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COMMENTARY

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Acceleration of vegetation phenological changes

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Abstract

Piao et al. (2022) presents an interesting study on vegetation phenology from a novel angle. The study examined the speed of canopy development and senescence, or the "acceleration of vegetation phenological changes", and investigated its relationship with the trend of vegetation greening/browning and the underlying climate driving factors. It is an important contribution to the understanding of vegetation response to climate change, and may inspire new directions of vegetation phenology research.

Vegetation phenology can be described as the timings of crucial vegetation physiological events throughout the year. It has been identified as a sensitive ecological indicator of global climate change and is also known to regulate vegetation's feedback to the climate in many aspects, including the critically important land-atmosphere exchanges of carbon, water, and energy (Chen et al., 2016; Richardson et al., 2013). Therefore, the scientific importance of vegetation phenology has been increasingly recognized over the past few decades, and growing efforts have been dedicated to the understanding of the underlying drivers and mechanisms of vegetation phenological changes, particularly the long-term trend (Piao et al., 2019).

The vegetation canopy generally absorbs more incoming solar radiation in the visible spectral band, particularly in the red band, and in contrast reflects more near-infrared radiation. Remotely sensed vegetation indices (VIs), such as the Normalized Vegetation Difference Index (NDVI) and the Enhanced Vegetation Index, were developed on top of such spectral features and have been successfully applied to monitor the seasonal variations of vegetation canopy over large spatial domains and long time spans (Zeng et al., 2022). Numerous studies have used VIs to study the first-order changes of phenology, that is, the changes in the key timings of vegetation phenological events, such as the start, end, and length of the growing season, and commonly suggest a worldwide lengthened vegetation growing season in response to the warming climate, usually with an advanced start of the growing season and a delayed end of the growing season. Nevertheless, further important questions regarding the second-order changes have been rarely touched; that is, does the speed of vegetation phenological variations, such as the canopy development and senescence, change in response to climate change? If the answer is yes, how does it change over time and affect the overall greening/browning trend, and what are the underlying drivers?

Piao et al. (2022) in the current issue brings an interesting study that represents a pioneering investigation of these important questions. In the work of Piao et al. (2022), a three-decade-long remotely sensed NDVI dataset was used to investigate the vegetation phenology of temperate China, a region recognized as a hotspot of global greening (Chen et al., 2019) and having large climate and vegetation distribution gradients that are ideal for comprehensively understanding the relationship between climate and vegetation changes. Piao et al. (2022) creatively introduced V_{NDVI}, the change in NDVI between two consecutive months, to quantify the velocity of vegetation canopy development or senescence. The trends in the calculated monthly V_{NDVI} thus represent the response of vegetation to climate change at different growing stages and reflect the contributions of these stages to the overall trend of vegetation greening or browning. As reported in the study of Piao et al. (2022), while increased NDVI was found in nearly all growing-season months except June and November in temperate China, the trend of V_{NDVI} varied largely over the months, that is, different canopy development and senescence stages. Significant

This is a commentary on Piao *et al*., 2022, https://onlinelibrary.wiley.com/doi/10.1111/gcb.16408 increase in V_{NDVI} only happened in April and October, while significant decrease in V_{NDVI} only happened in November, indicating that the region generally had faster canopy development in early spring, slower canopy senescence in early autumn, but faster leaf fall at the end of the growing season. These findings suggest an interesting fact that 'the change' and 'the speed of change' of vegetation greenness may not necessarily be consistent with each other. More interestingly, locations with the largest positive NDVI trends are coincident with those with increased V_{NDVI} in April, indicating the potentially important contribution of the speed of canopy development to the overall greening trend. Furthermore, the authors applied partial correlation analyses to understand the climate controls on the change of V_{NDVI}. The findings are complex since the relationships between climate factors and V_{NDVI} vary over time and space: although it is clear that overall temperature is a dominant factor affecting V_{NDVI}, precipitation is positively correlated to V_{NDVI} in spring and summer in semiarid regions, and photoperiod plays a less important role. The advanced start of the growing season triggered by the warming climate was likely the major reason for the increasing V_{NDVI} in the early growing season, and the warming-caused delay in autumn phenology likely caused the slower canopy senescence in early autumn.

Similar to Newton's Second Law, studying the acceleration of vegetation's 'motion' like Piao et al. (2022) on the speed of canopy development and senescence could be a fundamental contribution to the research field of global change ecology, especially in the background of rapid climate change (IPCC, 2021). Although numerous exciting research progresses on vegetation phenology have been achieved in the past years, terrestrial ecosystems and the larger Earth system are so complicated that we still know little about them. Poor understanding of vegetation phenology has been identified as a key uncertainty source of ecological model predictions of vegetation changes and the associated critically important land-atmosphere interactions (Migliavacca et al., 2012; Richardson et al., 2012), and thus, the insight provided by Piao et al. (2022) brings us one step forward to better address this uncertainty from the new angle. Further explorations could extend to a different or larger region to complete a global story. Future studies could also be inspired by this study to use novel remote sensing metrics such as solar-induced chlorophyll fluorescence to study the acceleration of vegetation photosynthetic phenology, which would provide more direct insights into the land-atmosphere carbon exchange. All the results can be used as constraints to evaluate and improve our ecological and climate predictions.

DATA AVAILABILITY STATEMENT

No data was used for this commentary.

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