

Comment on “Global Convergence in the Temperature Sensitivity of Respiration at Ecosystem Level”

Alexander Graf,* Lutz Weihermüller, Johan A. Huisman, Michael Herbst, Harry Vereecken

Mahecha *et al.* (Reports, 13 August 2010, p. 838) estimated the temperature sensitivity of ecosystem respiration (Q_{10}) and showed that temperature sensitivity and its site-to-site variability are lower than previously reported. We demonstrate that their Q_{10} value of 1.4 is an underestimate if interpreted as the averaged sensitivities of all ecosystem components, because fast temperature fluctuations penetrate poorly into the soil.

Respiration is an important feedback mechanism in Earth's climate system because of its strong response to temperature. The factor by which respiration multiplies in response to a 10° temperature increase (Q_{10}) was reported to vary considerably not only between ecosystem components but also between ecosystems. Recently, Mahecha *et al.* (1) determined a convergent Q_{10} value of 1.4 (± 0.1) for a wide range of mean annual temperatures and biomes using FLUXNET (2) ecosystem respiration data and the scale-dependent parameter estimation (SCAPE) methodology to exclude confounding effects. This value is considerably lower than previous estimates, and the authors pointed out that it has to be interpreted carefully, in particular with respect to soil respiration. They recommended further evaluation using soil respiration and soil temperature measurements. We commend the authors for their valuable contribution to the analysis of both aboveground and soil respiration. By extending their synthetic validation experiment with soil respiration, we could indeed reproduce their finding of overestimated Q_{10} values by the conventional methodology. However, we also found that the SCAPE methodology leads to an underestimation of Q_{10} whenever the following criteria apply: (i) Soil respiration at depths where short-term temperature fluctuations are dampened contributes substantially to ecosystem respiration and (ii) Ecosystem-level Q_{10} is defined as the contribution-weighted average of the Q_{10} s of all single ecosystem components, and thus as the sensitivity that applies when all parts of the system warm equally. Our study may in part explain the low Q_{10} estimate of 1.4 that was critically discussed by the authors themselves and in a related commentary article (3).

The SCAPE methodology (1) aims at excluding confounding effects from the temperature-

respiration relation by focusing on less affected temporal scales. It is based on the observation that confounding effects on temperature sensitivity act on different time scales. For example, biomass and litter production change on seasonal and longer time scales. As a consequence, basal respiration R_b exhibits an annual cycle. If R_b and the annual temperature cycle are correlated, this will affect the apparent temperature sensitivity of respiration. Therefore, Mahecha *et al.* decomposed temperature and log-transformed ecosystem respiration time series from a wide range of sites into frequency bins, with the first bin containing all fluctuations with a period longer than 3 months. For each frequency bin, they calculated Q_{10} values separately. Using synthetic experiments, Mahecha *et al.* demonstrated that the Q_{10} values for intermediate and high frequencies converged toward the prescribed value. The conventional Q_{10} and the Q_{10} of the lowest frequency bins, in contrast, were subject to large errors. The validation experiments assumed that the temperature time series reflects the conditions at the location that acts as a source for respiration. For soil respiration, this is not necessarily the case because of the damping of temperature fluctuations as a function of soil depth. This effect has already been recognized as a major source of uncertainty in the determination of the temperature sensitivity of soil respiration (4–12). In addition, it can be shown that high-frequency temperature variations are dampened more than low-frequency temperature variations (13). In an artificial experiment with diurnal and annual temperature waves, it was shown that the sensitivity of apparent Q_{10} values to the choice of soil temperature measurement depth can be reduced by daily averaging of the soil respiration and soil temperature time series (8). Cycles between the diurnal and annual cycle, however, were not considered in (8).

The analysis of Mahecha *et al.* (1) was based on daily (nighttime) averages of temperature and respiration. Annual variations were also excluded by the SCAPE methodology, and the remaining intermediate frequencies were used to determine

Q_{10} . At these frequencies, soil temperature may still differ considerably from air temperature. When air temperature is statistically related to a respiration flux that is composed of contributions from various sources in a range of depths with varying soil temperature, the resulting Q_{10} cannot be considered as the weighted average of the intrinsic temperature sensitivity of these sources. To illustrate this, we present a synthetic experiment similar to that described in (1). We used six soil temperature time series at different depths in addition to the air temperature time series to generate the artificial respiration signal (see supporting online material for details).

The results obtained in (1) are reproduced in the upper row of Fig. 1. The Q_{10} values converge toward the prescribed Q_{10} for high frequencies, whereas the conventional Q_{10} matches the prescribed value of 2 only if R_b is constant. For the case in which 33% of respiration is belowground (second row), all binned Q_{10} values underestimate the prescribed value except for the value corresponding to the lowest-frequency bin. When the belowground contribution increases further (third and fourth row), the high-frequency Q_{10} approaches unity. The magnitude of the contribution of soil respiration to ecosystem respiration can vary between a few percent and more than 50%, depending on the ecosystem and on whether or not root respiration is included in the belowground respiration (14, 15). We therefore suggest extending the SCAPE methodology to account for the vertical source distribution of soil respiration as affected by varying soil temperature, even if it aims at ecosystem-level sensitivity only. A global convergence may still be found. However, the Q_{10} value obtained by such an extended methodology may vary between 1.4 and previously reported estimates, thus bridging the gap between these disparate results. For application in models that are driven by air temperature and aim at short-term changes, such as gap-filling models, values determined with the SCAPE methodology may even be the more appropriate ones, as it implicitly contains the damping of fluctuations with soil depth. On the decadal temporal scale covered by global climate modeling, however, trends in soil temperature almost equal trends in air temperature because of the nature of heat transfer (13). In such a model, the same value would lead to a systematic underestimation of long-term respiration.

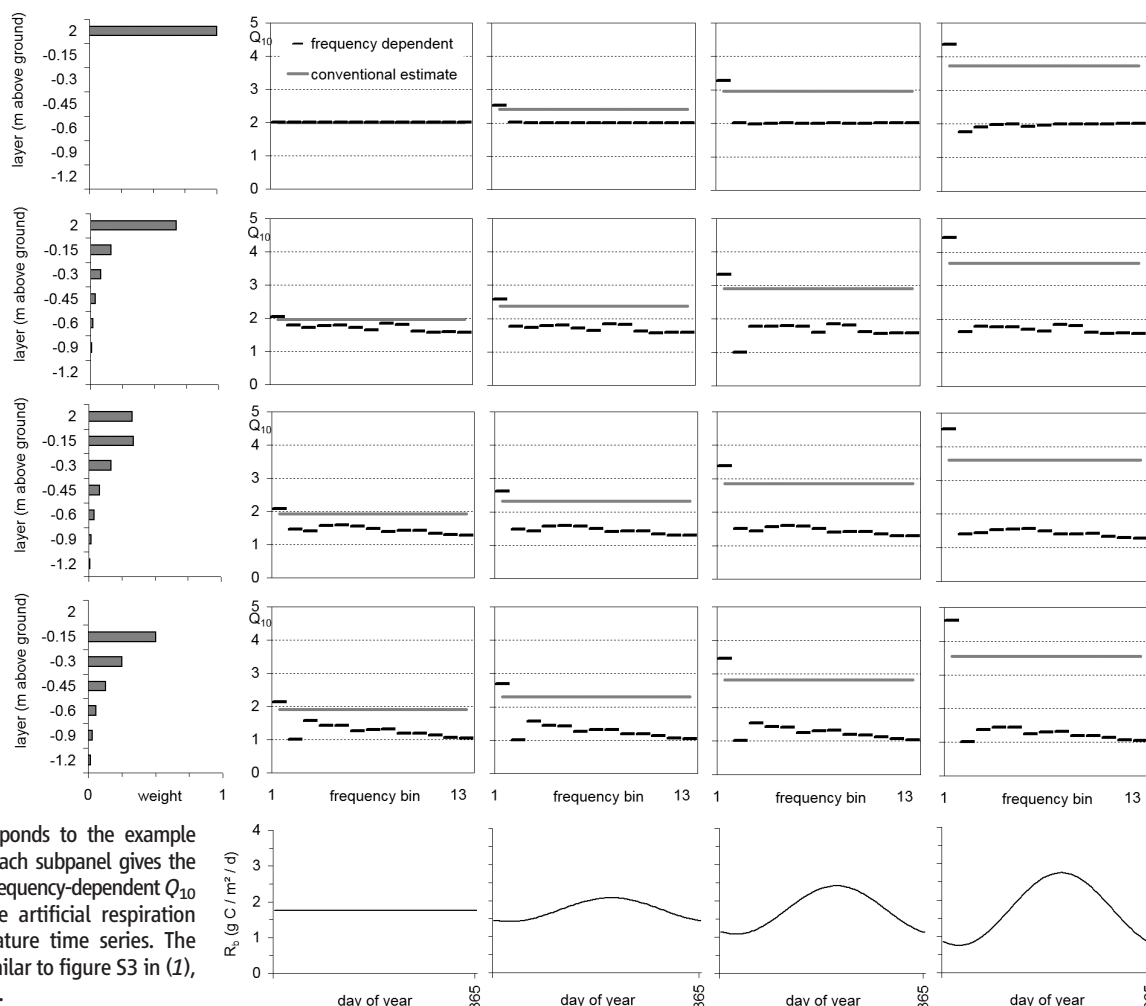
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Fig. 1. Results of synthetic experiments. Real-world daily time series of air temperature and soil temperature at various depths were used for generating artificial respiration signals from various layers of the ecosystem. Total ecosystem respiration was calculated as the sum of weighted contributions from these layers for different cases of vertical source distribution (left column). The uppermost case corresponds to the assumption implicit in the artificial experiments in (1), namely that all respiration sources are subject to air temperature; the lowermost case corresponds to the extreme where all sources are belowground. The prescribed Q_{10} value was 2, and the prescribed amplitude of R_b for different cases is given in the bottom row. The case shown on the right corresponds to the example given in figure S2 in (1). Each subpanel gives the conventional Q_{10} and the frequency-dependent Q_{10} values estimated from the artificial respiration data and the air temperature time series. The upper right subpanel is similar to figure S3 in (1), but without artificial noise.



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Supporting Online Material

www.sciencemag.org/cgi/content/full/331/6022/1265-c/DC1
Materials and Methods

Fig. S1
Table S1
References

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