Heterotrophic respiration in a warmer world: controversy or consensus?

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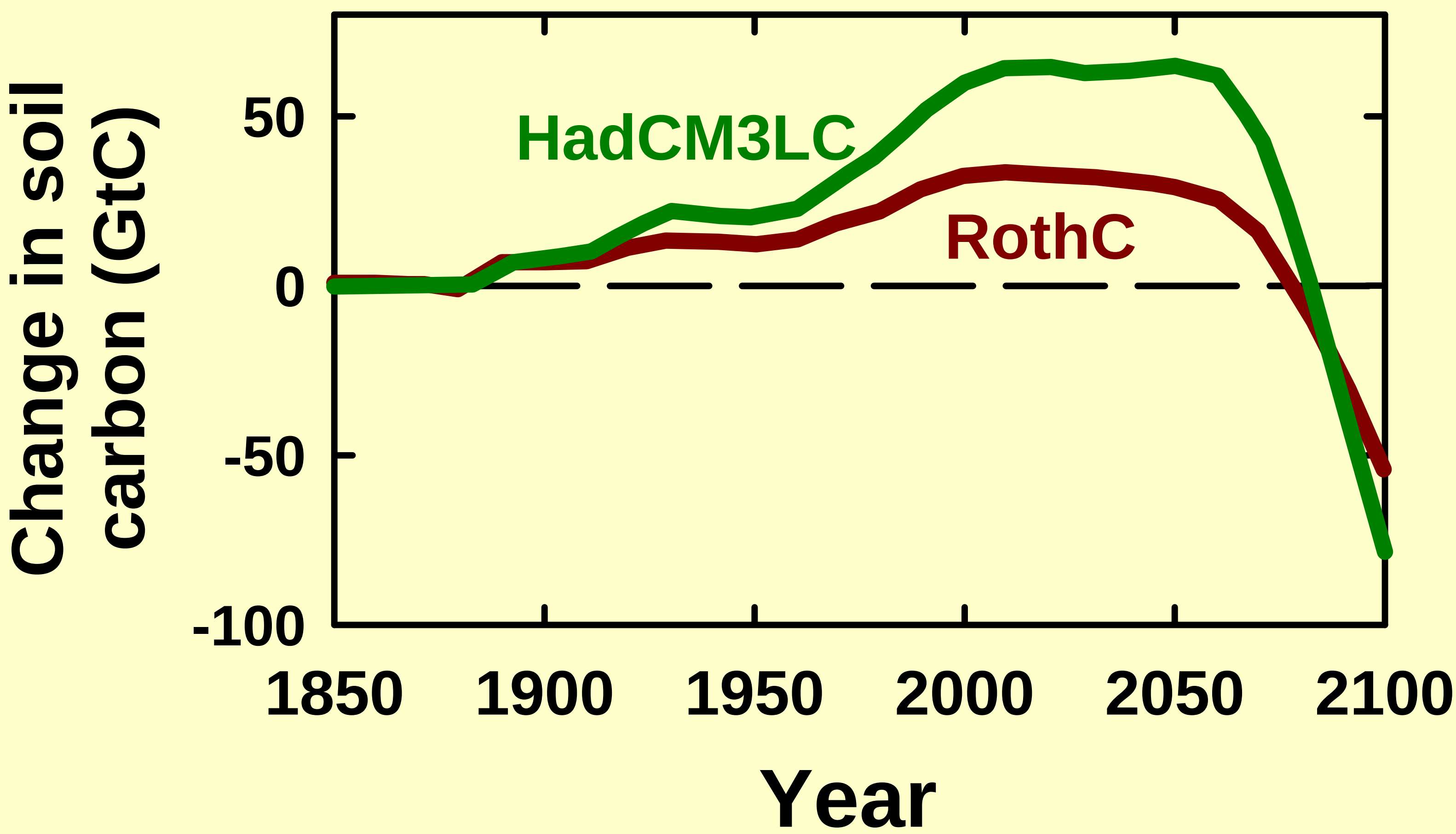
The importance of understanding soil carbon

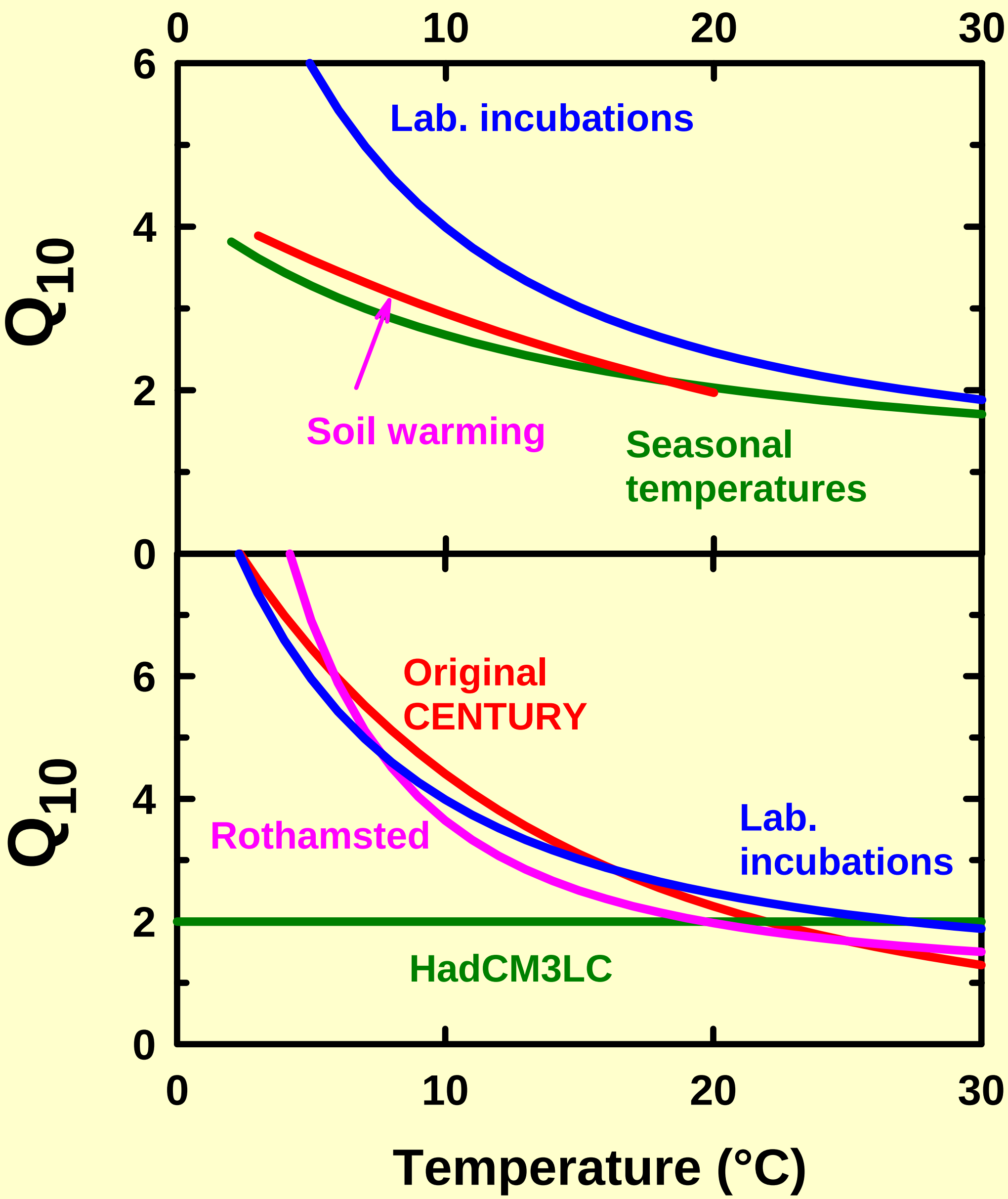


HadCM3LC – single pool
RothC – 4-pool model
Different T response fn

Models suggest that changes in soil carbon can play a significant role in net emissions to the atmosphere. Different models, however, give different predictions.

Jones et al. (2005)

Summary of different temperature response functions

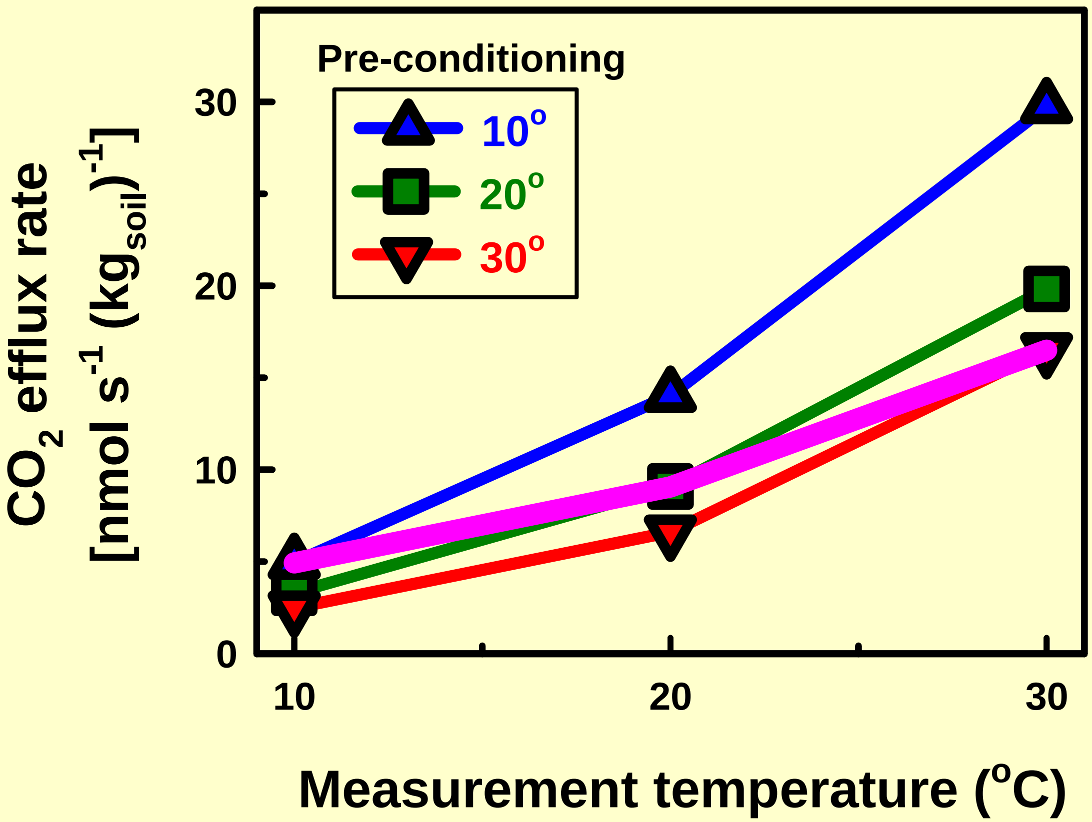


All experimental approaches suggest a strong temperature dependence of heterotrophic respiration that is stronger at low temperature. This is consistent with relationships used in the Rotamsted and original CENTURY models, but global models, such as HadCM3LC, still use very flat temperature dependencies.

Kirschbaum (2000)

Variations in substrate availability

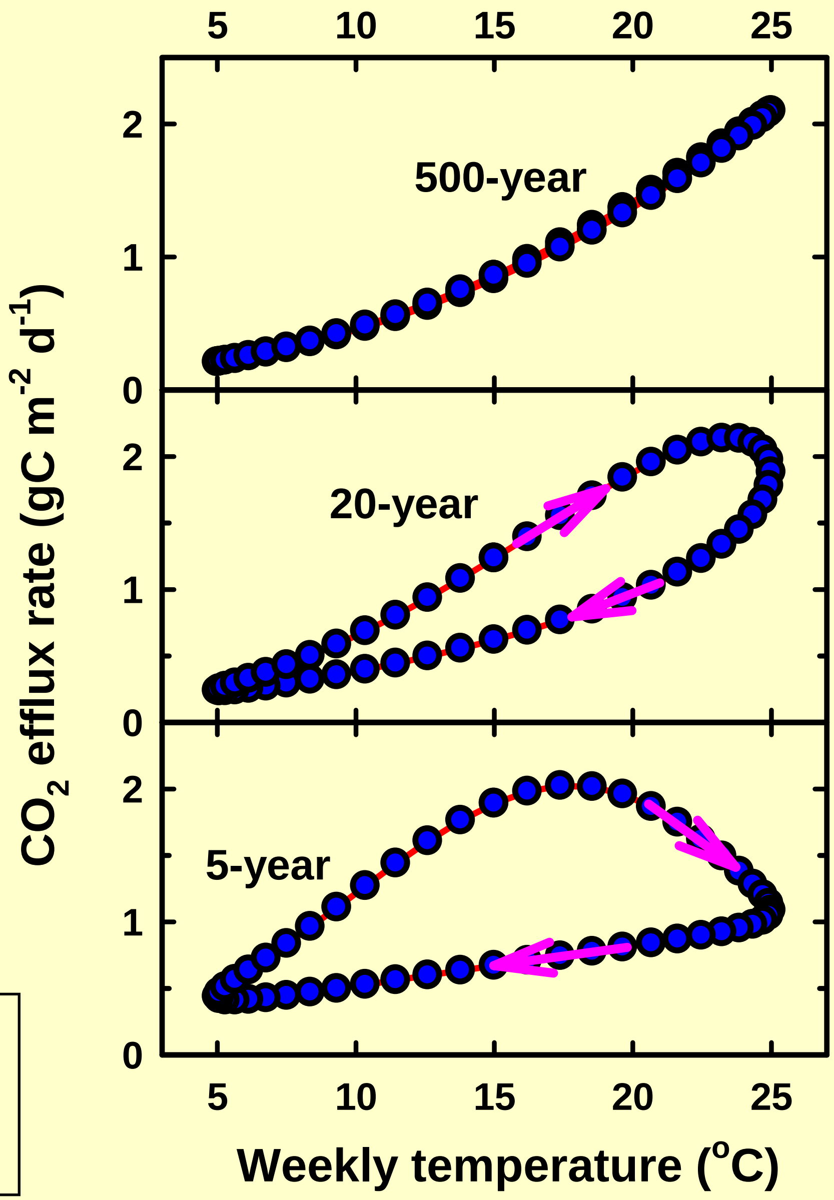
Substrate availability in laboratory incubations



Koepf incubated samples at different temperature and then changed temperature rapidly to get responses at different temperature. Samples incubated at high temperatures had reduced rates because of substrate depletion but the relative response the temperature did not change. Most experiments follow the pink line with incubation and measurement at the same temperature, showing how that depresses the apparent derived temperature response.

Koepf (1953)

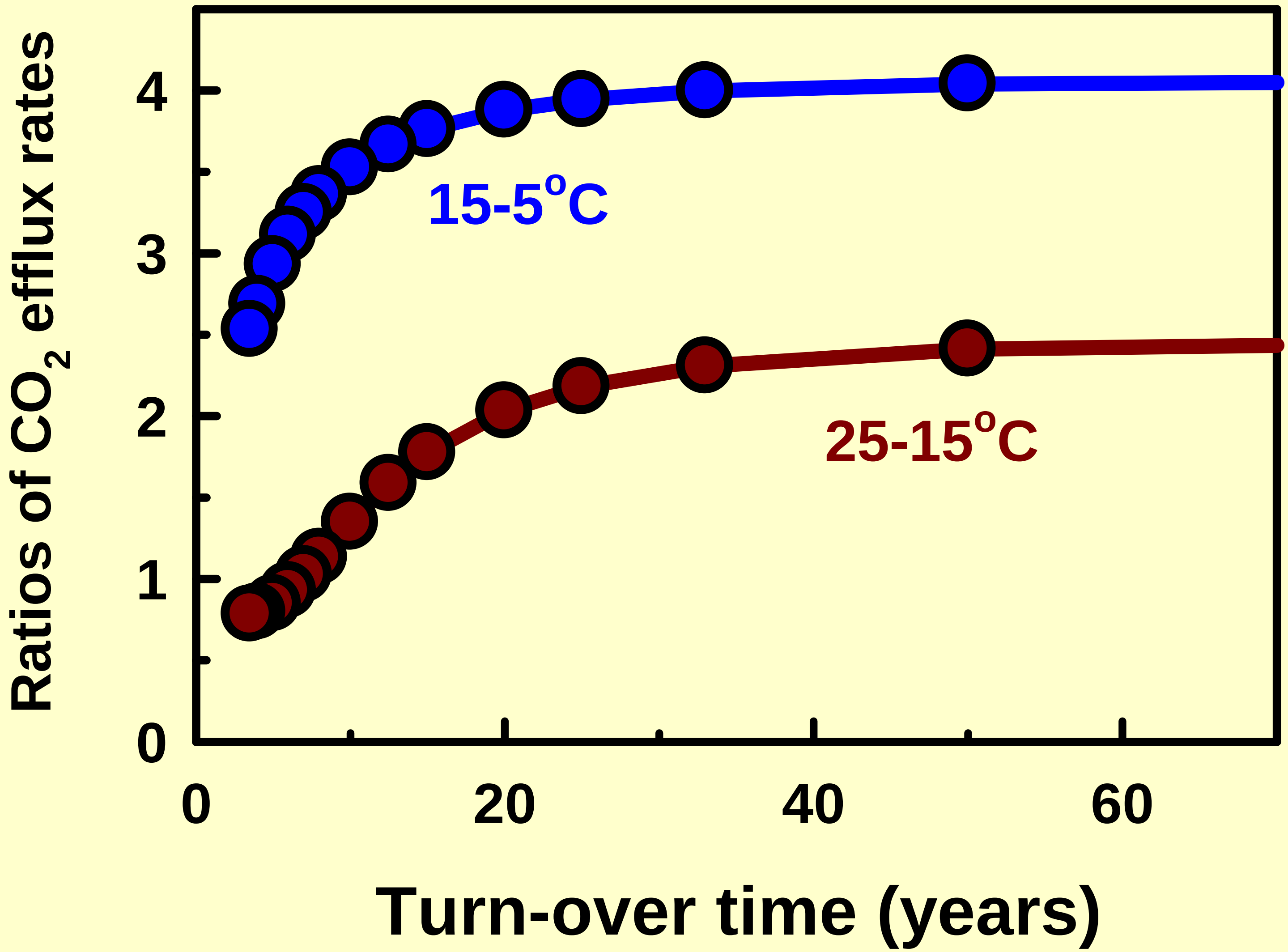
Substrate availability in the field



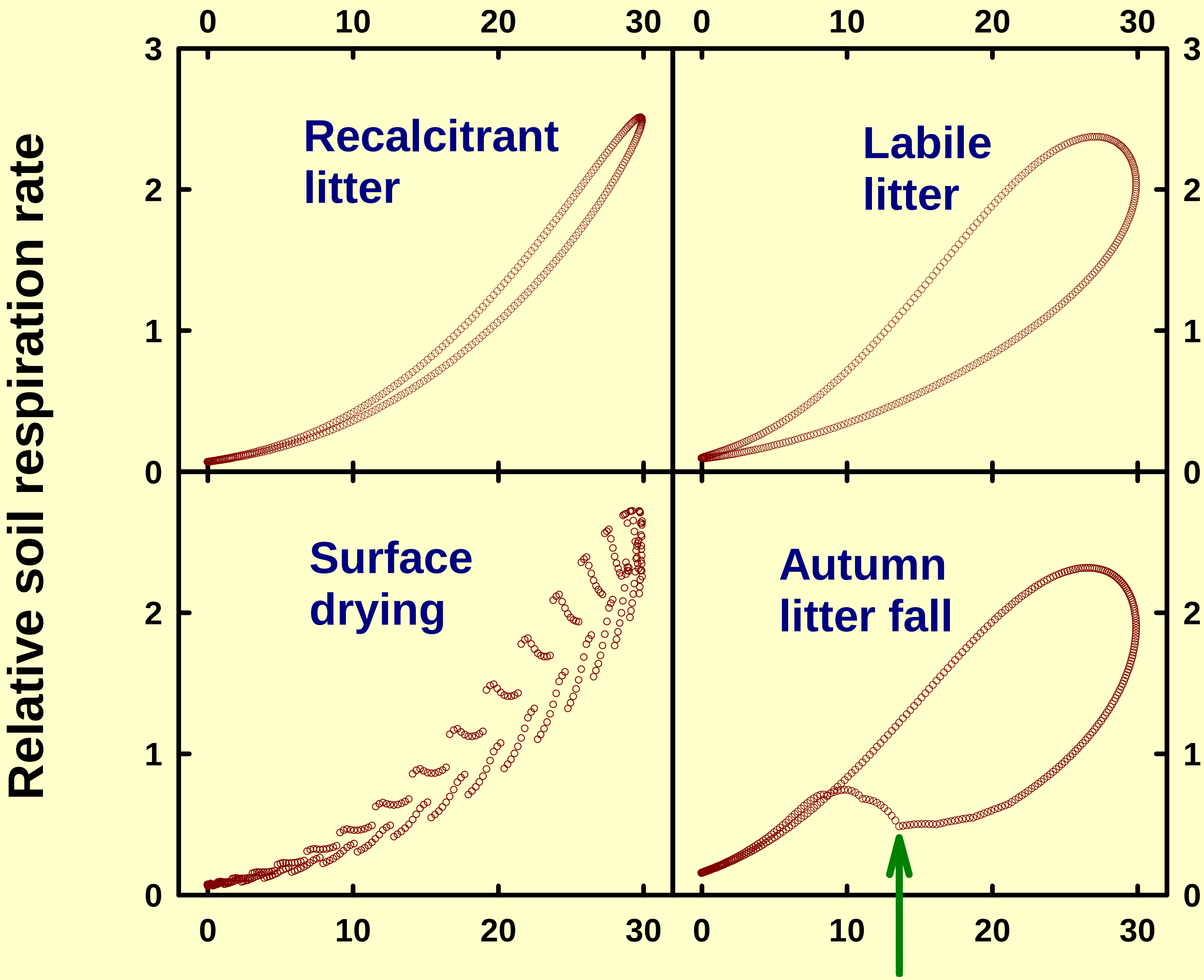
Constant litter input
One pool
Recalcitrance quantified
by turn-over times

Kirschbaum (2006)

Labile substrate confounds temperature response

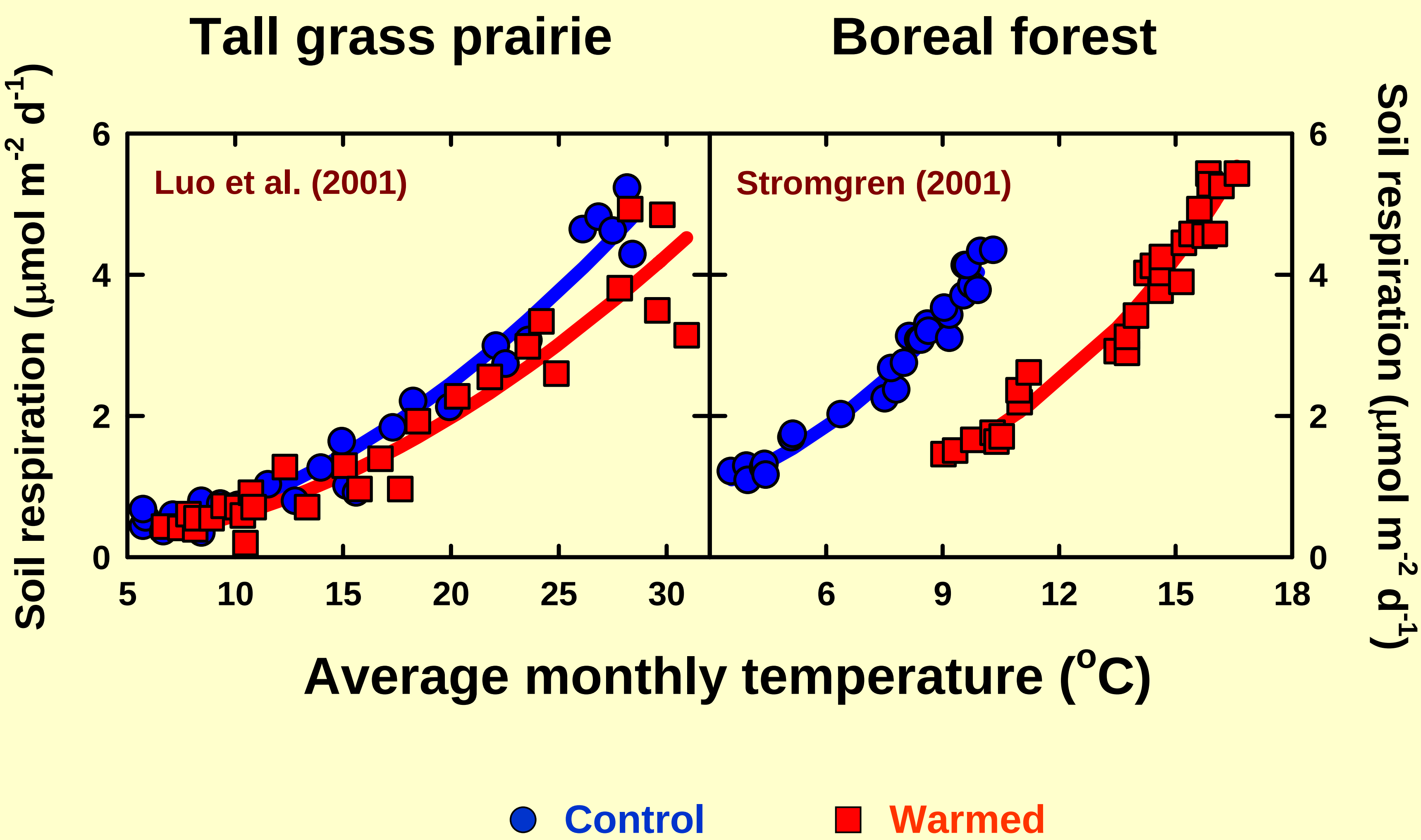


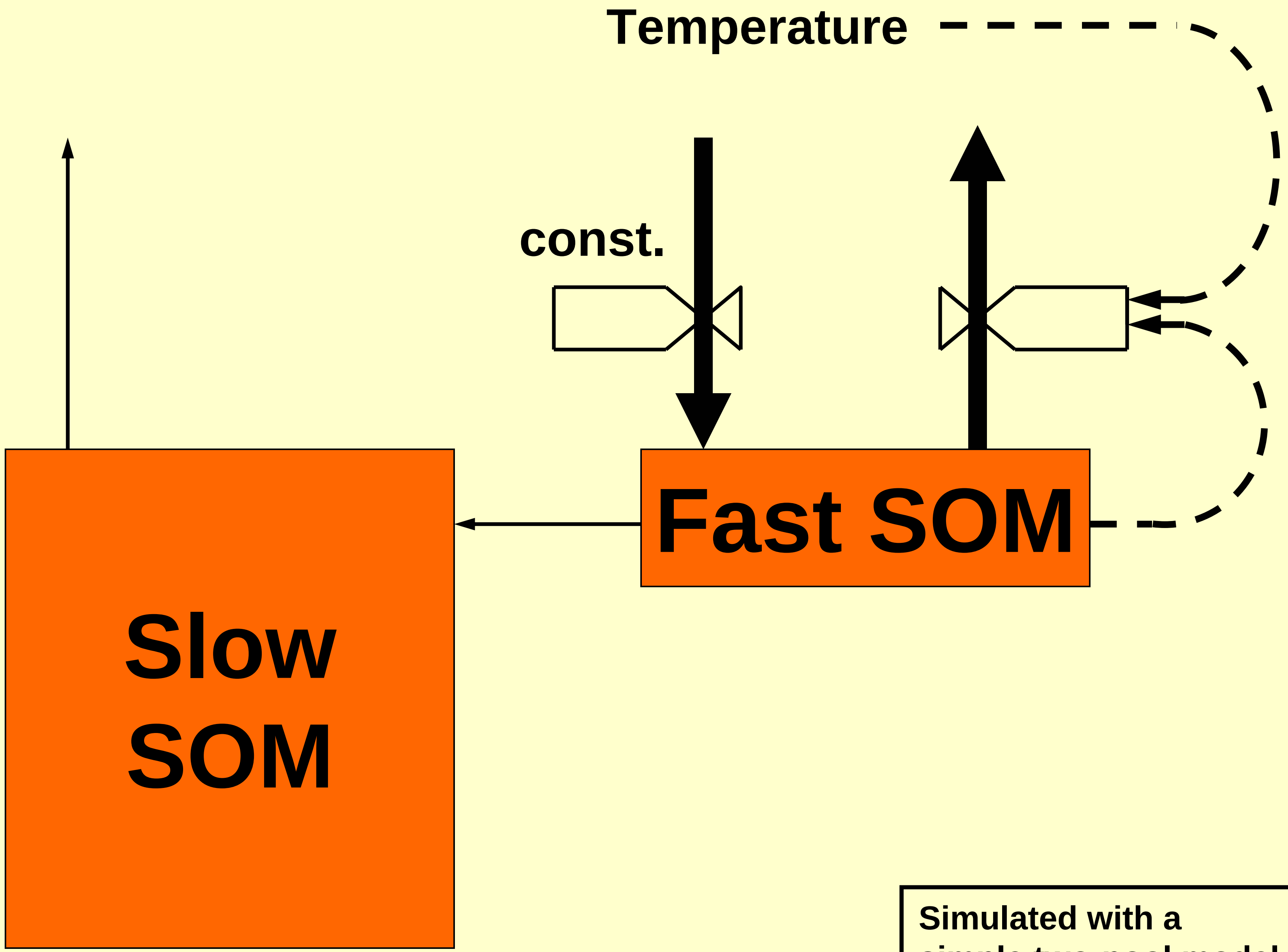
Labile substrate with more realistic simulations



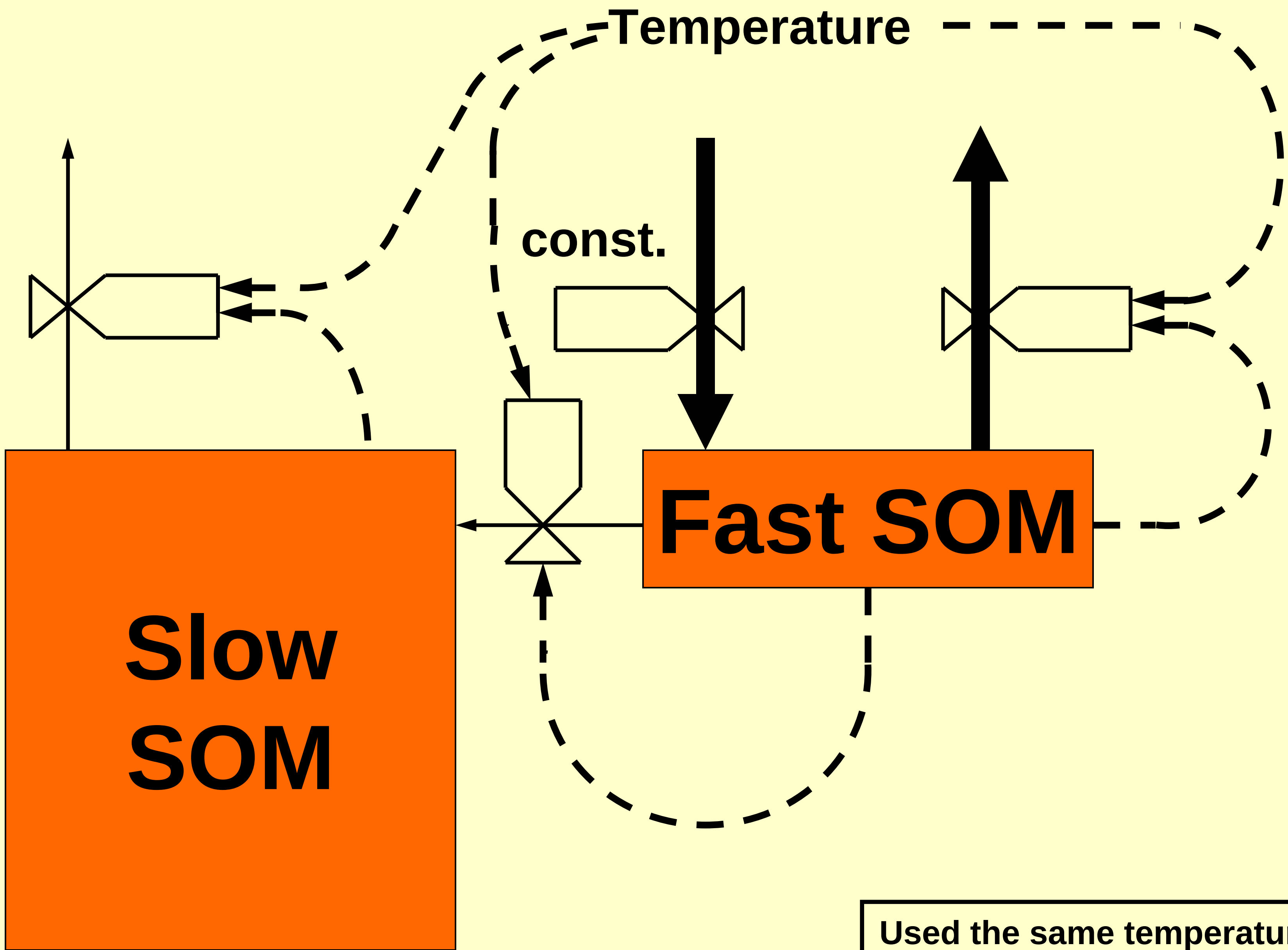
CenW/CENTURY
Multiple pools
Daily calculations

Substrate in soil warming experiments



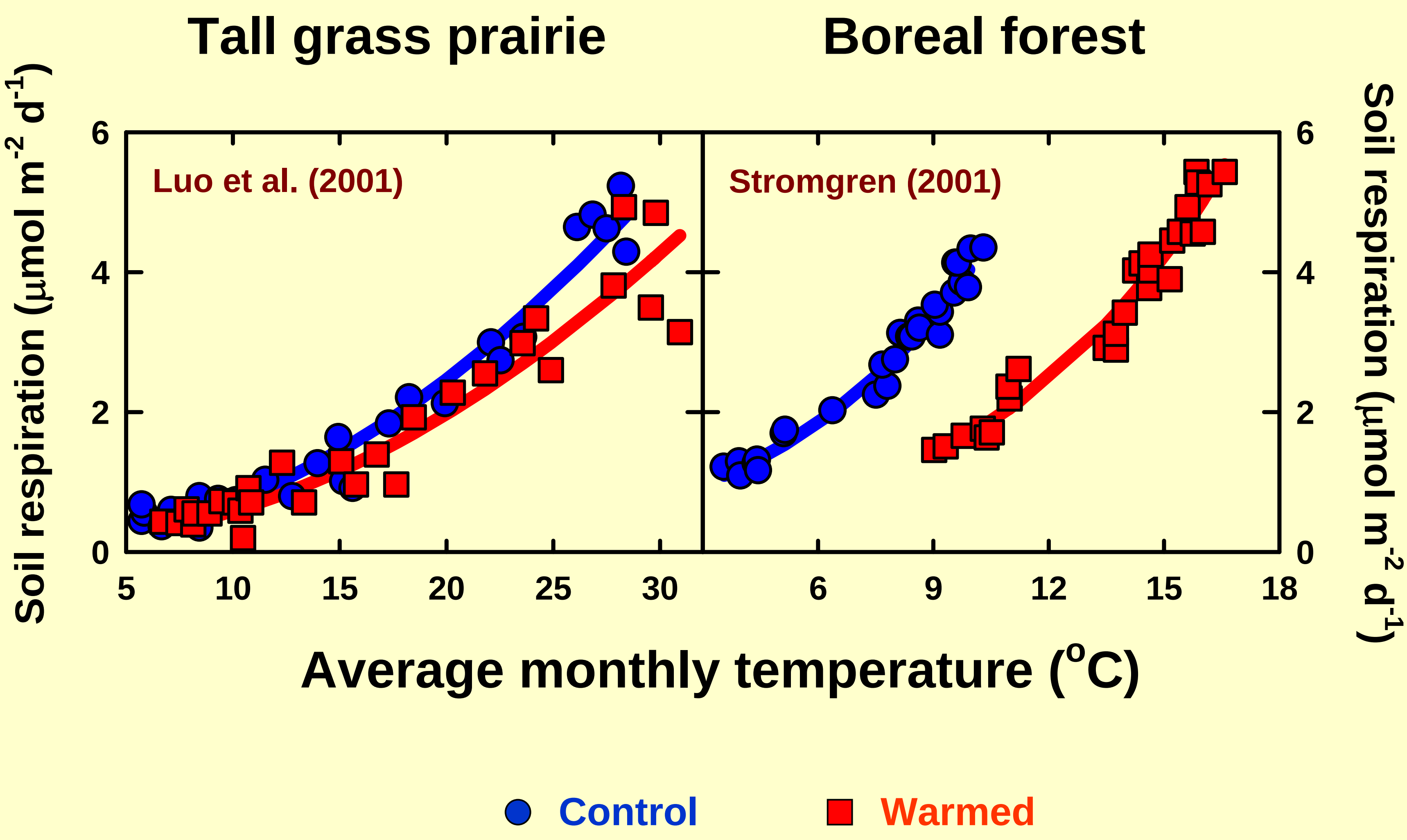


Simulated with a
simple two-pool model

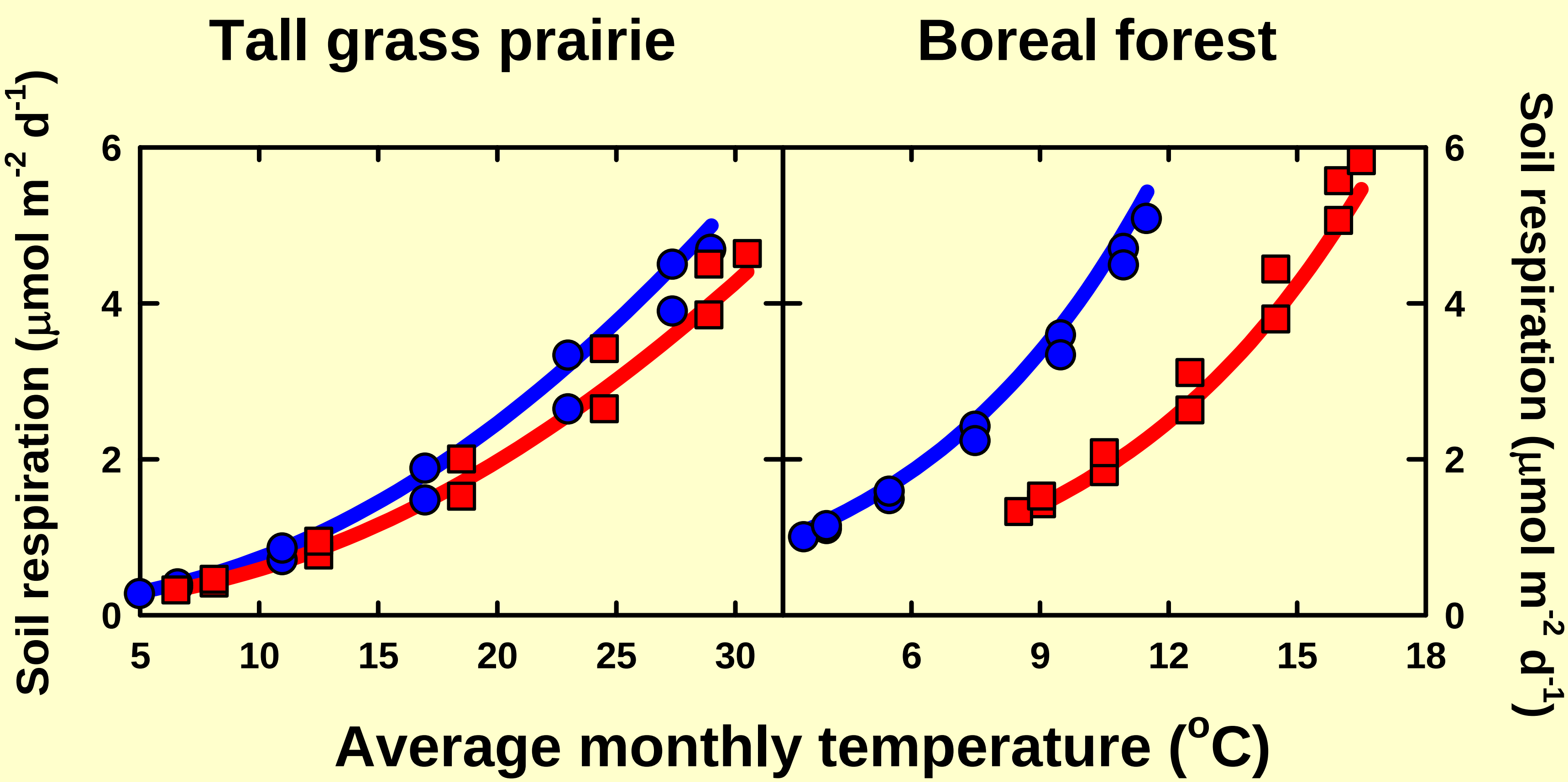


Used the same temperature dependence for all processes

Observations



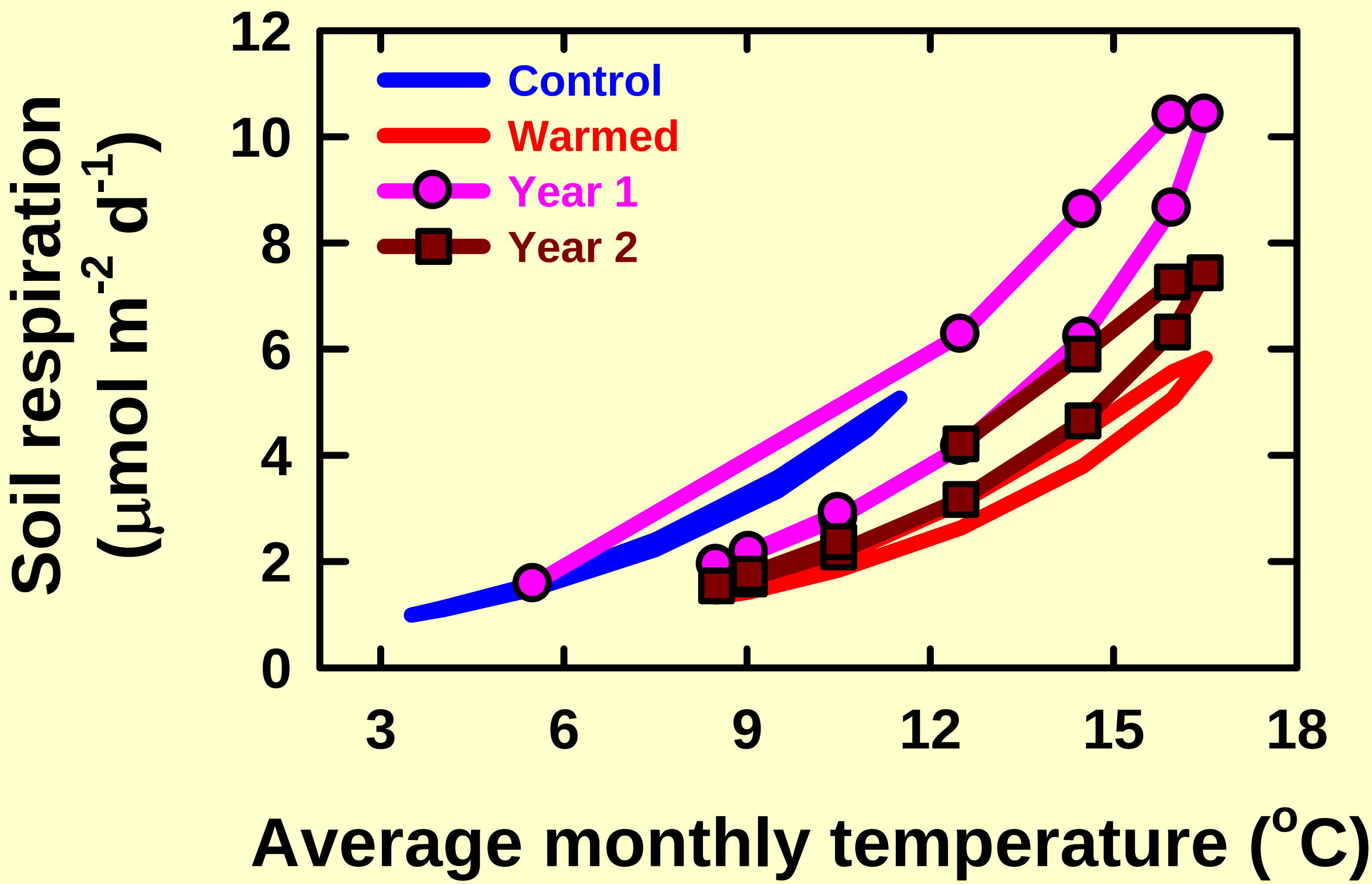
Simulations



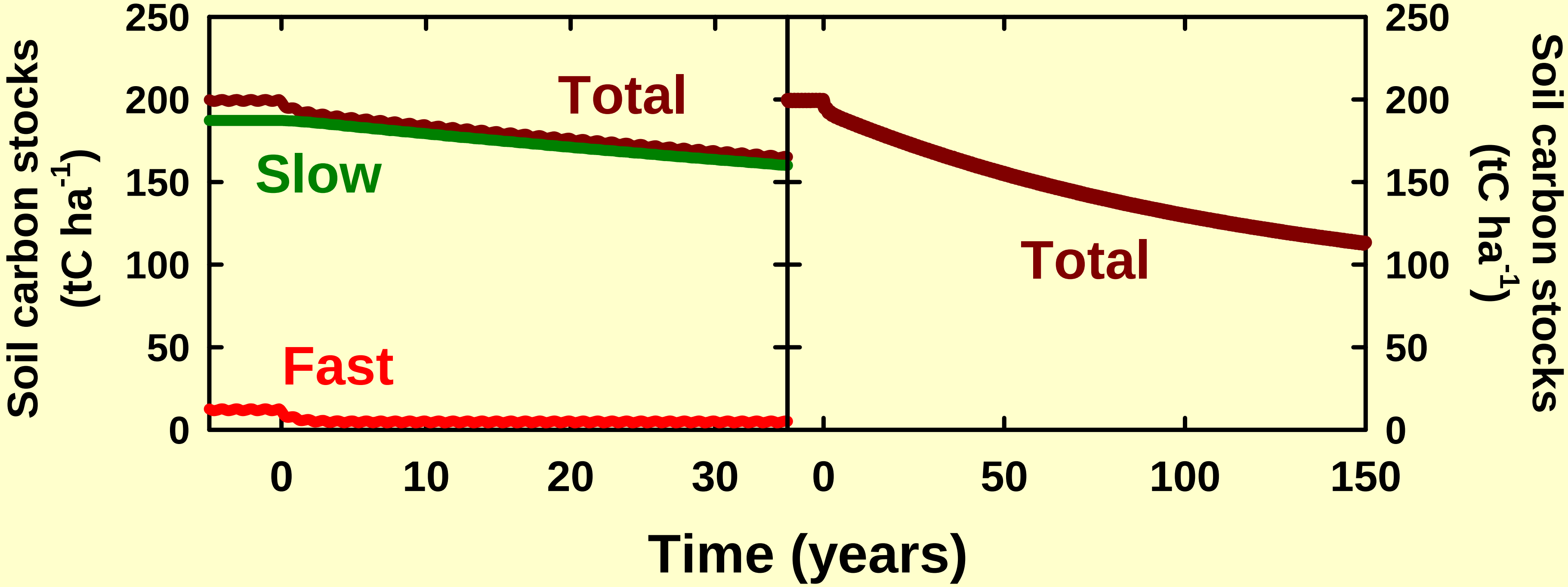
Kirschbaum (2004)

Curves: from experiments
Points: modelled

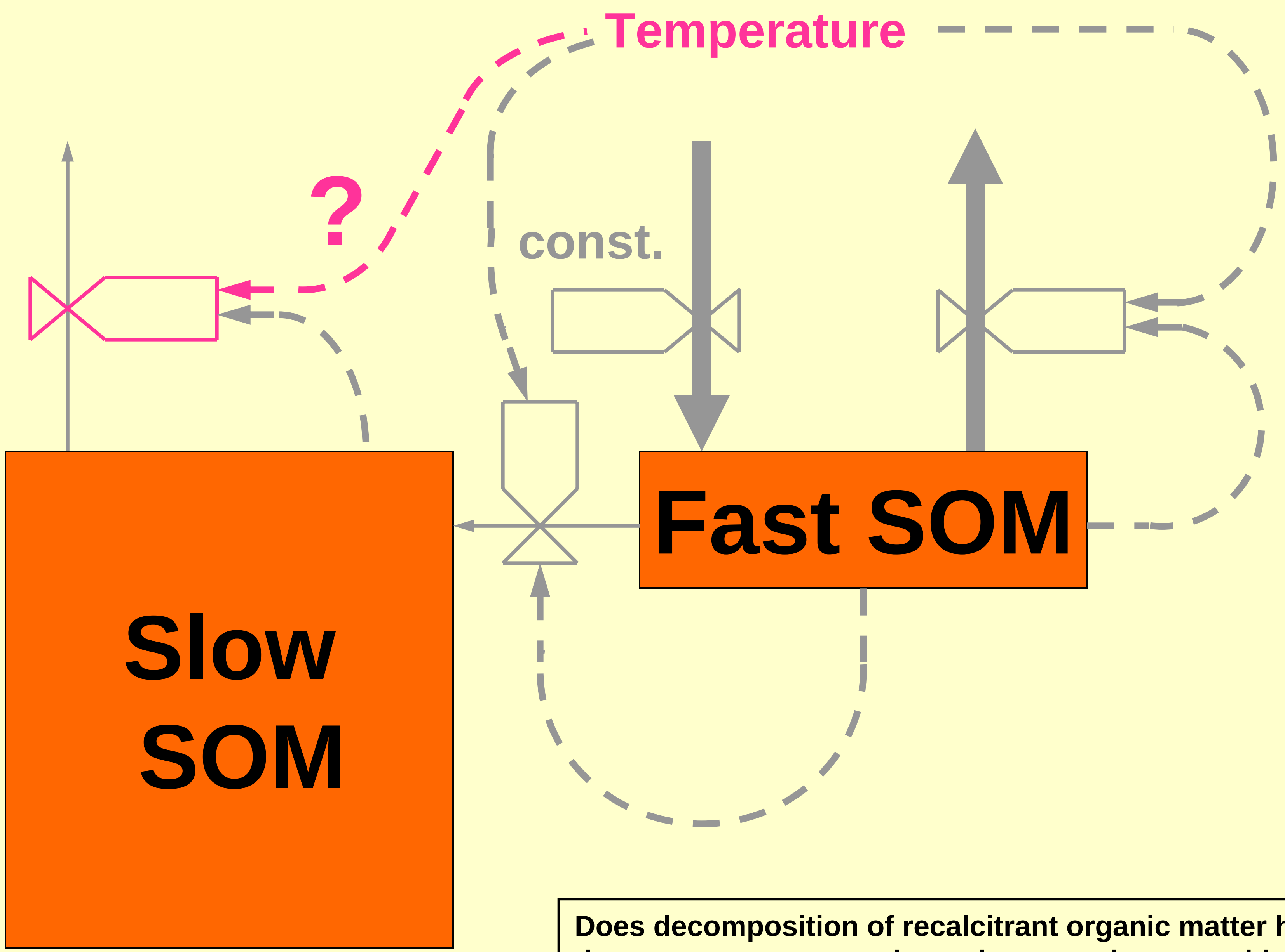
The transition phase



Long-term response to increasing temperature by 5°C



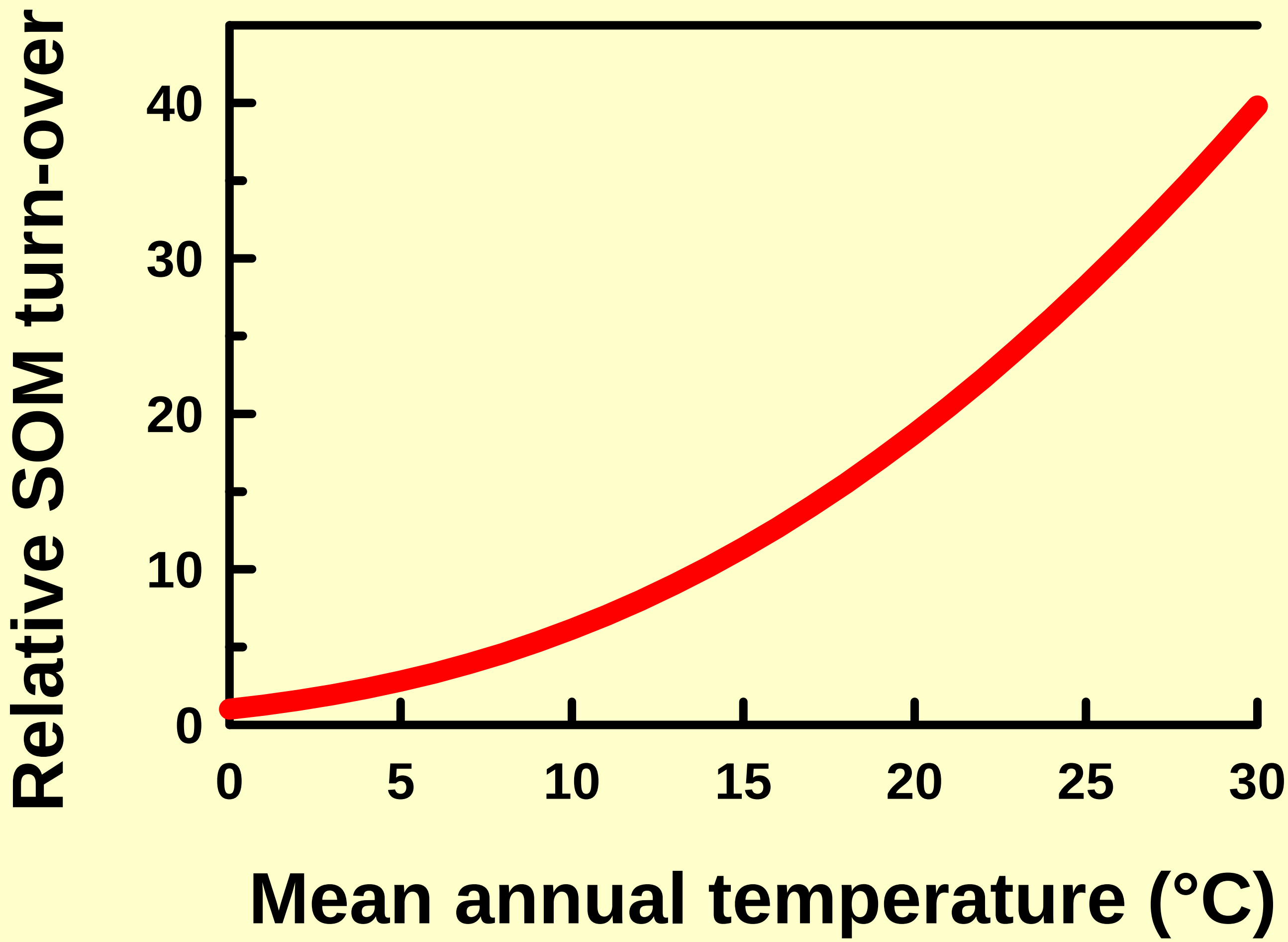
Same model and parameters that is used to describe the short-term response in the soil warming experiment



Does decomposition of recalcitrant organic matter have the same temperature dependence as decomposition of labile organic matter? Current evidence is inconclusive.

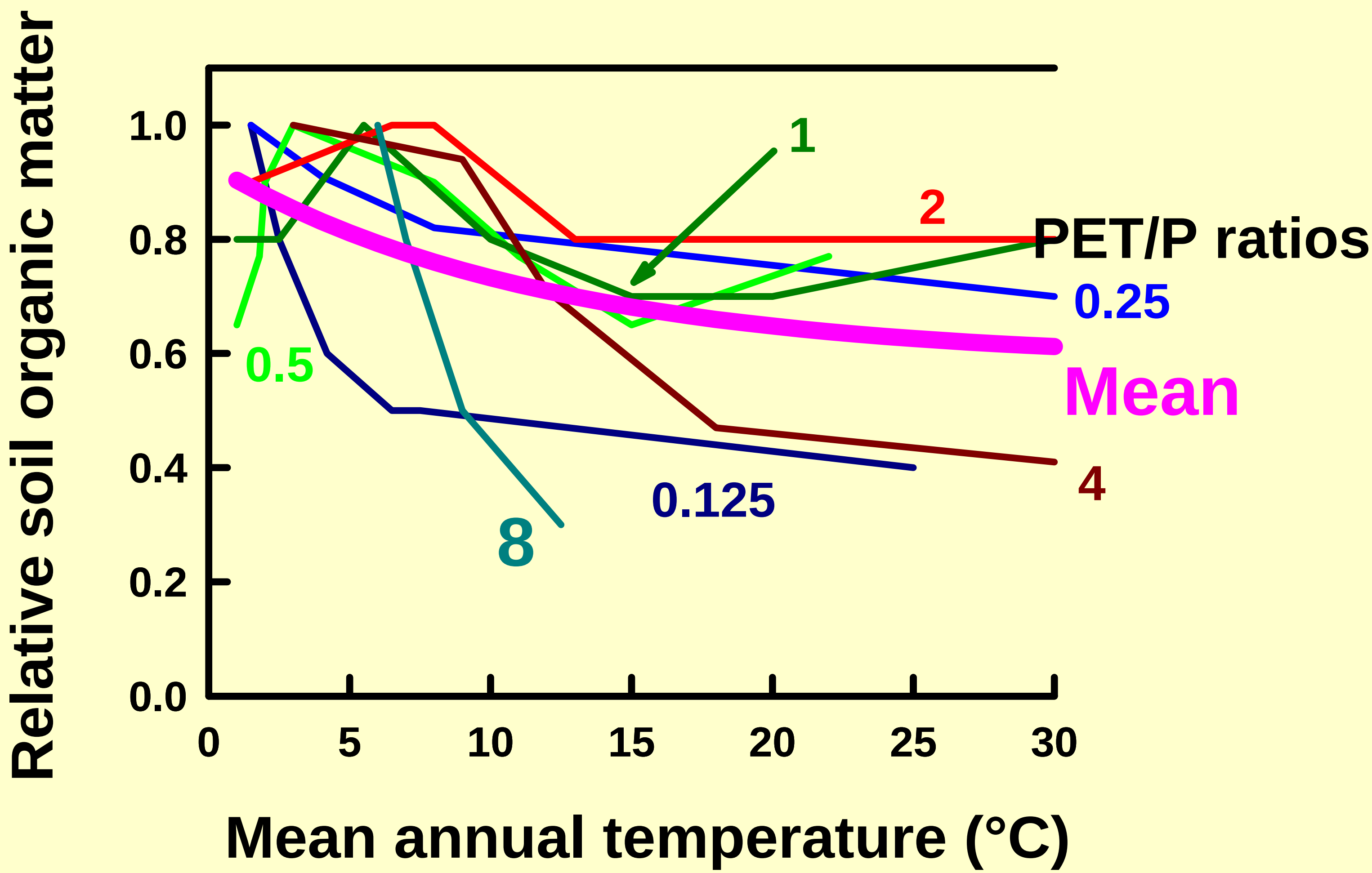
Seasonal temperature variations

Temperature response of decomposition rate



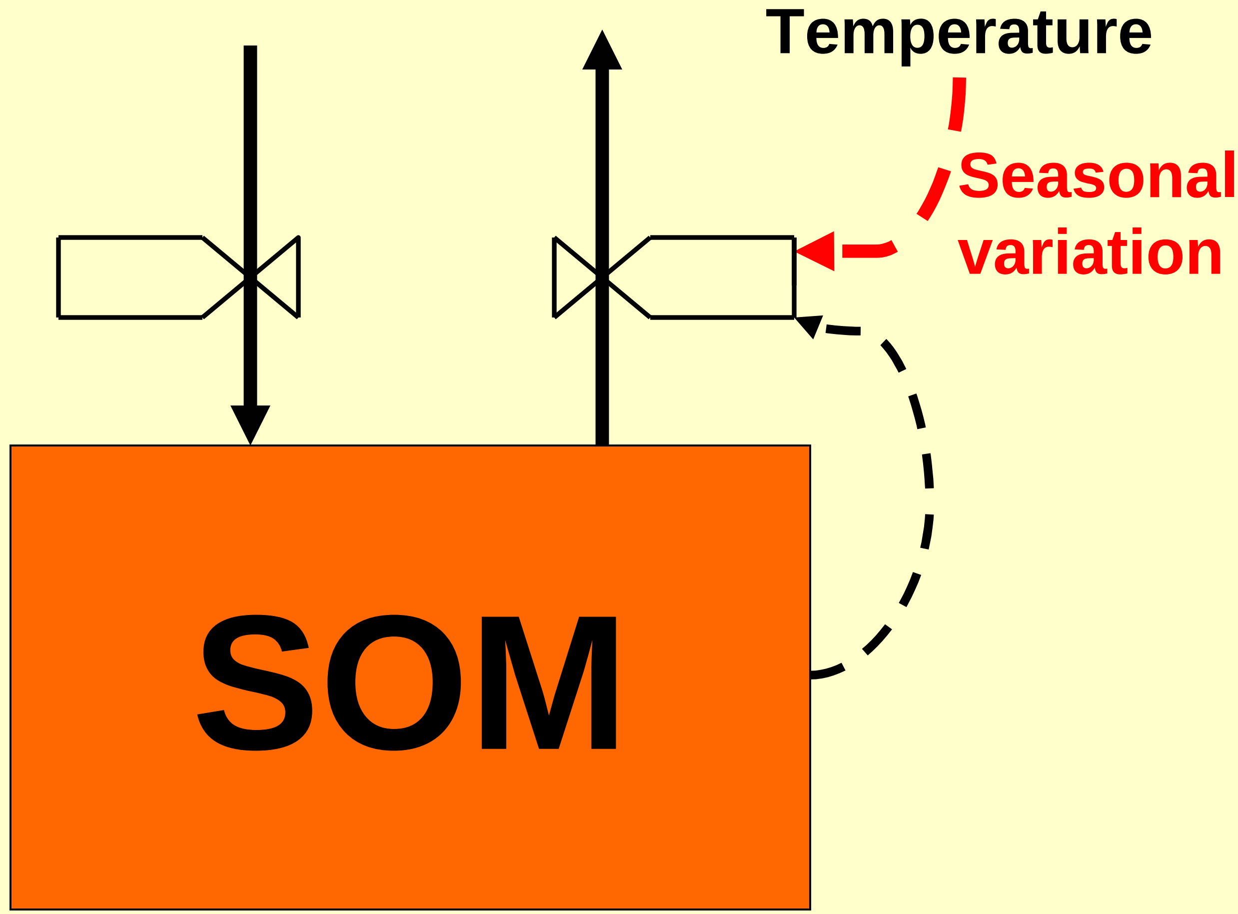
Based on the observed temperature dependence in laboratory incubations

Soil-organic carbon stocks across the globe

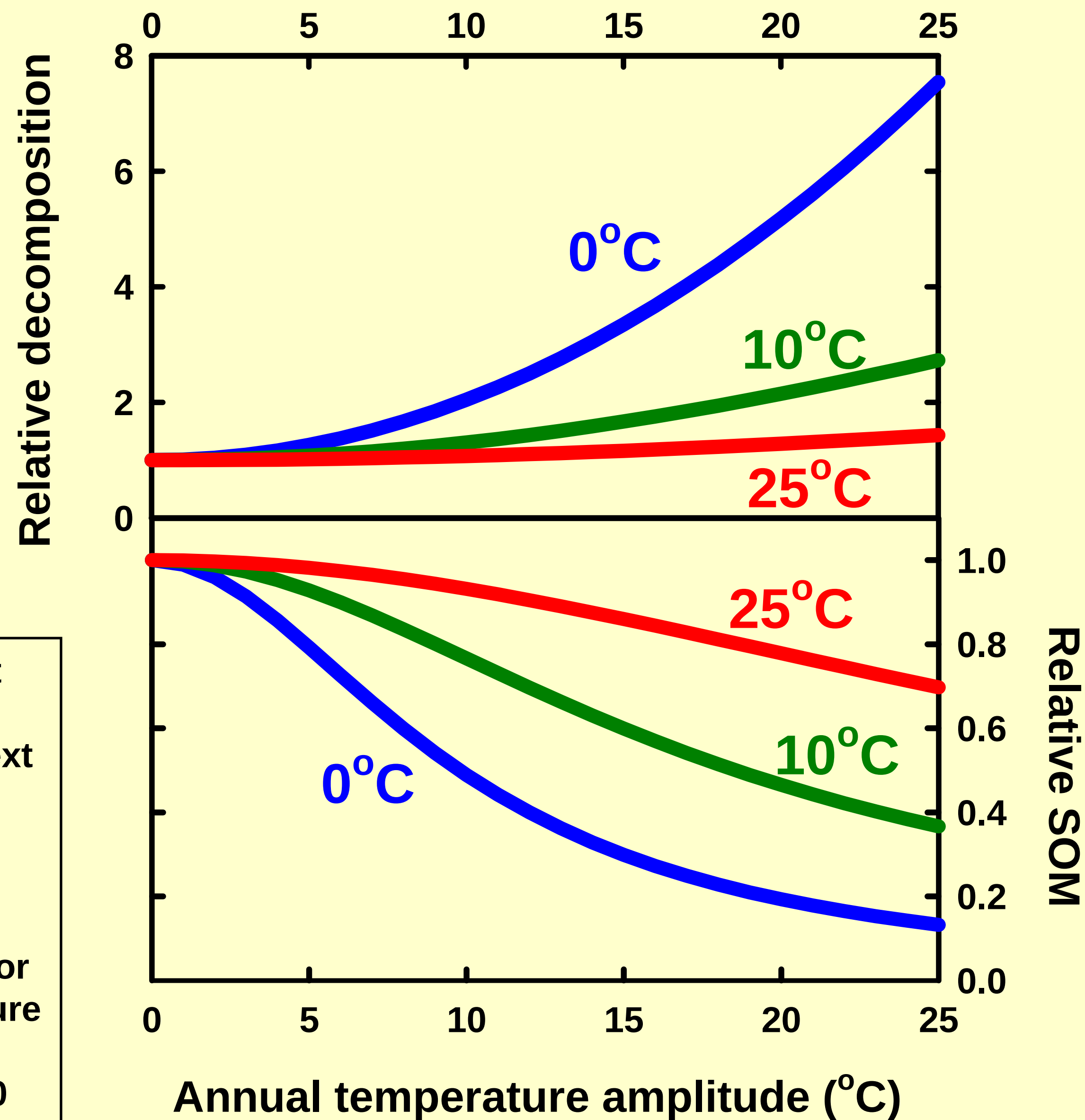


Is the strong temperature dependence consistent with flat temperature dependence of observed organic carbon stocks?

Post et al. (1985)

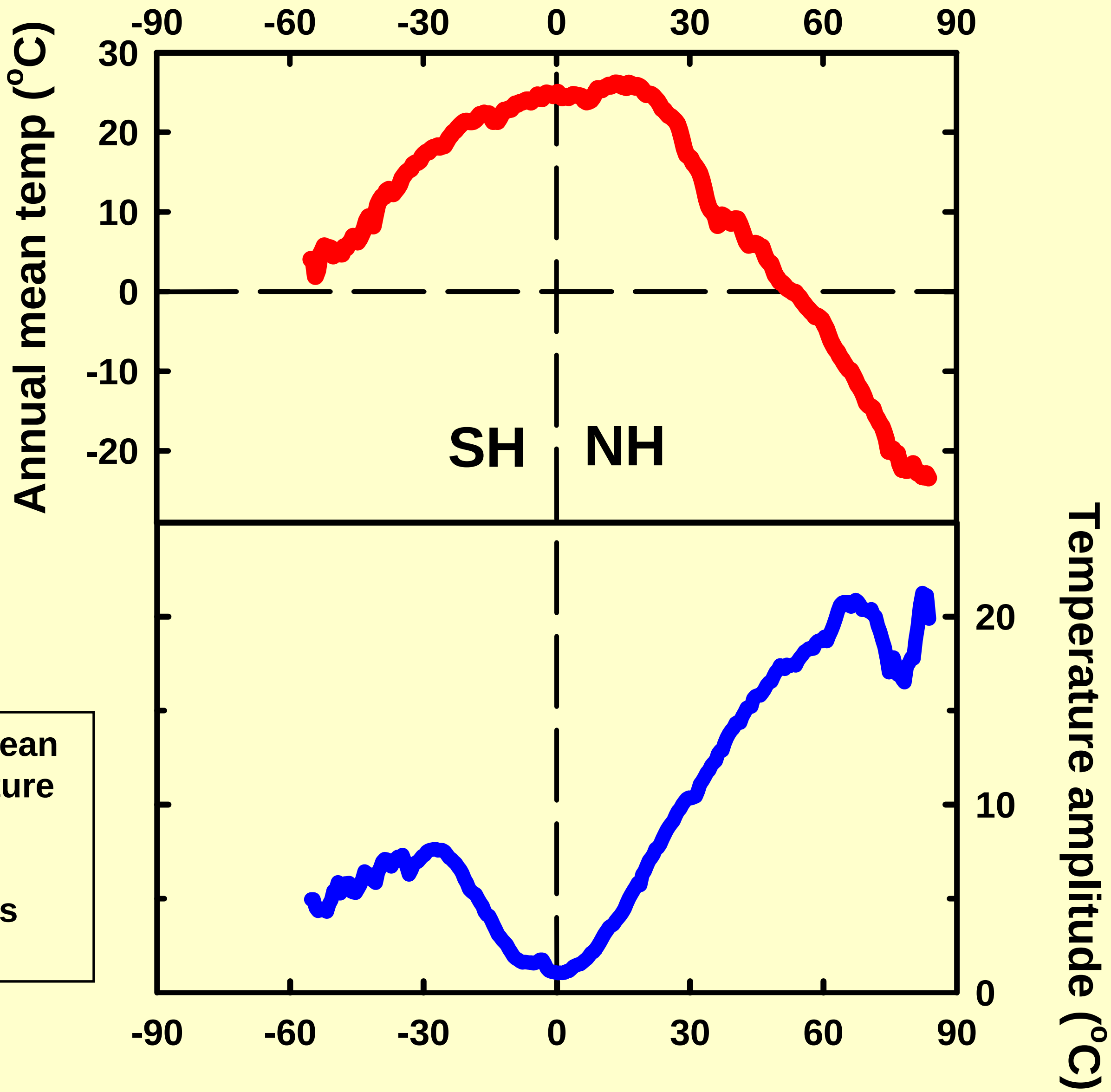

Temperature
Seasonal
variation
SOM

The importance of seasonal temperature variations



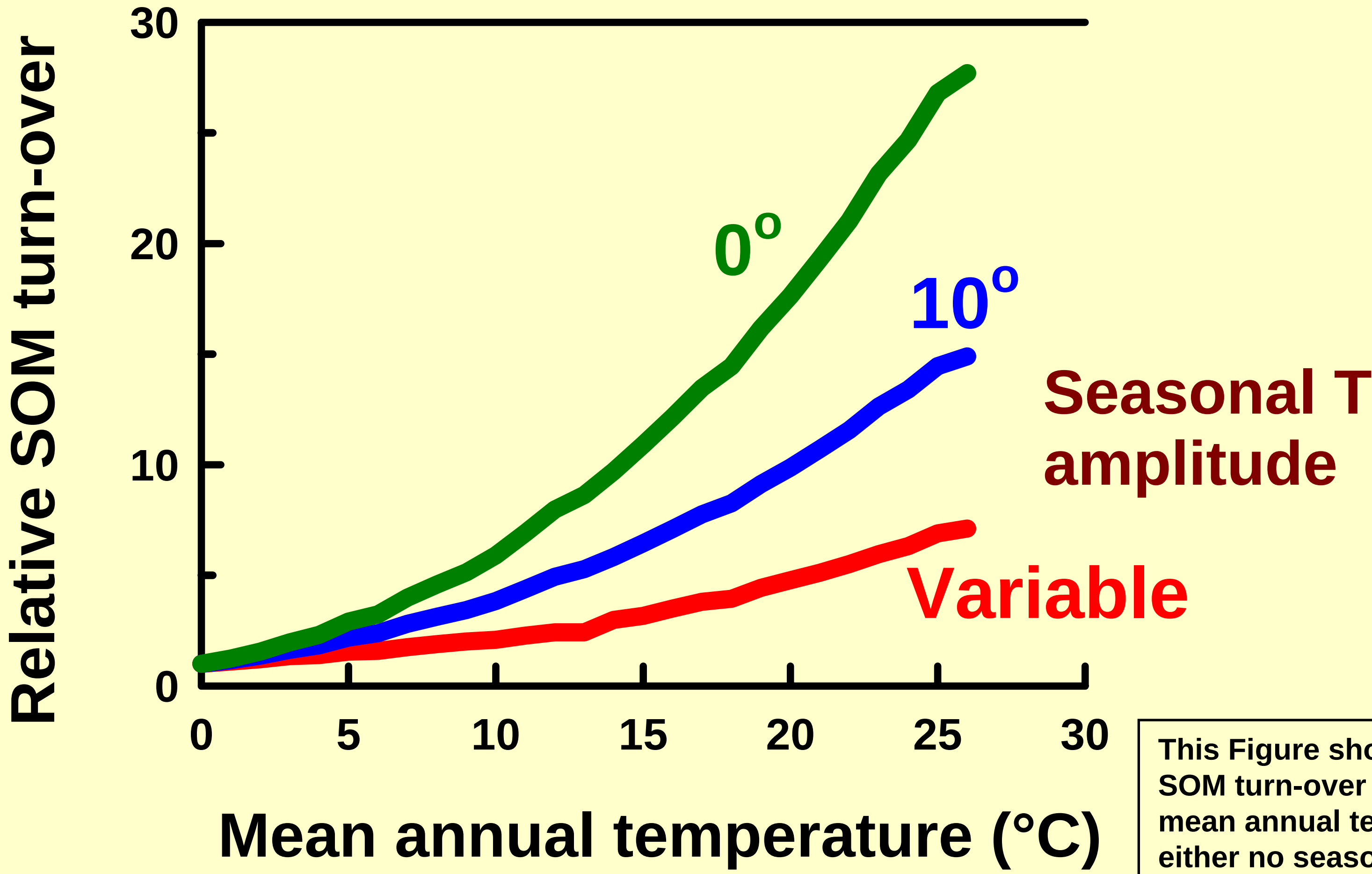
Each line refers to soils at the same annual mean temperature (as shown next to each line) and shows how decomposer activity and resultant equilibrium organic matter stocks change if there is greater or lesser seasonal temperature variation. All lines have been normalised to '1' at 0 degree amplitude.

Global temperature patterns

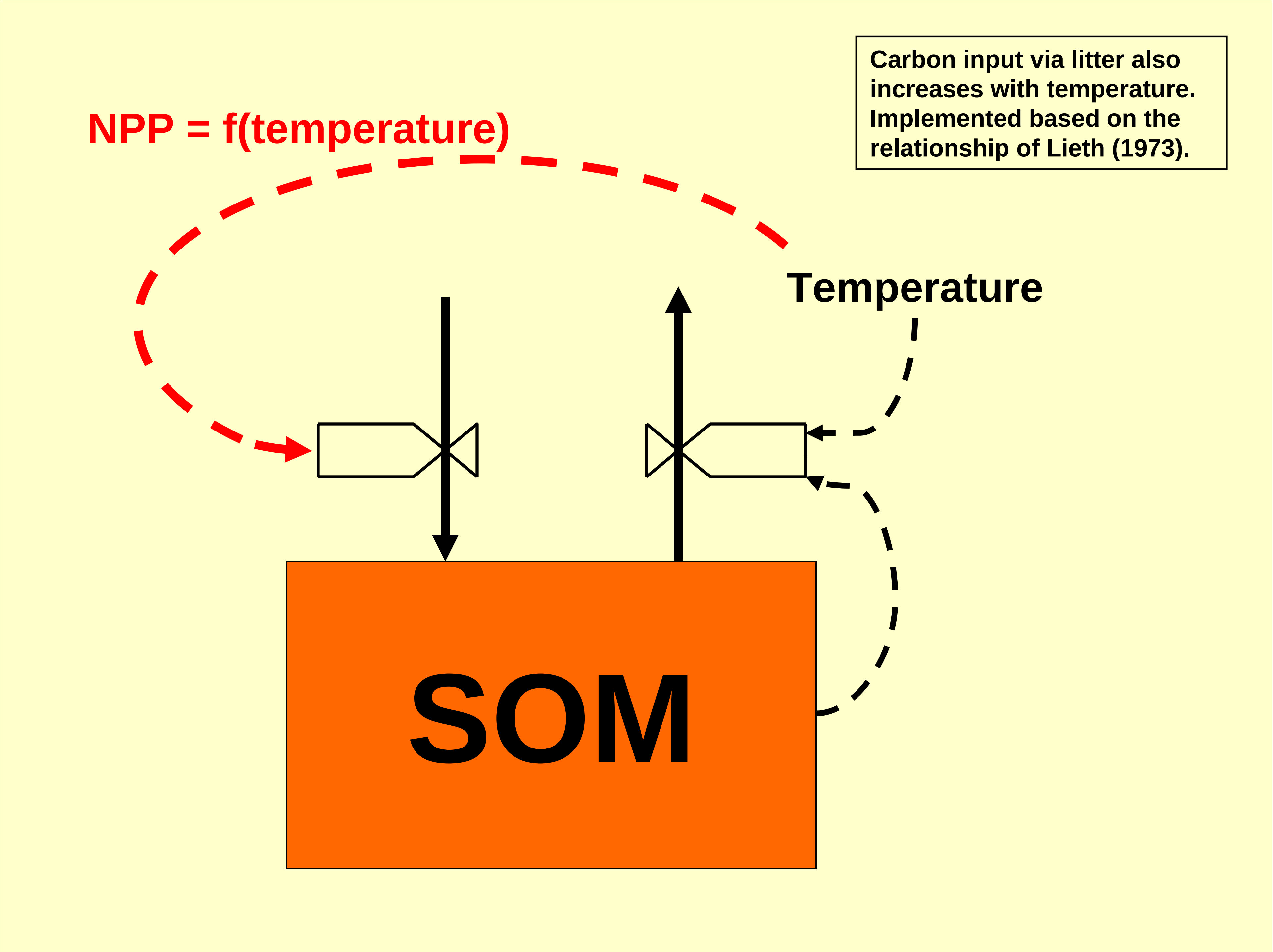


The observed mean annual temperature and seasonal temperature amplitude across the globe

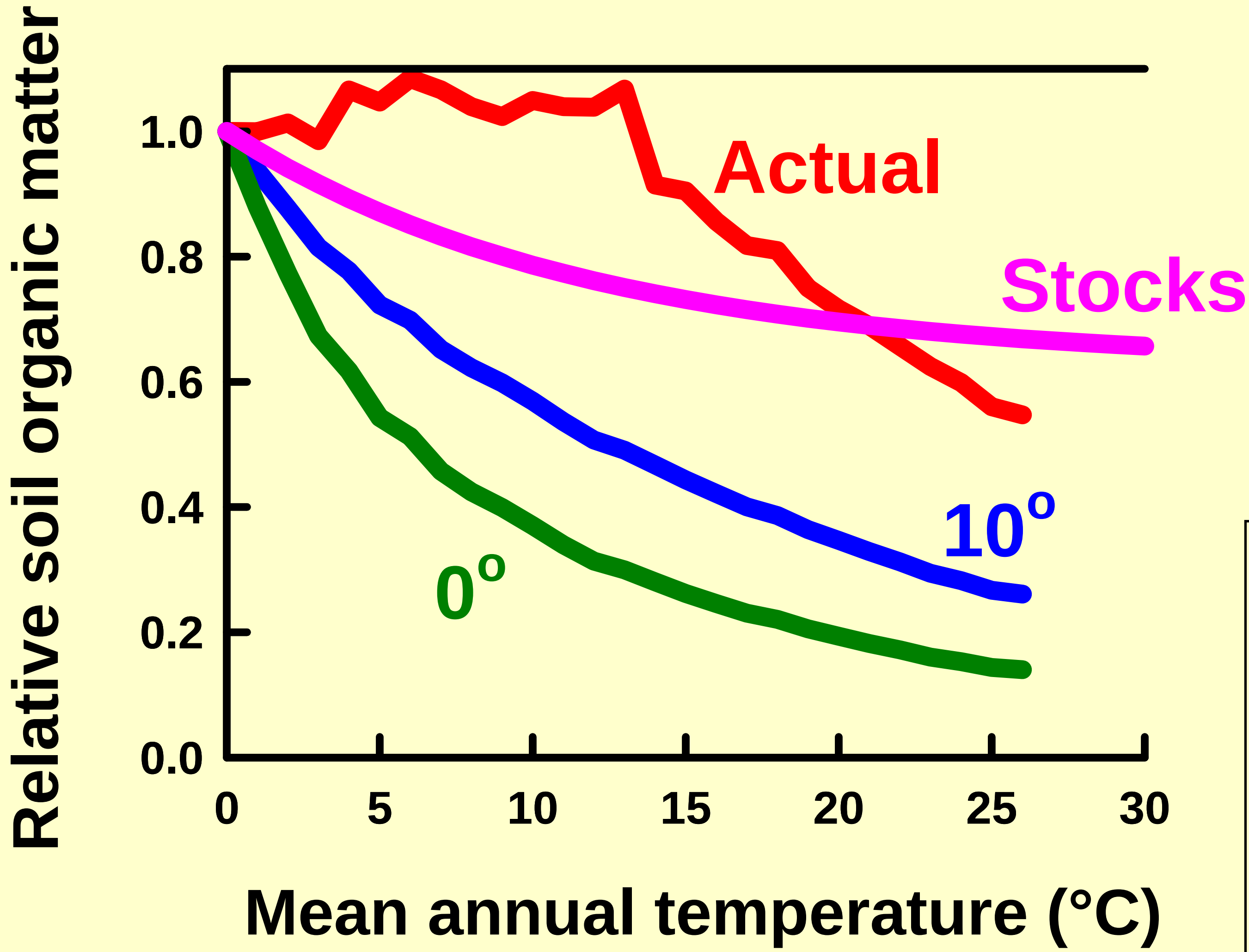
SOM turn-over



This Figure shows the relative SOM turn-over as a function of mean annual temperature with either no seasonal temperature variation, a fixed 10 degree amplitude or one based on the observed seasonal amplitude at different annual mean temperatures. All lines have been normalised to '1' at 0 degrees.

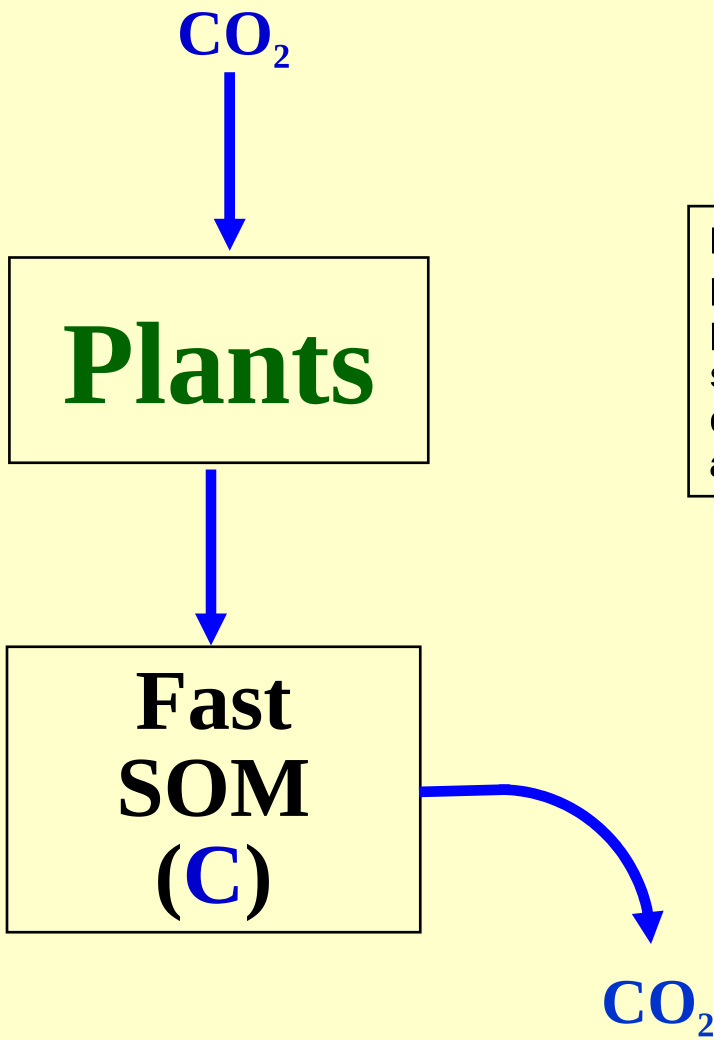

Carbon input via litter also increases with temperature. Implemented based on the relationship of Lieth (1973).
NPP = f(temperature)
Temperature
SOM

Soil-organic carbon stocks across the globe

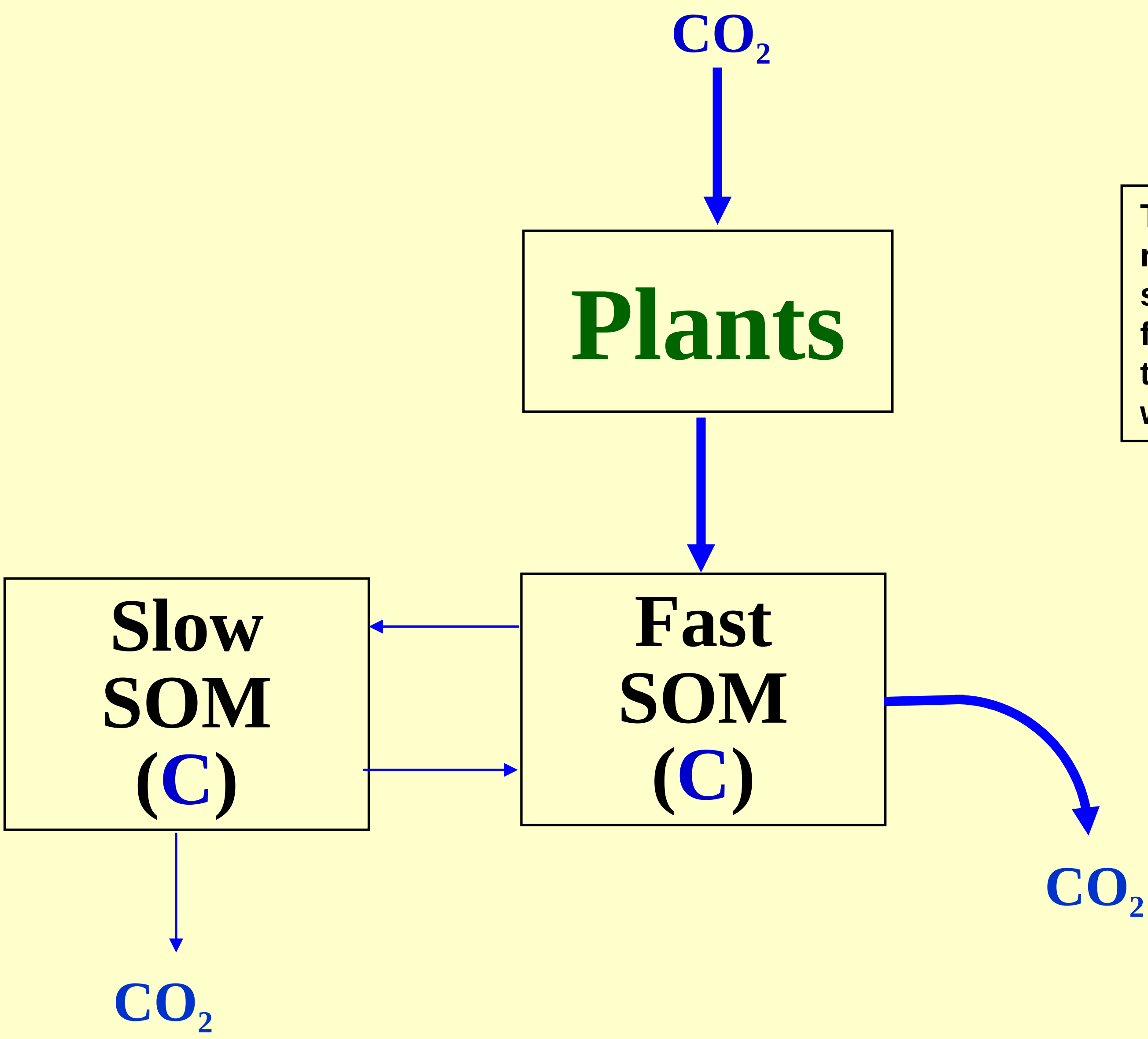


If seasonal temperature variations are ignored, one would predict organic carbon stocks to decrease much more with temperature than is observed. With seasonal temperature variations included, modelled changes in carbon stocks are similar to observed changes.

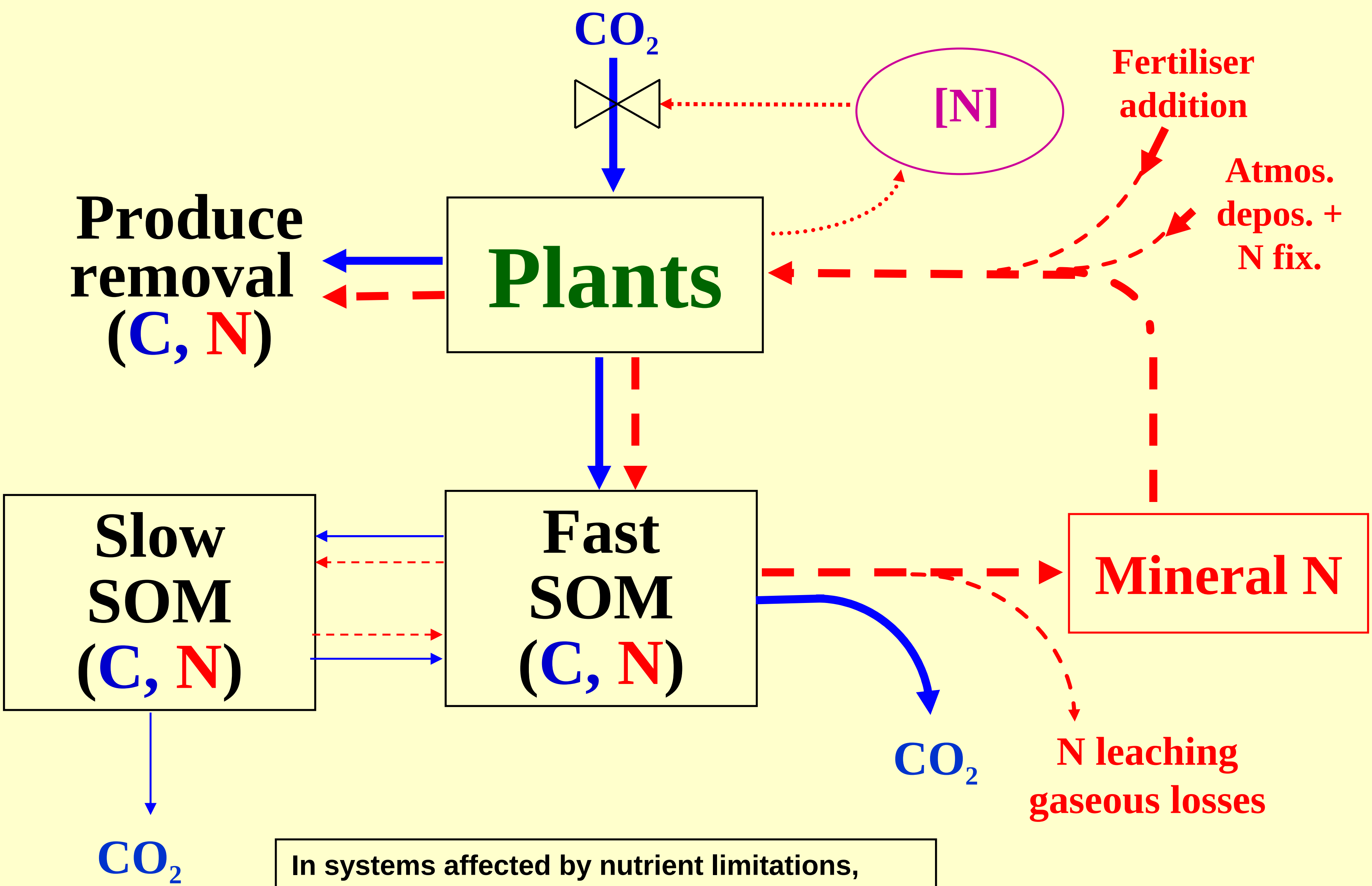
Carbon and nutrients



If one is only interested in predictions of static properties of soil carbon, a simple one-pool model driven by controls on inputs and outputs is adequate.



To study dynamic system responses a sub-division of soil carbon into slow and fast pools is necessary or the magnitude of responses will be overpredicted.



In systems affected by nutrient limitations, nutrient dynamics add a further stabilising element. Changes in soil carbon will then be even less than in models that ignore nutrients.

Conclusions (controversy or consensus?)

- Different observations are consistent if explicit account is taken of system differences
- Substrate supply is critical
- Inter-annual temperature changes are critical
- Strong underlying temperature sensitivity
- Compare like with like
- Nutrients a stabilising constraint