
We sincerely thank the reviewer for the constructive comments and suggestions. These comments have greatly helped us improve the clarity and scientific rigor of the manuscript. We have carefully revised the manuscript according to all comments. Below we provide detailed responses to each comment. All responses made are highlighted *in blue* color in the following remarked.

In the context of global change, carbon-water flux coupling is a critical and lasting research topic. This study by Gao et al. evaluates carbon and water fluxes in an alpine meadow ecosystem on the eastern Tibetan Plateau, using six years of eddy covariance data. While the topic fits the scope of Biogeosciences, I have concerns regarding the data sufficiency, the novelty of the scientific conclusions, and the overall quality of the manuscript. My detailed comments are as follows:

General comments

Comment 1

The study relies on a single EC flux site, which is insufficient to capture the vast spatial extent and functional diversity of alpine meadows across the Tibetan Plateau. Furthermore, while a six-year dataset is inherently valuable, it may not span a long enough period to adequately characterize inter-annual climate variability or provide robust conclusions on long-term trends.

Response

We are grateful to the reviewers for their valuable comments. We also agree that six years of observational data are indeed insufficient to characterize the interannual scale variation features. However, these six years of observational data have certain representativeness in terms of the time scale and also have a certain regional representativeness in the spatial scale. Meanwhile, the focus of the article's analysis is on the daily and monthly time scales, and the research on the interannual scale is very limited and weak.

First, the dataset has temporal representativeness. According to the long-term climate record (1967–2020) at the Maqu meteorological station, the temperature during the study period (2012–2017) represents typical climatic conditions of the region. Meanwhile, precipitation during these six years includes three relatively wet years, two relatively dry years, and one near-average year, thus covering a range of hydroclimatic conditions and allowing us to explore ecosystem responses under different moisture regimes.

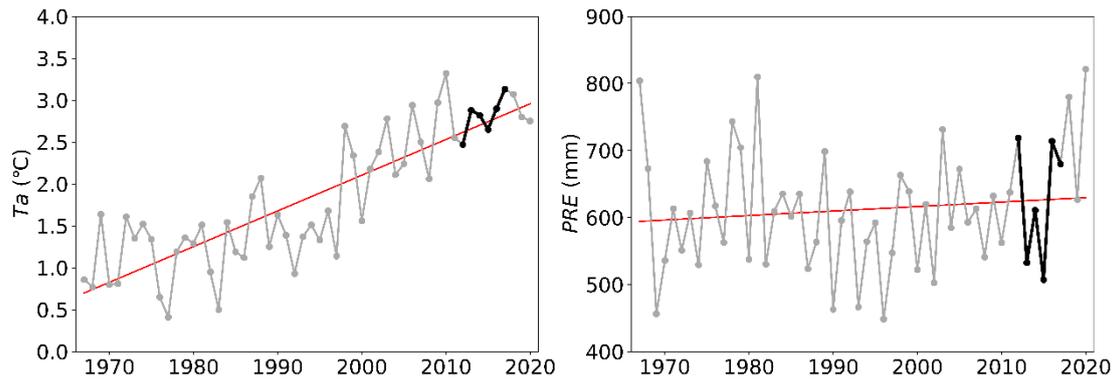


Figure 1 Annual average temperature and annual cumulative precipitation at Maqu Station from 1967 to 2020.

Second, the study site has spatial representativeness. Alpine meadows are widely distributed across the eastern and northeastern Tibetan Plateau, and the Maqu region is considered a typical alpine meadow ecosystem with high vegetation coverage and relatively natural conditions (Xu et al., 2008). Therefore, it provides an important reference for understanding carbon–water interactions in humid alpine grasslands on the Plateau.

Third, we agree that a six-year dataset may not be sufficient to fully characterize long-term interannual variability. Therefore, in the revised manuscript we have moderated our interpretation of inter-annual results, emphasizing that these analyses aim to reveal patterns and potential mechanisms rather than definitive causal relationships. We have also strengthened comparisons with findings from other regions to provide broader context.

Comment 2

The current analysis is largely descriptive. Most figures are restricted to basic time-series displays of raw variables (GPP, Re, NEE, ET, and WUE). The manuscript lacks in-depth statistical inference or process-based modeling, making it read more like a site-level "data report" than a rigorous scientific investigation into the mechanisms of carbon-water coupling in alpine meadows.

Response

Thanks to the valuable comments from the reviewers. The authors also realized that there were many time series graphs of the original variables in the article, which would make the scientific issues the article intends to convey less prominent. Therefore, we deleted or combined some of the relatively basic time series graphs, so that the scientific idea of the entire article becomes more focused.

First, we have adjusted the structure and length of the Results section. Descriptive statements about the temporal characteristics of GPP, Re, NEE, ET, and WUE have been streamlined, while more emphasis has been placed on interpreting the mechanisms behind the observed patterns.

Second, strengthened the analytical interpretation. We further elaborated on the mechanisms explaining why the dominant environmental drivers shift with timescale. Specifically, short-term variations are mainly regulated by instantaneous thermal conditions, whereas longer-term dynamics are more strongly influenced by water availability and vegetation conditions.

Third, we have strengthened the discussion regarding why the dominant drivers of carbon and water flux coupling may vary across temporal scales. In particular, we further discuss how the relative influence of climatic factors and vegetation characteristics shifts with temporal change, which represents one of the key perspectives and novel aspects of this study.

Comment 3

The novelty of the primary conclusions is limited. The findings—such as carbon fluxes being primarily driven by soil temperature (Ts) while ET is controlled by radiation—are well-established for alpine meadow ecosystems. The manuscript fails to go beyond these known patterns to offer new mechanistic insights.

Response

Thank you for this insightful comment. We agree that some of the general patterns identified in this study—such as the strong influence of soil temperature on carbon fluxes and the dominant control of radiation on ET—have been reported in previous studies of alpine meadow ecosystems. However, the main objective of this study is not only to confirm these general relationships but also to provide additional insights into the mechanisms of carbon–water coupling from multi-time scale. We have clarified and strengthened these aspects in the revised manuscript.

First, we emphasize the temporal-scale dependence of the driving factors of carbon–water coupling. Our results show that the dominant drivers vary across temporal scales (e.g., daily and seasonal), indicating that the relative importance of climatic and vegetation factors can shift with temporal aggregation. This scale-dependent perspective provides a more comprehensive understanding of the controls on carbon–water interactions in alpine meadow ecosystems.

Second, although the study site is located in a relatively humid alpine meadow

region, our results indicate that temperature is the primary driver of ecosystem fluxes, while water-related factors still play a critical modulating role. In the revised manuscript, we further discuss how moisture conditions interact with temperature and radiation to influence ecosystem carbon and water processes.

Third, this study attempts to quantitatively evaluate the strength of carbon–water coupling under different environmental conditions. Specifically, we analyze under what conditions the coupling between carbon uptake and water consumption is stronger, when it becomes weaker, and when partial decoupling may occur. This perspective helps move beyond simple identification of dominant drivers and contributes to a better understanding of the mechanisms regulating carbon–water interactions in alpine meadow ecosystems.

These revisions aim to clarify the novel contributions of this study and better highlight its implications for understanding carbon–water coupling in alpine meadow ecosystems on the Tibetan Plateau.

Comment 4

The introduction lacks a coherent logical flow. Many cited studies are not directly relevant to alpine grasslands, failing to provide a solid foundation for the authors' claims regarding regional driver differences. Additionally, the assertion that most existing studies focus on a single time scale is inaccurate. Extensive research has already addressed grassland carbon-water fluxes across multiple temporal scales (e.g., Kurc & Small, 2007; Fang et al., 2018; Novick et al., 2004; Wolf et al., 2013).

Response

We thank the reviewer for this helpful suggestion. We agree that the original Introduction lacked sufficient clarity and balance in reviewing previous studies.

In the revised manuscript we have:

1. Reorganized the Introduction to improve the logical flow, beginning with the importance of carbon–water coupling, followed by previous studies on grassland ecosystems, and finally the specific knowledge gaps addressed in this study.

2. Revised and expanded the literature review, incorporating additional studies on carbon–water flux dynamics across multiple temporal scales.

3. Modified the statement regarding previous studies, acknowledging that many studies have indeed examined flux dynamics at multiple scales, while emphasizing that integrated analyses of carbon–water coupling across daily, seasonal, and inter-annual timescales remain relatively limited, particularly in alpine meadow ecosystems of the

Tibetan Plateau.

Specific comments:

Comment 1

L135: the authors may provide a justification that why a composite model based on Ts and SWC was chosen to model Re instead of the more widely used daytime-/nighttime-partition approaches in flux community (Lasslop et al. 2010; Reichsten et al. 2012)?

Response

Thank you for this valuable comment regarding the ecosystem respiration (Re) modeling approach. We have clarified the rationale for selecting the composite model based on soil temperature (Ts) and soil water content (SWC) in the revised manuscript. Our response is as follows:

First, it should be noted that our approach differs conceptually from the daytime partitioning method proposed by Lasslop et al. (2010). In the method of Lasslop et al., daytime NEE is combined with incoming radiation and temperature to fit a light-response curve of photosynthesis, and vapor pressure deficit (VPD) is introduced as a modifier to account for environmental stress. In contrast, our study follows a different framework: ecosystem respiration is first estimated from nighttime flux observations, and the fitted parameters are subsequently extrapolated to daytime conditions. Therefore, our method is based on nighttime respiration dynamics rather than daytime photosynthetic light-response fitting.

Second, the alpine meadow ecosystem on the Qinghai–Tibetan Plateau is characterized by extremely strong solar radiation and relatively low temperatures. Under such conditions, plant photosynthesis is often constrained by both low temperature and strong radiation, which can suppress photosynthetic activity and reduce the reliability of light-response curve fitting. Moreover, the plateau environment exhibits large fluctuations in vapor pressure deficit (VPD) and strong spatial heterogeneity in soil moisture. In many daytime partitioning approaches, the VPD correction applied to the light-response model is typically an empirical exponential decay function, which may introduce considerable systematic uncertainty under such highly variable environmental conditions. In comparison, the nighttime extrapolation approach avoids the direct influence of daytime photosynthetic physiological stress and allows a more stable separation of the ecosystem respiration component.

Third, although our approach uses nighttime data as the basis for parameter

estimation, it differs from the traditional nighttime temperature-response models that only consider temperature controls. In this study, we adopted a composite model incorporating both soil temperature (T_s) and soil water content (SWC). This modification explicitly accounts for the influence of soil moisture on respiration processes, which is particularly important in alpine meadow ecosystems where water availability can modulate microbial and root respiration. Therefore, the composite T_s –SWC model is expected to provide a more accurate representation of ecosystem respiration dynamics than temperature-only models.

Comment 2

There are many formatting issues or typos in the manuscript. E.g., PREand, thatET, daily scalce...

Response

We thank the reviewer for pointing this out. The whole manuscript has been carefully proofread and revised to correct typographical errors, formatting inconsistencies, and grammatical issues throughout the text.