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Conference Abstract

On the Increasing Occurrence of a Green Christmas: A Perspective from Long-Term Eddy Covariance Observations on Winter Dormancy Interruptions in a Subalpine Forest

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Abstract

Seasonal dormancy in temperate and boreal forests is an adaptive trait that guarantees tree survival during the winter season. This phenomenon is mainly affected by temperature and photoperiod (Heide 1974). However, increasing evidence suggests that winter dormancy is not a static state but rather a dynamic period influenced by intermittent warm spells that can temporarily reactivate ecosystem processes. These dormancy interruptions, particularly during "Green Christmas" events — characterized by reduced snow cover and anomalous winter temperatures — have the potential to alter seasonal carbon fluxes, shift forest phenology, and alter physiological cycles. As climate change intensifies, understanding the frequency and implications of these interruptions becomes crucial for predicting long-term shifts in ecosystem carbon dynamics and energy fluxes.

Recent studies have reported that evergreen forests can initiate photosynthesis well before complete snowmelt (Bowling 2024), while deciduous forests exhibit a delayed

response to warming trends. Additionally, Körner (2023) challenges conventional meteorological definitions of growing seasons, emphasizing that photosynthetic activity does not always align with temperature-based phenological markers. While there is strong evidence that climate warming influences seasonal carbon fluxes, long-term Eddy Covariance (EC) records reveal mixed trends in photosynthetic activity, suggesting that additional research is needed to uncover the underlying ecological and physiological mechanisms driving these shifts.

As multiple EC flux tower sites established under the EUROFLUX project approach three decades of continuous observations, they offer a valuable opportunity to assess the long-term effects of climate variability on forest dormancy and carbon cycling. These extensive datasets allow for detailed trend analyses of winter dormancy interruptions, providing insights into their frequency, intensity, and potential impact on annual carbon sequestration.

For this study, we selected the Renon-Selvaverde site (ICOS ID: IT-Ren, eLTER ID: BOL1), a subalpine forest with a long-term EC measurement record. To enhance the completeness of our dataset, we incorporated locally processed EC data, extending the NEE record from the Warm Winter Dataset (Gharun 2024) up to the present (1997-2024). Additionally, we ensured continuity in meteorological observations for the whole time span of our analysis.

Leveraging this long-term dataset, we investigated how winter dormancy interruptions influence seasonal carbon dynamics. By integrating EC observations with environmental drivers, we aimed to refine our understanding of subalpine ecosystem responses to mid-winter warming events and evaluate their broader implications for carbon balance in the context of climate change.

Winter dormancy interruptions were identified based on periods when NEE fluxes were significantly different from zero during the winter months. We then examined the relationships between NEE, shortwave radiation, soil temperature, and air temperature from the vertical profile during these interruptions. To quantify these interactions, we conducted a correlation analysis to assess the strength and significance of environmental drivers influencing ecosystem-level fluxes.

Our analysis revealed an increase in the frequency of warm spells beginning in 2020. However, we did not detect a significant pattern in the duration of these events. Currently, warm spells appear to be isolated occurrences, allowing the forest stand to return to its dormant state after each event. Additionally, we observed that dormancy interruptions correspond to periods when soil temperatures remain above freezing and snow cover is absent, supporting the hypothesis that soil conditions play a critical role in determining ecosystem activity during winter. Anyhow, it is important to distinguish between warm spells characterized by non-freezing soil temperature (with or without snow cover) and photosynthetic activation driven by solar radiation but occurring under soil freezing conditions. In the latter case, photosynthesis may be initiated but remains constrained by water availability, with unclear effects on NEE.

At present, these dormancy interruptions do not significantly impact the winter carbon budget of the observed ecosystem. However, we hypothesize that a continued increase in both the frequency and duration of warm spells could lead to fundamental shifts in seasonal or even annual carbon dynamics. An extended period of mid-winter photosynthetic reactivation could alter the seasonal carbon budget and potentially reduce the ability of subalpine forests to function as a long-term carbon sink, affecting their contribution to carbon neutrality.

Future research should focus on mechanistic modelling approaches to predict long-term changes in carbon sequestration capacity under scenarios of increased winter warming and reduced snow cover.

Keywords

Winter Dormancy, Climate Change, ICOS, eLTER, Subalpine Forest

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Conflicts of interest

The authors have declared that no competing interests exist.

References

- Bowling D, et al. (2024) Phenology of Photosynthesis in Winter-Dormant Temperate and Boreal Forests: Long-Term Observations From Flux Towers and Quantitative Evaluation of Phenology Models. Journal of Geophysical Research: Biogeosciences 129 (5). https://doi.org/10.1029/2023JG007839
- Gharun M, et al. (2024) Divergent responses of evergreen needle-leaf forests in Europe to the 2020 warm winter. https://doi.org/10.5194/egusphere-2023-2964

- Heide O (1974) Growth and Dormancy in Norway Spruce Ecotypes (*Picea abies*) I. Interaction of Photoperiod and Temperature. Physiologia Plantarum 30 (1): 1-12. https://doi.org/10.1111/j.1399-3054.1974.tb04983.x
- Körner C, et al. (2023) Four ways to define the growing season. Ecology Letters 26 (8): 1277-1292. https://doi.org/10.1111/ele.14260