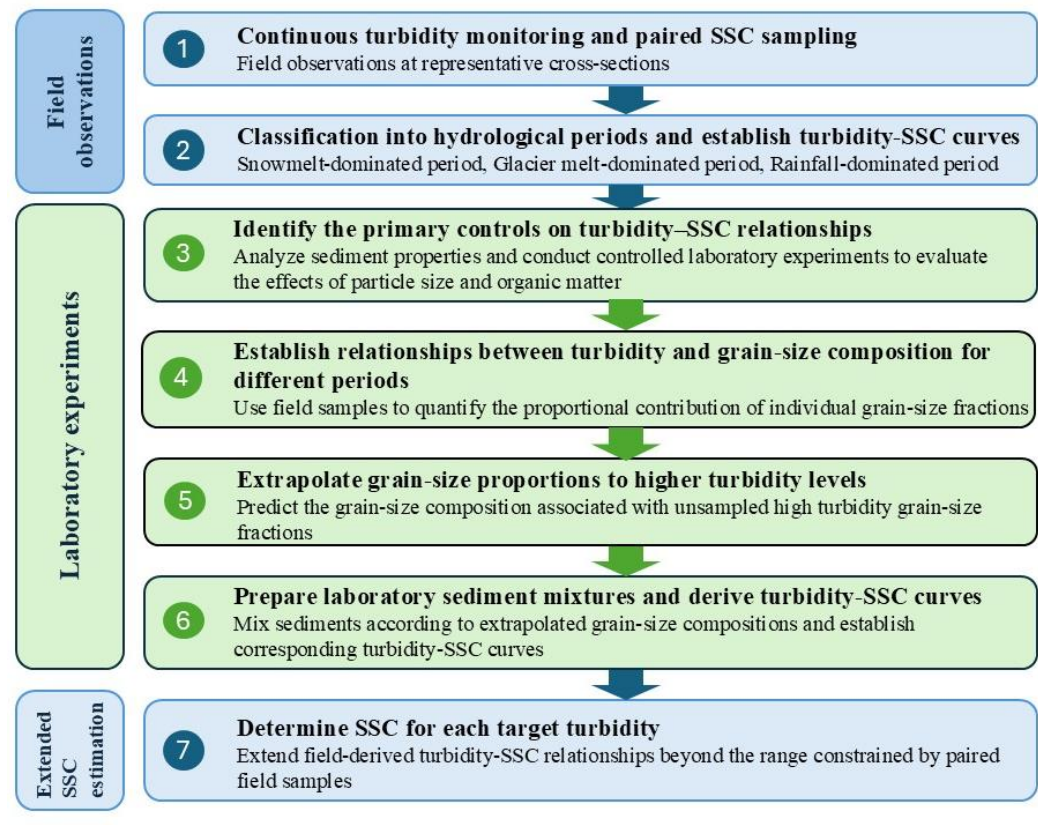


Fig. 2 The workflow diagram

2. Lines 182-183: The manuscript states that the snowmelt-, glacier melt-, and rainfall-dominated periods were classified based on turbidity, air temperature, precipitation, and related observations, while readers are mainly referred to Liu et al. (2025), which appears to be a previous study by the authors. Because

this classification forms the basis for establishing the period specific turbidity—SSC relationships, I suggest briefly summarizing the main classification criteria in either the manuscript or the Supplement.

Response: Thank you for this helpful comment. We agree that the criteria used to distinguish the three hydrological periods should be described more explicitly in the present manuscript because this classification provides the basis for the period specific turbidity—SSC relationships. We have therefore added a concise summary of the classification criteria as Text S1 in the Supplement and cited this new supplementary text at the corresponding location in the main manuscript (Line 185).

Specifically, the snowmelt-, glacier melt-, and rainfall-dominated periods were identified based on the combined temporal variations in turbidity, air temperature, precipitation, and associated hydrometeorological conditions. The newly added Text S1 briefly explains how these observations were used to distinguish the dominant runoff-generating process during each period, while Liu et al. (2025) is retained as the reference for the detailed classification procedure.

Because the new classification description has been inserted as Text S1, the original supplementary sections have been renumbered accordingly: the original Text S1, Text S2, and Text S3 are now Text S2, Text S3, and Text S4, respectively, and all corresponding citations in the manuscript and Supplement have been updated (Lines 220, 287, 476).

We believe that these revisions make the basis for the hydrological-period classification clearer and improve the reproducibility of the subsequent period-specific turbidity—SSC analysis.

“Text S1:

Delineation of snowmelt-, glacier melt-, and rainfall-dominated events

On the basis of meteorological and hydrological observations and remote sensing snow cover data for the Kuoqionggangri Glacier Basin, suspended sediment transport events dominated by different factors were classified according to the following criteria:
(1) A typical snowmelt event occurs when the snow cover area on a given day exceeds

that on the following day. Statistical analysis revealed that for a daily maximum temperature at the glacier terminus (DMTGT) $\geq 7^{\circ}\text{C}$, the suspended sediment concentration at the river basin outlet significantly increased during snowmelt events. Moreover, full consideration was given to the rationale for excluding glacier melt under this condition. (2) Rainfall events are defined by 24-hour rainfall ≥ 10 mm. (3) Measurements of the glacier terminus temperature and the suspended sediment concentration at the river basin outlet revealed that Glacier melt events happen with temperatures at the glacier terminus higher than that of snowmelt. Specifically, for DMTGT $\geq 9^{\circ}\text{C}$, there was a significant increase in the suspended sediment concentration at the river basin outlet during period without snowmelt or rainfall events. Consequently, DMTGT $\geq 9^{\circ}\text{C}$ was employed to identify glacier melt dominance (Liu et al., 2025).”

3. **Line 192: Please provide the number of field SSC samples corresponding to each cross section and hydrological period. The manuscript states that a total of 370 suspended sediment samples were collected, but it does not indicate how these samples were distributed among the six combinations of cross-section and hydrological period. Since the number and distribution of observations may affect the fitted relationships and their reported coefficients of determination (R^2), it would be helpful to provide the sample size (n) for each group in the main text, Fig. 2, or a supplementary table. In addition, the reported R^2 values for the period-specific relationships range from 0.78 to 0.98, and the rainfall-period relationship at the glacier terminus ($R^2 = 0.78$) is actually lower than the corresponding full-period relationship ($R^2 = 0.85$). This may partly be related to sample size. Therefore, rather than stating that stratification always improves the fit, the authors may wish to indicate that stratification generally improves the relationships and, more importantly, reveals systematic differences among hydrological periods.**

Response: Thank you for this careful and helpful comment. We agree that the distribution of field samples among the different cross-sections and hydrological periods should be reported explicitly because sample size may affect the robustness of the fitted turbidity–SSC relationships. Although a total of 370 suspended-sediment samples were collected, the original manuscript did not provide the sample number for two cross-sections at three periods. We have therefore added the corresponding sample sizes in Sect. 3.2 and Fig. 3 (the original Fig. 2):

“Fig. 3(a) shows the field-derived turbidity (y)–SSC (x) relationships at the glacier terminus and basin outlet when all observations were pooled without accounting for hydrological period differences. Clear differences were observed between the two cross-sections. At the glacier terminus, the fitted relationship is $y = 0.0012x^{1.26}$ ($R^2 = 0.85$, $n=96$), whereas at the basin outlet it is $y = 0.0008x^{1.22}$ ($R^2 = 0.86$, $n=274$). (Lines 324-328)”

“For example, at the glacier terminus, the fitted relationships are $y = 0.0021x^{1.15}$ ($R^2 = 0.98$, $n=56$) during the snowmelt period, $y = 0.0032x^{1.18}$ ($R^2 = 0.92$, $n=15$) during the glacier melt period, and $y = 0.0017x^{1.12}$ ($R^2 = 0.78$, $n=25$) during the rainfall-dominated period. At the basin outlet, the fitted relationships are $y = 0.0007x^{1.29}$ ($R^2 = 0.96$, $n=115$) during the snowmelt period, $y = 0.0024x^{1.07}$ ($R^2 = 0.94$, $n=95$) during the glacier melt period, and $y = 0.0007x^{1.16}$ ($R^2 = 0.93$, $n=64$) during the rainfall-dominated period. (Lines 337-342)”

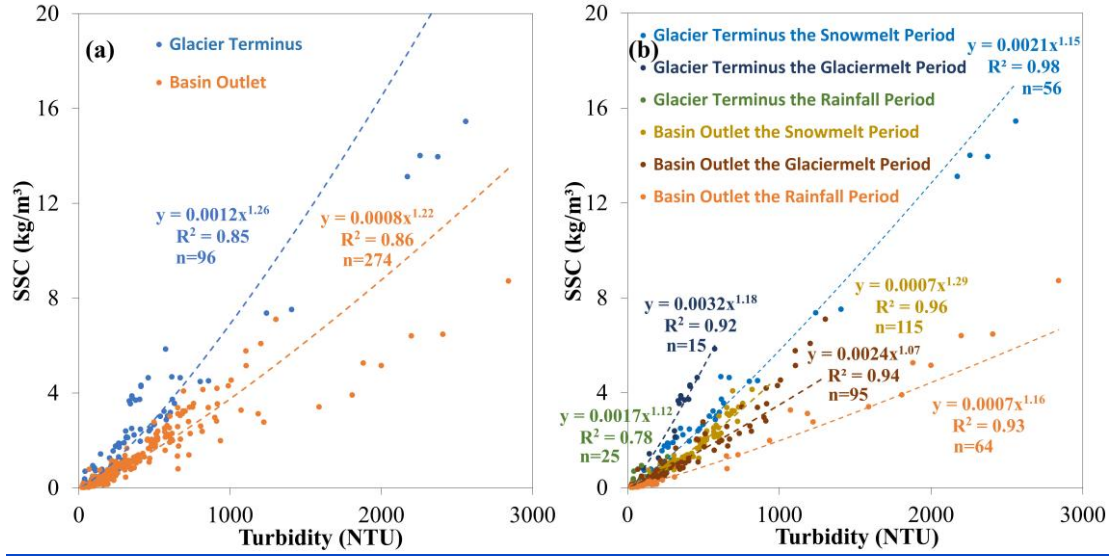


Fig. 3. (a) Field-observed turbidity–SSC relationship; (b) fitted turbidity–SSC relationships for the three periods at the two cross-sections

This information allows readers to more clearly evaluate the observational basis of each period-specific regression.

We agree that the original wording overstated the improvement resulting from hydrological-period stratification. Although most period-specific relationships showed high coefficients of determination, the rainfall-period relationship at the glacier terminus had an R^2 of 0.78, which was lower than the R^2 of 0.85 obtained from the full-period relationship at that cross-section. The relatively lower R^2 may partly reflect the number and distribution of samples, together with greater variability in sediment characteristics during rainfall conditions; however, we have avoided attributing this difference solely to sample size.

Accordingly, we have revised the relevant statements in the Abstract, Sect. 3.2, and Conclusion to avoid implying that stratification invariably improves goodness of fit. The revised text now emphasizes that period-based stratification generally improves the fitted relationships and, more importantly, reveals systematic differences in turbidity–SSC relationships among contrasting hydrological regimes.

The corresponding sentence (Lines 23-25) in Abstract has been revised to:

“Relative to the full-period curves ($R^2=0.85\sim0.86$), period-specific curves generally showed improved fits, with the highest R^2 reaching 0.98. (Lines 23-25)”

The corresponding sentence (Lines 342-346) in Sect. 3.2 has been revised to:

“After stratification by dominant hydrological regime, the goodness of fit of the period-specific power-law relationships generally improved, although performance varied among periods. These results indicate that process-based stratification better captures the variability in turbidity–SSC relationships under contrasting runoff and sediment-supply conditions. (Lines 342-346)”

We believe these revisions provide a more complete description of the sampling basis and a more accurate interpretation of the effect of hydrological-period stratification.

- 4. The rationale for selecting the two cases used to test direct extrapolation could be explained more explicitly. The manuscript uses the snowmelt period at the glacier terminus and the rainfall period at the basin outlet to compare observed SSC with SSC extrapolated from relationships fitted using turbidity values below 1400 NTU. I understand that these two cases were selected because they cover relatively wide turbidity ranges, but it would be useful to clarify whether they are sufficiently representative of the general extrapolation problem observed during the other hydrological periods.**

Response: Thank you for this helpful comment. We agree that the rationale for selecting these two cases should be explained more explicitly. The snowmelt period at the glacier terminus and the rainfall period at the basin outlet were selected because both datasets span relatively wide turbidity ranges and contain sufficient paired turbidity–SSC observations within both the low-turbidity fitting range (<1400 NTU) and the medium-turbidity validation range (1400–3000 NTU). This allowed the turbidity–SSC relationships to be fitted using only the low-turbidity observations and their extrapolation performance to be evaluated directly against field observations in the higher-turbidity range that were not used for fitting.

We have also clarified that the thresholds used to define the fitting and validation

ranges are not fixed or universally applicable. The <1400 NTU and 1400–3000 NTU ranges were adopted for these two illustrative cases because of their observational coverage. For two cross-sections at other periods, the fitting and validation ranges may differ according to the available paired observations and their turbidity distributions. To further clarify this point, we have added Fig. S5 to the Supplement, which provides additional fitting–validation tests for two cross-sections at other periods and demonstrates that direct extrapolation of the fitted turbidity–SSC curves generally result in relatively low predictive accuracy. The figures in the Supplement have also been renumbered accordingly.

In addition, we now explicitly state that these two cases are intended as illustrative validation examples rather than exhaustive representations of all hydrological periods. Their purpose is to demonstrate the potential uncertainty associated with directly extrapolating a turbidity–SSC relationship beyond its calibration range. In both cases, predictive performance deteriorated substantially after extrapolation, with NSE values of 0.11 and –0.67, respectively. These results indicate that a relationship calibrated under relatively low-turbidity conditions may not remain applicable at higher turbidity when suspended-sediment characteristics change.

Accordingly, the relevant text in Sect. 3.2 and Fig. S5 in the Supplement has been added as follows:

“The two cases were used as illustrative examples rather than as exhaustive representations of all hydrological periods. The thresholds separating the fitting and validation ranges are not fixed; for other cases, they were adjusted according to the available paired observations and their turbidity distributions. (Lines 367-370)”

“Similar fitting–validation tests for two cross-sections at other periods, using turbidity ranges defined according to their respective observational coverage, are presented in Fig. S5. (Lines 378-380)”

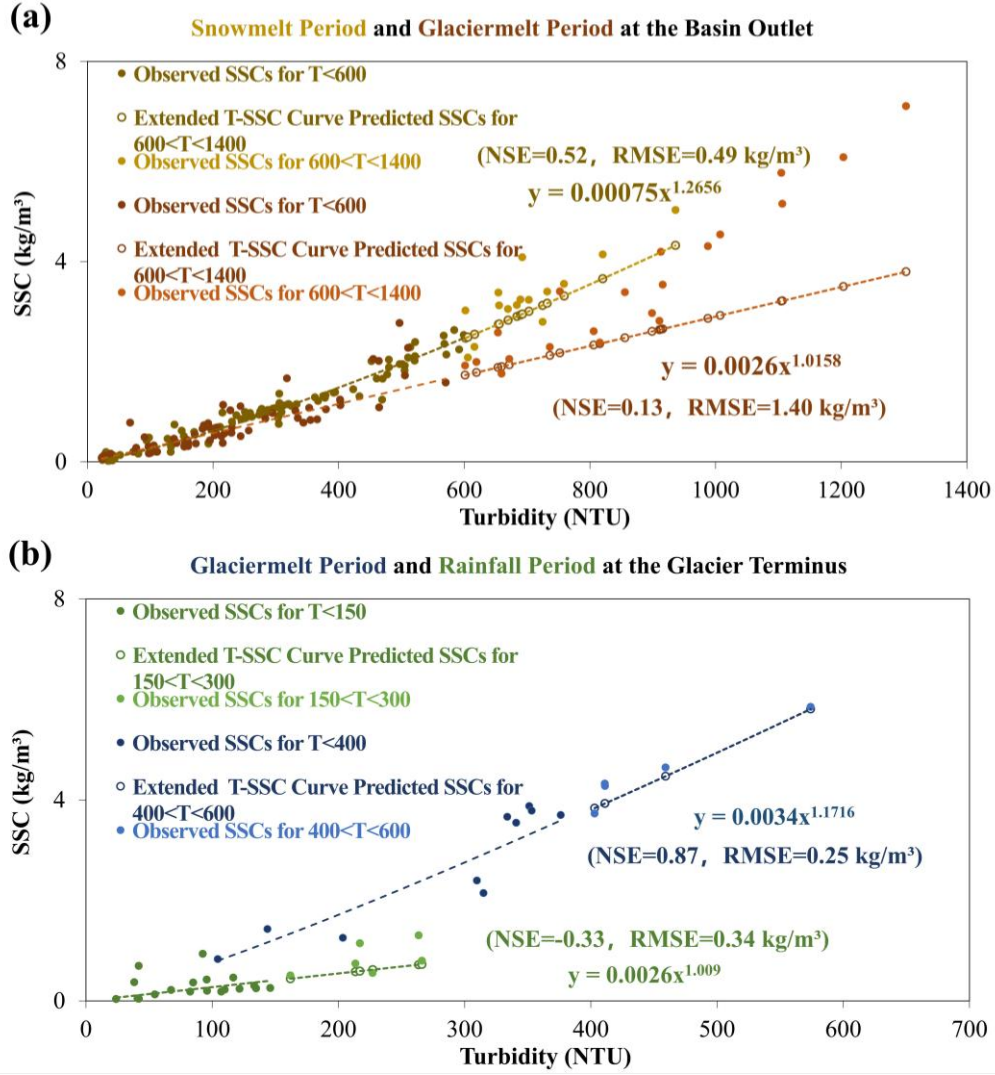


Fig. S5. Validation of extrapolated turbidity–SSC relationships for two cross-sections at other periods

We believe that these revisions clarify both the rationale for selecting the two illustrative cases and the intended application of the fitting–validation procedure under different observational conditions.

5. The terminology “grain-size distribution” and “grain-size composition” should be used more consistently throughout the manuscript. In particular, “grain-size composition” appears to refer specifically to the proportional contribution of individual grain-size fractions. I suggest clearly defining these two terms and then using them consistently throughout the manuscript. This

would also help clarify why Group A uses (D₅₀) as a summary metric, whereas Group C explicitly considers multiple grain-size fractions.

Response: Thank you for this helpful comment. We agree that the distinction between “grain-size distribution” and “grain-size composition” should be made explicit and used consistently throughout the manuscript. We have therefore revised the terminology accordingly.

In the revised manuscript, “grain-size distribution” refers to the overall distribution of suspended sediment particle sizes within a sample, whereas “grain-size composition” refers specifically to the proportional contribution of the predefined grain-size fractions used in the subsequent analysis and laboratory proportioning experiments. This distinction has now been clarified when these terms are first introduced, and their usage has been checked throughout the manuscript for consistency.

We have also clarified the different roles of grain-size information in Groups A and C. In Group A, D₅₀ was used as a summary descriptor to compare source materials with contrasting characteristic particle sizes and to identify the overall influence of particle size on turbidity–SSC relationships. In contrast, Group C was designed to reproduce and extend field-derived turbidity–SSC relationships, for which changes in the relative proportions of individual grain-size fractions are important. Therefore, the full grain-size composition, rather than a single characteristic size such as D₅₀, was explicitly considered in Group C. This distinction is consistent with the experimental design described in the manuscript.

The corresponding methodological text has been revised to make this distinction clearer.

Specifically, the following clarification has been added after the description of Group C in Sect. 2.4:

“In this study, grain-size distribution refers to the overall distribution of particle sizes within a sediment sample, whereas grain-size composition refers to the proportional contribution of the individual grain-size fractions. D₅₀ was used in Group

A as a summary metric to compare the characteristic particle sizes of different source materials, whereas the proportional composition of multiple grain-size fractions was explicitly considered in Group C to reproduce and extend the field-derived turbidity–SSC relationships. (Lines 257-262)”

We believe these revisions improve terminological consistency and make the respective purposes of the Group A and Group C experiments clearer.

6. **Several minor language and formatting issues should be checked throughout the manuscript. For example, “in situ” should generally be written without a hyphen; numerical ranges such as “1400—3000 NTU” are clearer and more standard than “1400~3000 NTU”; and section titles such as “2 Method and materials” and “3 Result” could be revised to “2 Materials and methods” and “3 Results”. A careful language and formatting check would further improve the manuscript. In addition, the use of hyphens in compound modifiers such as “grain-size-informed”, “field-derived”, and “power-law” should be made consistent, and the formatting of units such as kg/m³ and percentages should also be standardized throughout the manuscript.**

Response: Thank you for this careful comment. We have conducted a systematic language and formatting check throughout the manuscript and Supplement and have revised the relevant inconsistencies.

Specifically, the following changes were made: (1) “in-situ” was standardized to “in situ” throughout the text; (2) numerical ranges previously expressed using “~” were replaced with “—”, for example, “1400–3000 NTU”; (3) the section titles “2 Method and materials” and “3 Result” were revised to “2 Materials and methods” and “3 Results”, respectively; (4) hyphenation of compound modifiers was standardized, including terms such as “grain-size-informed,” “field-derived,” “laboratory-derived,” “period-specific,” and “power-law”; and (5) units and numerical formatting were standardized throughout the manuscript, including changing concentration units to

kg/m³ and applying a consistent format to percentages.

We also checked the manuscript for related typographical, grammatical, capitalization, and spacing inconsistencies and corrected them where necessary. We believe that these revisions have improved the overall consistency and readability of the manuscript.