Lawrence Berkeley National Laboratory

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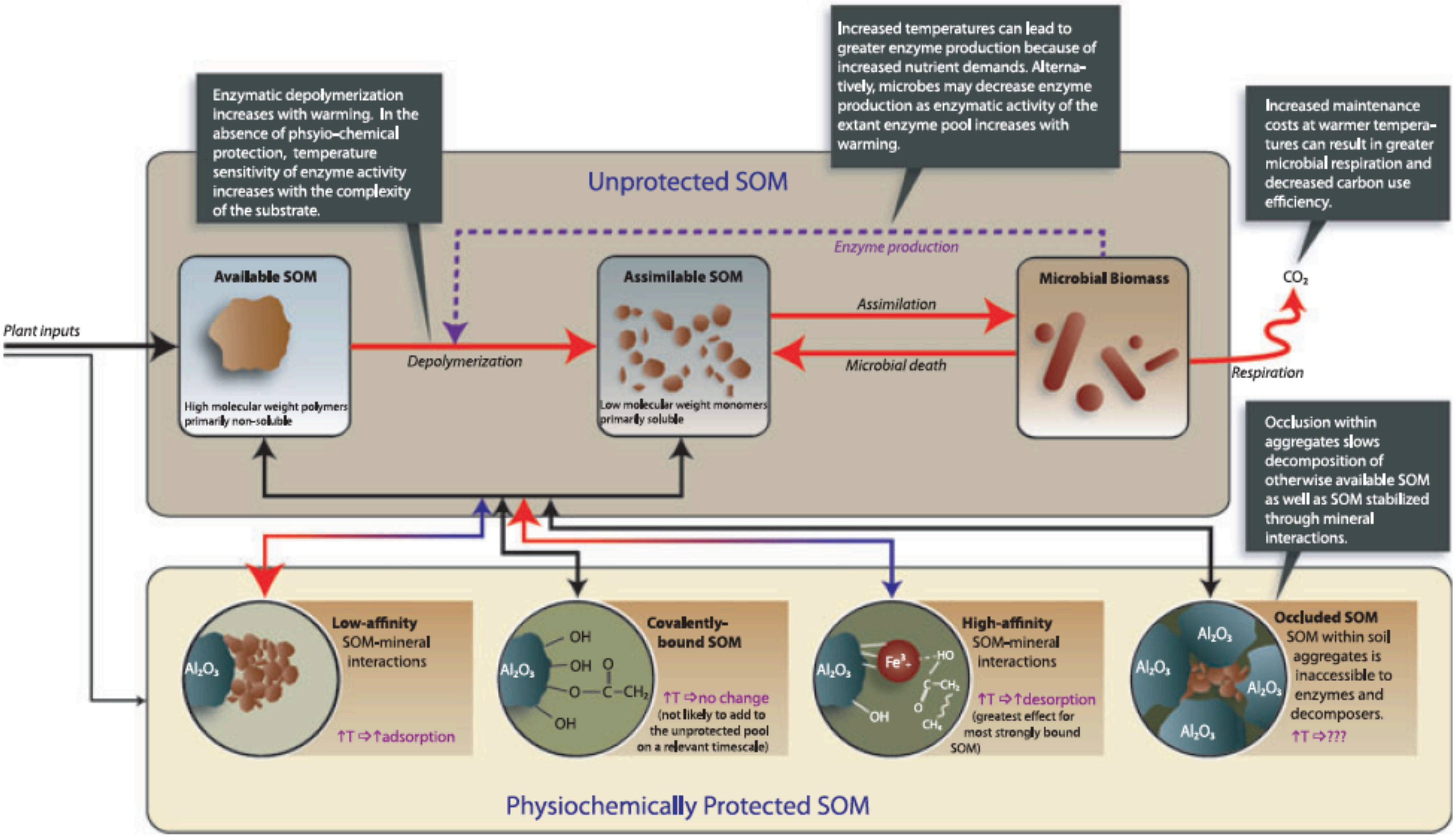
Biotic and abiotic interactions result in temperature sensitivity of soil carbon decomposition could not be parameterized with Q_{10}

Jinyun Tang and Bill Riley

SOM decomposition is complex



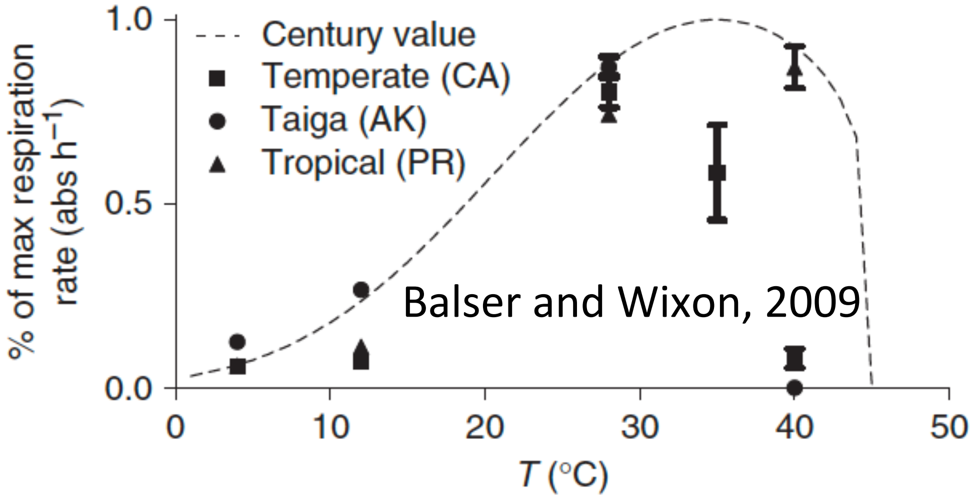
Conant et al., 2011

Temperature response in most models

$$\frac{dSOM}{dt} = f_1(moisture, OM, microbe, chemistry, others)\, f_2(temperature)$$

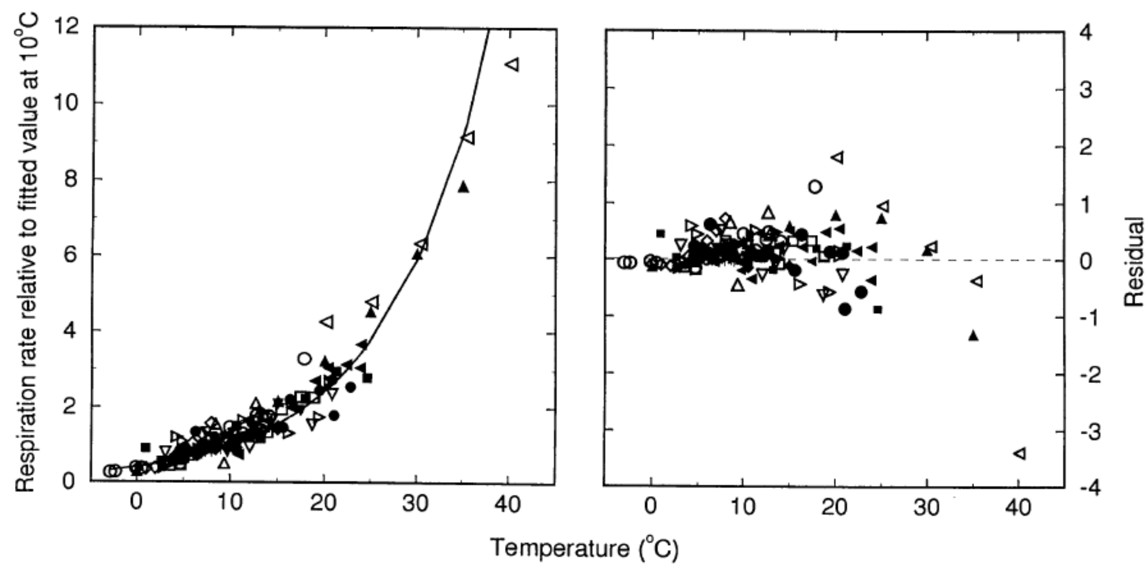
$f(x)$	Terms	Function name	Source
$f(T) =$			
$Q_{10}^{(T-10)/10}$	T: mean temperature	fT.Q10	
$\frac{47.9}{1+\exp(\frac{106}{T+18.3})}$	T: monthly temperature (°C)	fT.RothC	Jenkinson et al. (1990)
$\left(\frac{T_{max}-T}{T_{max}-T_{opt}}\right)^{0.2} \exp\left(\frac{0.2}{2.63}\left(1-\left(\frac{T_{max}-T}{T_{max}-T_{opt}}\right)^{2.63}\right)\right)$	T, T_{max} T_{opt}: monthly average, maximum, and optimal temperature	fT.Century1	Burke et al. (2003)
$3.439 \exp\left(\frac{0.2}{2.63}\left(1-\left(\frac{T_{max}-T}{T_{max}-T_{opt}}\right)^{2.63}\right)\left(\frac{T_{max}-T}{T_{max}-T_{opt}}\right)^{0.2}\right)$	T, T_{max} T_{opt}: monthly average, maximum, and optimal temperature	fT.Century2	Adair et al. (2008)
$0.8 \exp(0.095 T_s)$	T_s: Soil temperature	fT.Daycent1	Kelly et al. (2000)
$0.56 + (1.46 \arctan(\pi 0.0309(T_s - 15.7)))/\pi$	T_s: Soil temperature	fT.Daycent2	Parton et al. (2001); Grosso et al. (2005)
$0.198 + 0.036T$	T: monthly temperature	fT.linear	Adair et al. (2008)
$\exp\left(308.56\left(\frac{1}{56.02} - \frac{1}{(T+273)-227.13}\right)\right)$	T: monthly temperature	fT.LandT	Lloyd and Taylor (1994)
$\exp(-3.764 + 0.204T(1 - 0.5T/36.9))$	T: mean temperature	fT.KB	Kirschbaum (1995)
$\exp((\ln(Q_{10})/10)(T - 20))$	T: mean temperature. Q_{10}: temperature coefficient	fT.Demeter	Foley (2011)
$\exp(-(T/(T_{opt}+T_{lag}))^{T_{shape}})\, Q_{10}^{(T-10)/10}$	T, T_{max} T_{opt}: monthly average, maximum, and optimal temperature	fT.Standcarb	Harmon and Domingo (2001)

Observations from well controlled incubations

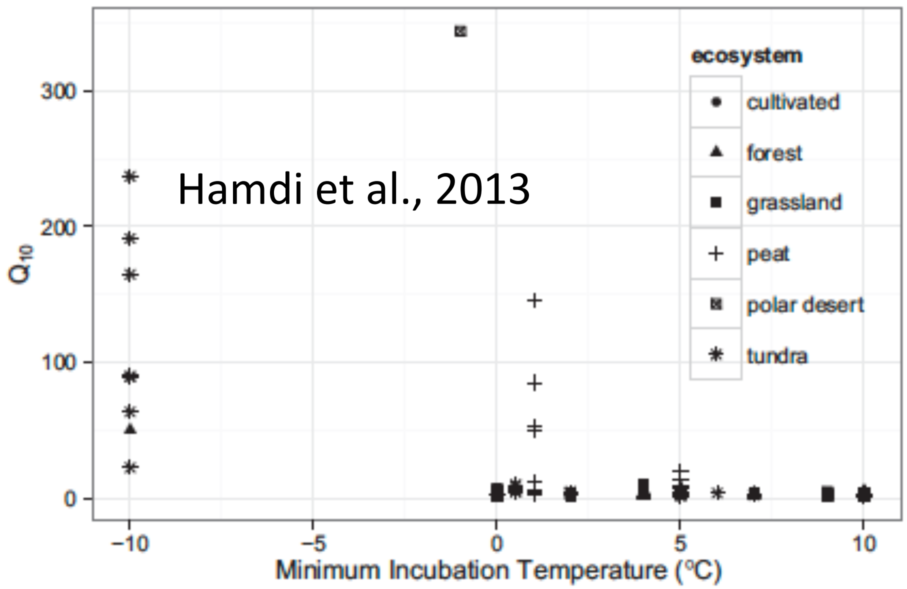


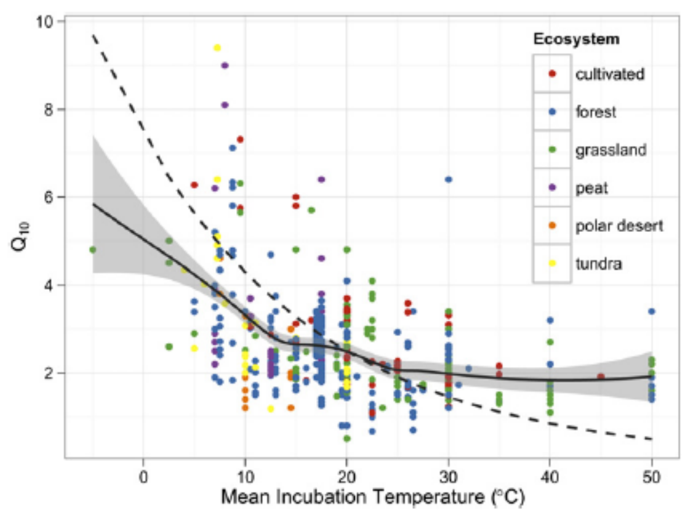
Balser and Wixon, 2009

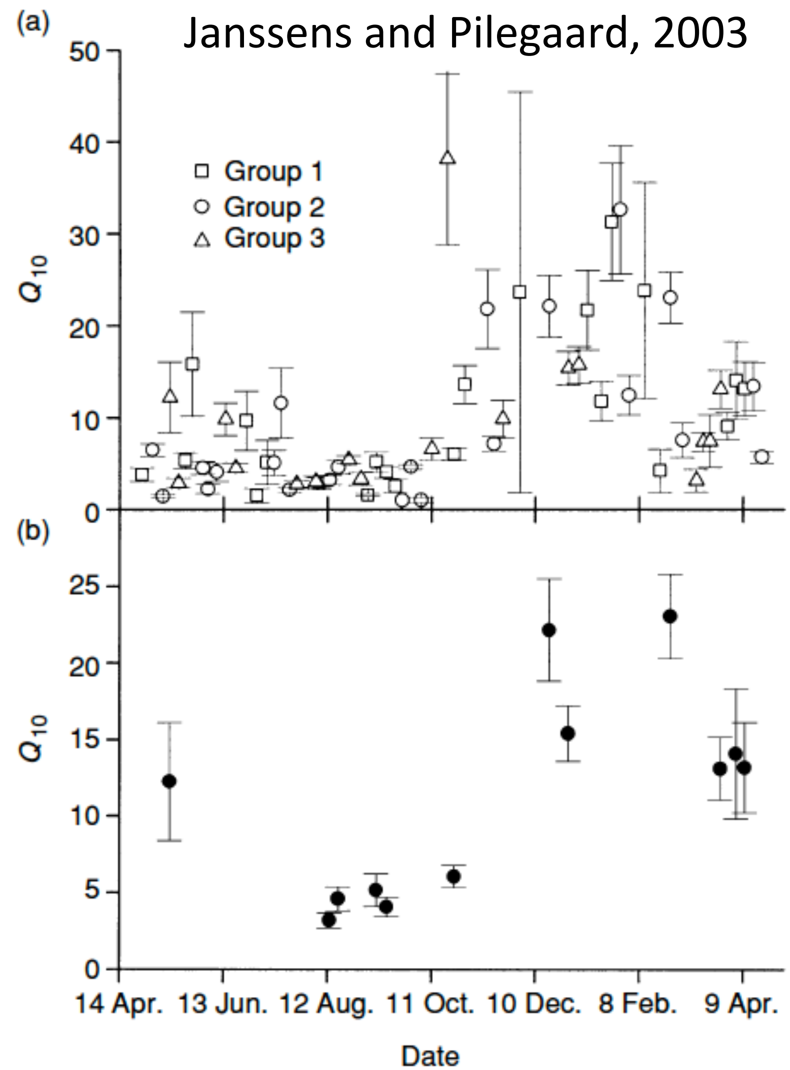
Lloyd and Taylor, 1994



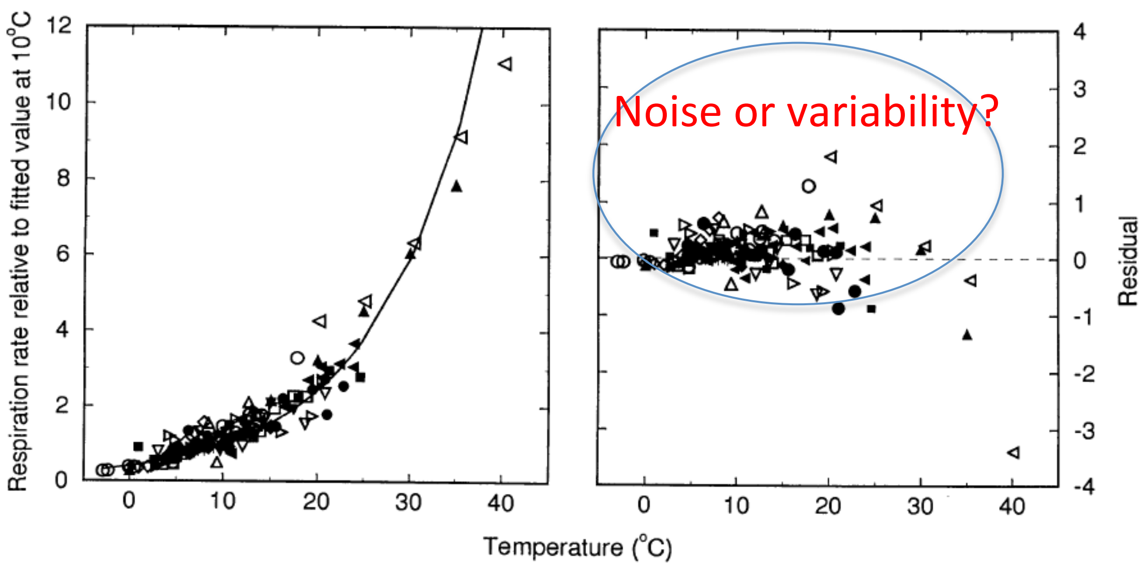
Yet empirical experiments overall imply highly variable Q_{10}





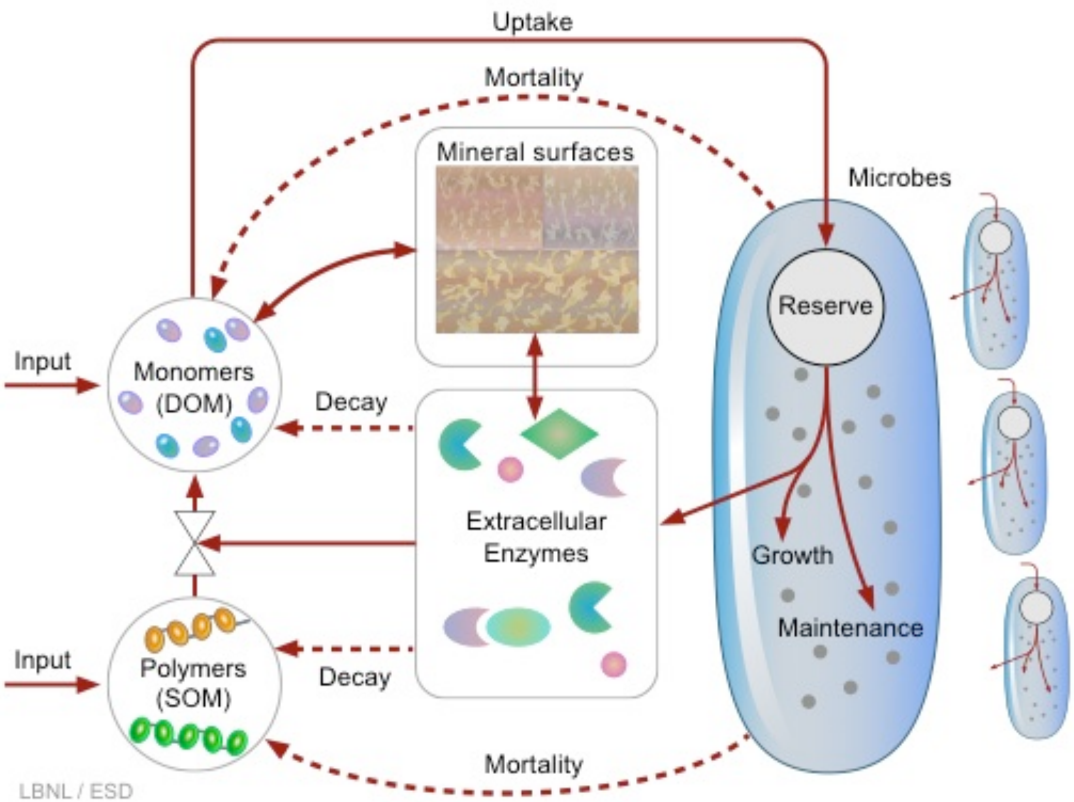


Are we lost in the beauty of (over)simplicity?



Lloyd and Taylor, 1994

Model structure



$$\frac{dS}{dt} = I_S - F_S + \gamma_{B1} B + f_E \gamma_E E$$

$$\frac{dC}{dt} = I_C + F_S - F_C + \gamma_{B1} X + (1 - f_E)\gamma_E E$$

$$\frac{dX}{dt} = Y_X F_C - (\kappa - g + \gamma_{B1}) X$$

$$\frac{dB}{dt} = (g - \gamma_{B1}) B$$

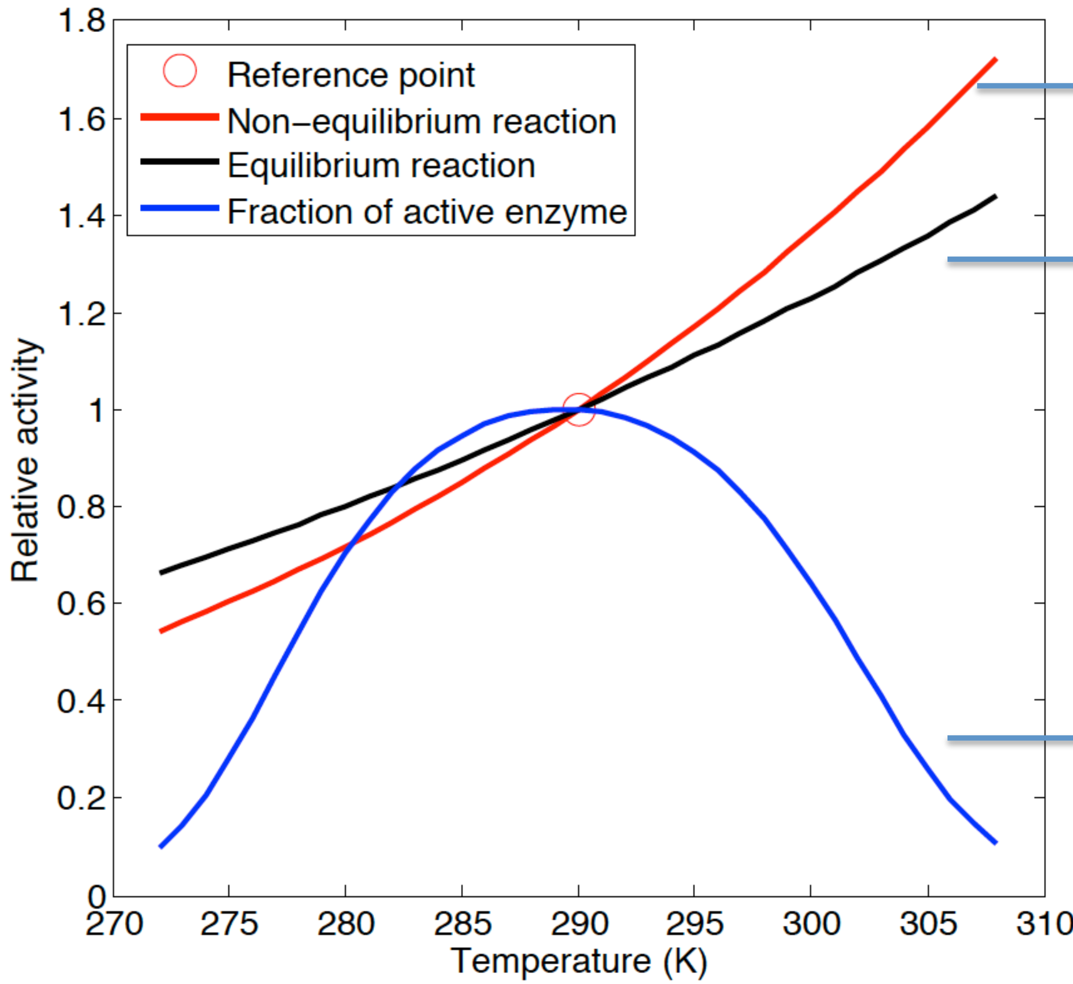
$$\frac{dE}{dt} = p_E B - \gamma_E E$$

$$R_{CO2} = (1 - Y_X) F_C + \left[m + g\left(\frac{1}{Y_B} - 1\right) + p_E \left(\frac{1}{Y_E} - 1\right)\right] B + F_r$$

Tang and Riley, 2014

One substrate one microbe model

Representing temperature sensitivities of different processes

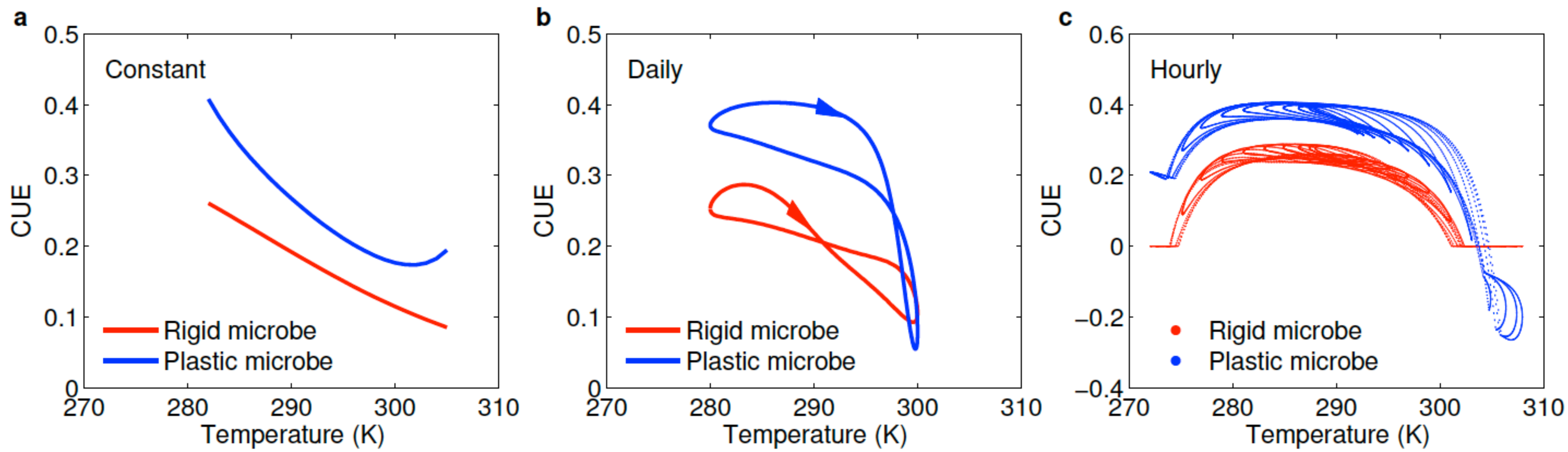


Transition state theory: substrate conversion

Arrhenius rate law: reversible binding processes, cell maintenance

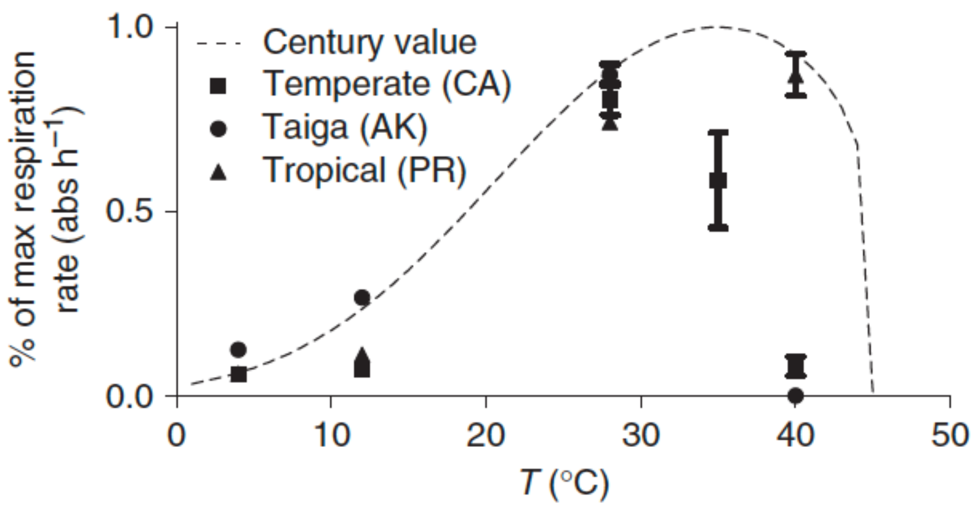
Enzyme stability

Highly variable CUE precludes direct empirical CUE parameterization

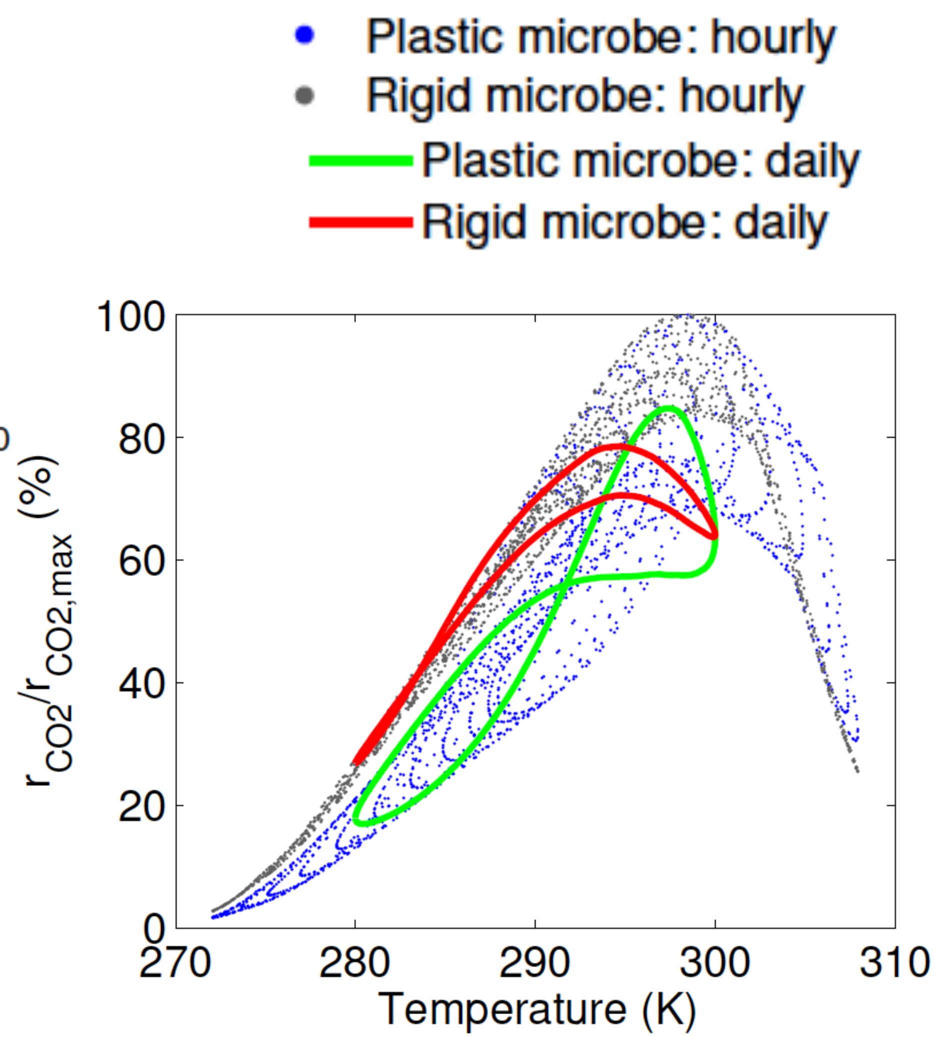


Insufficient empirical data to fully characterize the variability of CUE temperature dependence.

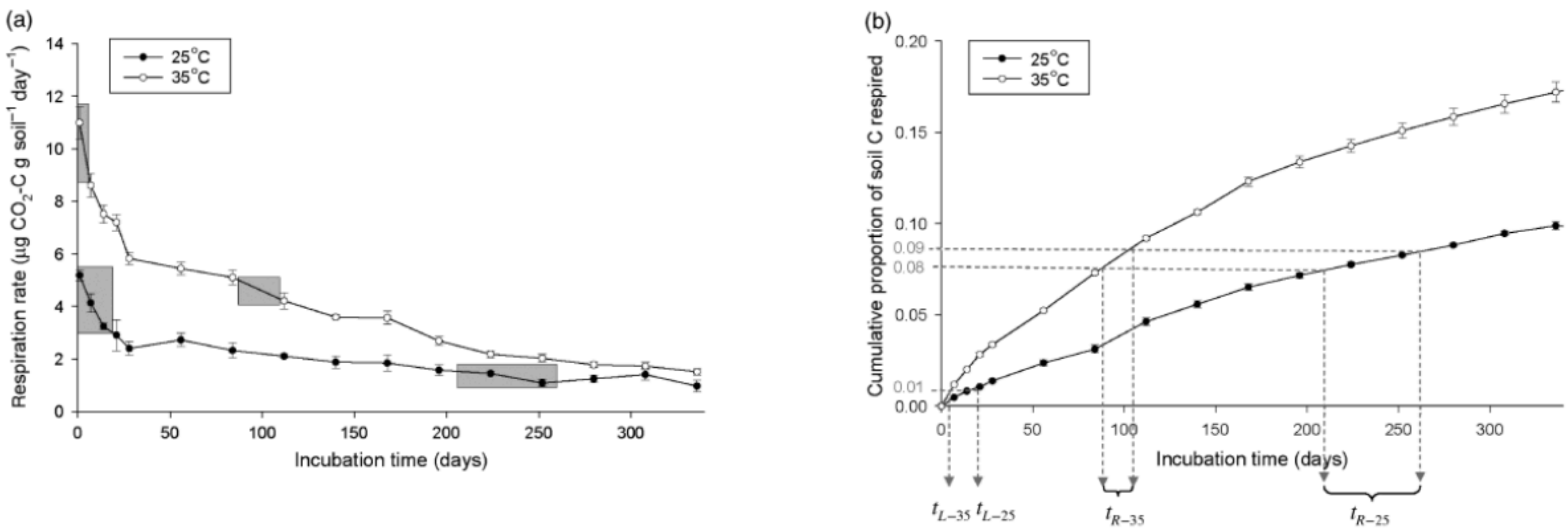
Empirical incubation only captures one aspect of the temperature sensitivity



Balser and Wixon, 2009

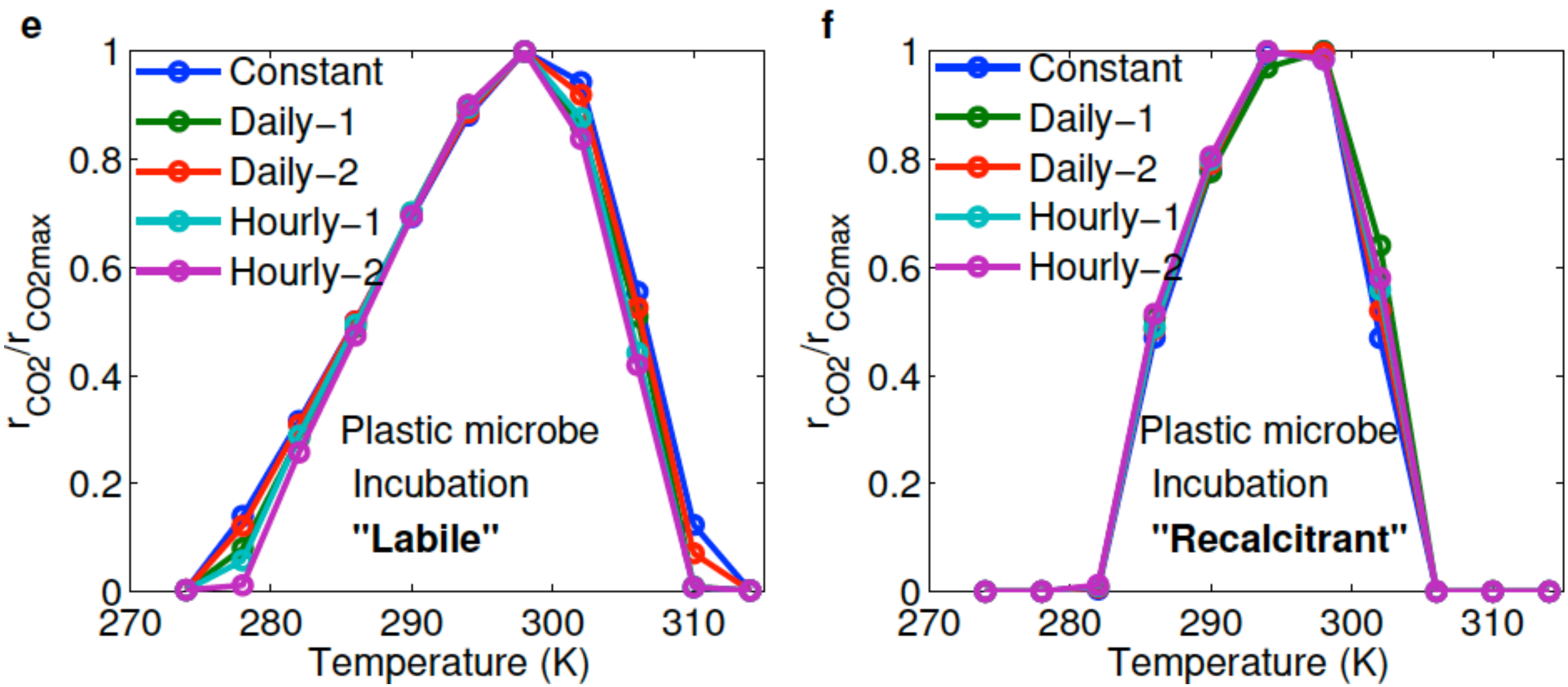


The recalcitrance illusion

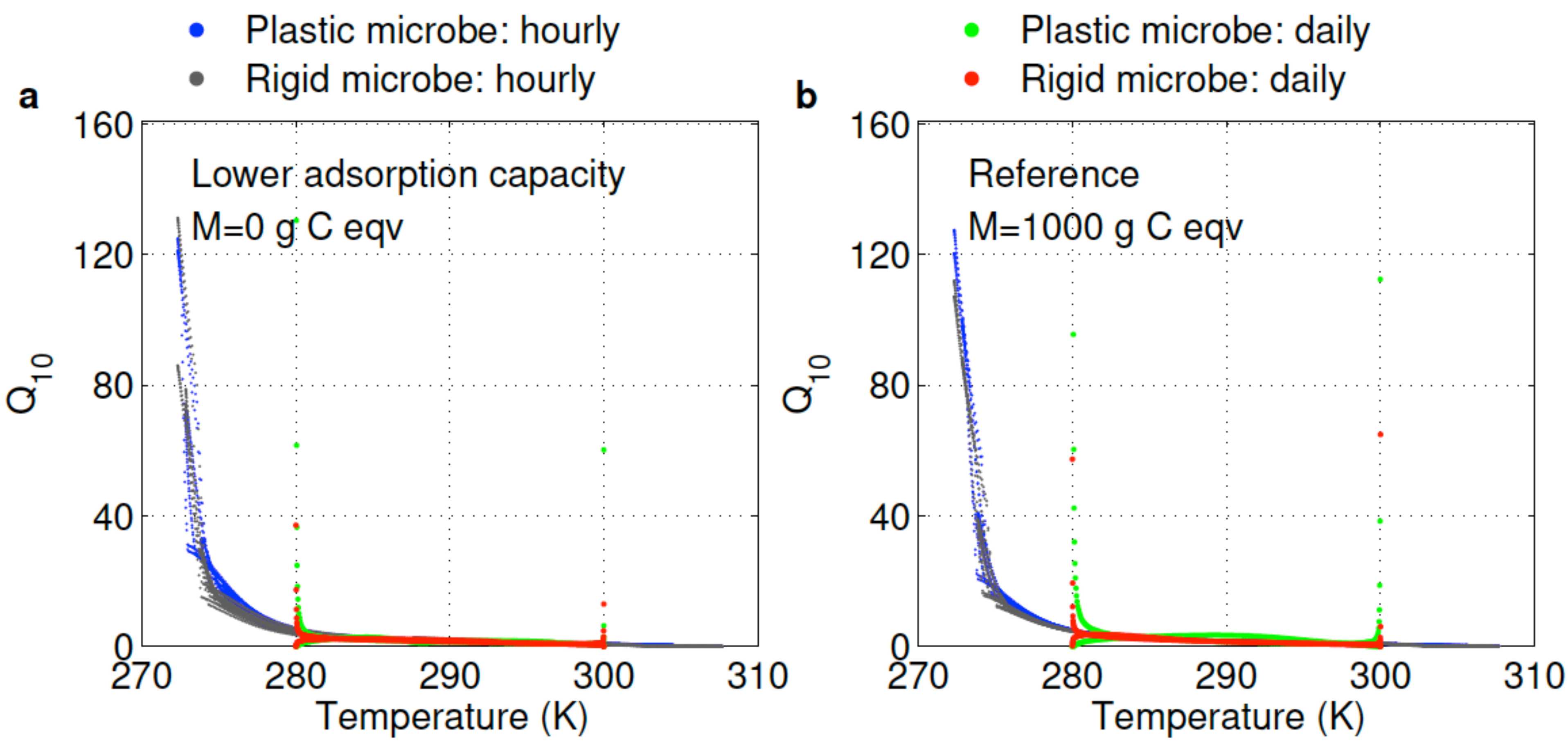


Equal carbon incubation method, from Conant et al., 2008

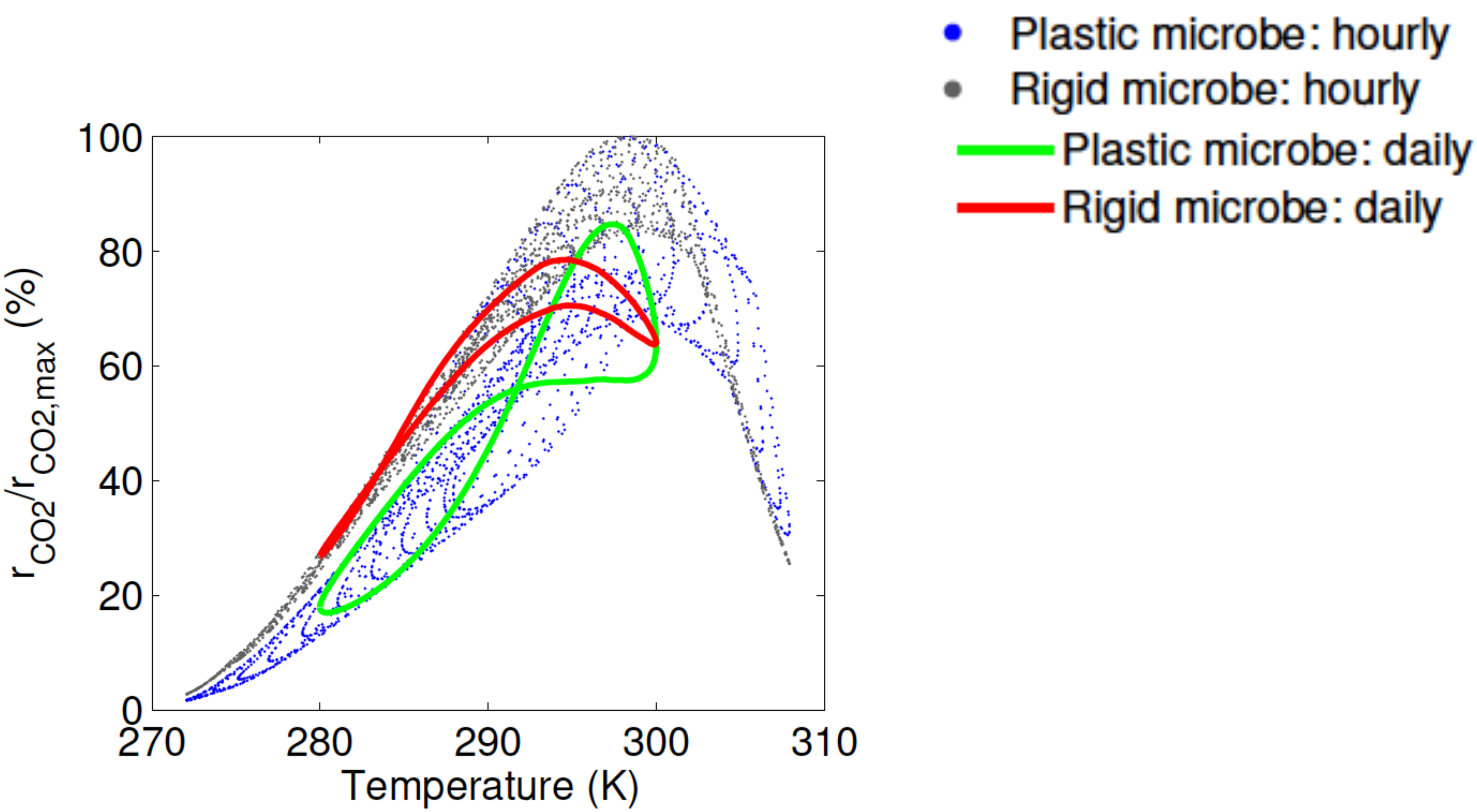
Emergent respiration temperature sensitivity



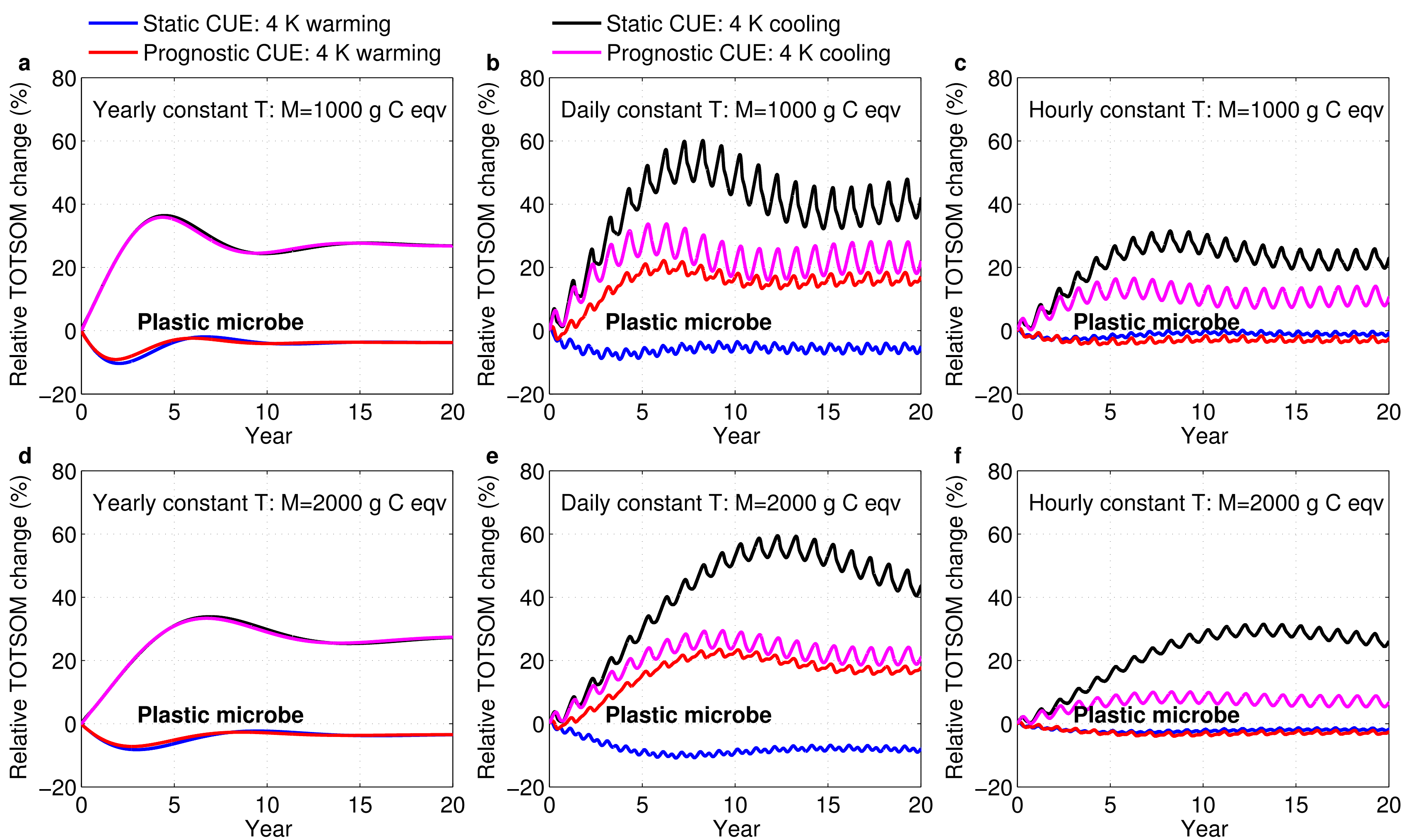
Large Q_{10} variability: >0



The temperature sensitivity is dynamic rather than static



Large uncertainties resulting from incorrect temperature sensitivity parameterizations: static CUE



Summary

- Both modeling and empirical studies should adopt the dynamic view of the temperature sensitivity and focus more on actual mechanisms.
- Emergent responses under various conditions should be measured and compared consistently.
- Similar problems might exist for moisture sensitivity in ESMs and measurements interpretations.