Editorial

https://doi.org/10.1038/s41559-023-01991-4

Climate science needs biology

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Incorporating biological feedbacks into climate and Earth system models is challenging owing to multiple sources of uncertainty. Filling these knowledge gaps and learning lessons from climate forecasts will help to improve our understanding of biodiversity under future environmental change.

According to forecasts from the UK's Met Office, 2023 is set to yet again be one of the hottest years on record, with average global temperatures estimated to be 1.2 °C above preindustrial levels. This will also be the tenth year in a row that global temperatures have been at least 1 °C above preindustrial levels.

As temperature is the dominant control on carbon cycle processes, such persistent increases will have profound effects on the Earth system. However, even with advances in climate modelling and the incorporation of biogeochemical processes in Earth system models, there remains plenty of uncertainty about the magnitude of feedbacks between climate and carbon, due in part to biological processes.

In this issue, three studies highlight this uncertainty through different lenses. Joly et al. tackle the longstanding issue of uncertainty in the degree to which climate is the dominant control on decomposition. Utilizing an established network of 200 forest sites across a climatic gradient in Europe, they first measure realistic decomposition using naturally occurring leaf litter at each site. They then repeat this experiment using standardized litter across all sites, before finally assessing all combinations of litter decomposition in a single common garden. Their results indicate only a small effect of the microenvironment on decomposition relative to macroclimate, in contrast to previous findings (M. A. Bradford et al. *Nat. Ecol. Evol.* **1**, 1836–1845; 2017) that did not investigate naturally occurring site-specific litter decomposition and that suggested a greater role for microbial biomass at local and regional scales. Joly et al.'s finding suggests that parameterizing predictive models using macroclimatic decomposition drivers could potentially be more straightforward than previously thought.

Working across sites at the continental scale, Joly et al. can account for broad-scale climatic variation. By contrast, in another study in this issue, Zhang et al. take a more tightly controlled approach to investigating the role of temperature variation on biogeochemical processes by bringing things back to the laboratory. Their incubation experiments on microbial respiration in subtropical forest soils reveal that increasing fluctuations in temperature over a 48-h period are associated with a stronger negative effect on biomass-specific respiration, as compared to the same mean temperature without fluctuations over the same period. These findings are consistent with an enhanced thermal adaptation response, in which microorganisms decrease respiration rates per unit biomass in response to temperature increases, weakening the strength of soil carbon–climate feedbacks. Moving beyond measures of only mean-temperature effects on biotic responses will be crucial in enhancing the predictive power of biogeochemical models, as climatic extremes look set to become ever more frequent – with implications for the carbon cycle and biodiversity alike (G. Murali et al. *Nature*, https://doi.org/10.1038/s41586-022-05606-z; 2023).

However, accounting for these adaptive responses, as well as scale-dependent effects, remains an ongoing challenge for predictive models. A third paper in this issue exemplifies these challenges by looking at long-term trends in leaf phenology across Northern Hemisphere deciduous forests. Coupling ground observations with remotely sensed data collected since the 1940s, Marqués et al. identify temporal scale-dependence in the relationship between growing-season total net CO_2 assimilation and end-of-season phenology. They show that, at the decadal time scale, CO_2 assimilation is positively correlated with end-of-season phenology, whereas at the interannual scale the opposite is true (indicating earlier autumn-leaf senescence). These scale-specific effects help to explain conflicting findings among previous studies. Such plasticity in response could be good news for carbon assimilation, as it suggests some plants may be able to adapt toward optimal functioning in warmer and more-variable climates.

The biogeochemical implications of abiotic controls on biotic processes such as microbial respiration and plant productivity have long been recognized, but it is notable that a whole day of high-level discussion at the 2022 United Nations Framework Convention on Climate Change COP27 was dedicated to the climate–biodiversity nexus. Biodiversity has often lagged behind climate science when it comes to global attention (*Nat. Ecol. Evol.* **6**, 1791; 2022) and research funding, but it is reassuring to now see closer connections being forged between the two sciences. Developing a deeper understanding of the impacts of biodiversity change for climate prediction, and vice versa, is in everyone's interests.

Co-opting some of the established tools of climate science into studies of ecological processes, such as statistical methods for detecting and attributing the relative impact of anthropogenic climate change (U. Büntgen et al. *Funct. Ecol.* **34**, 2270–2282; 2020), will require ongoing collaborations across disciplines but could help to drive a more mechanism-based understanding of biodiversity change. In comparison to the climate sciences, ecology is more constrained by a comparative paucity of high-resolution, long-term biodiversity data, as well as greater complexity than physical systems when taking into account biotic interactions. In this way, meeting the needs of environmental decision-makers for accurate annual or subannual predictions of ecological change is challenging, but ongoing work in near-term prediction by consortia such as the Ecological Forecasting Initiative is aiming to fill this gap, and provide collaborative, societally useful predictions with high certainty but on short time scales.

The urgency of the twin ecological and climate crises highlighted by the recent UN climate and biodiversity COPs reinforces the need to better understand interdependencies between climate and the biosphere in Earth system science. Studies that add the biological detail onto the physical scaffolds, such as those highlighted in this issue, will be crucial in addressing both crises. Further the strengthening of ties and knowledge sharing between the two disciplines is essential, and the time to act on that is now.

Published online: 9 February 2023