

Appendix E. Temperature dependence of $V_{c,max}$ and J_{max} .

Temperature sensitivities of $V_{c,max}$ and J_{max} were simulated either using a modified Arrhenius function (e.g. [Medlyn et al. 2002a](#), [Kattge and Knorr 2007](#), [Walker et al. 2014](#)) or using a function based on the Q_{10} concept ([Collatz et al. 1991](#), [Sellers et al. 1996](#)). Because temperature relationship could acclimate, we also examined Kattge & Knorr ([2007](#))'s formulation of with and without temperature acclimation to plant growth temperature. We used four temperature dependence functions of $V_{c,max}$ and J_{max} , which are described below.

a) *Temperature response function one* (TRF1)

TRF1 has been implemented in the community land model version 4 (CLM4). The temperature dependence of $V_{c,max}$ and J_{max} in CLM4 is based on the Q_{10} (2.4) concept ([Oleson et al. 2010](#)) as follows:

$$V_{c,max}(T_1) = V_{c,max25} (2.4^{0.1(T_1-T_0)}) (1 + e^{[(S_v T_1 - H_d)/(RT_1)])} \quad (\text{E.1})$$

$$J_{max}(T_1) = J_{max25} ((0.8 * 2.4)^{0.1(T_1-T_0)}) (1 + e^{[(S_v T_1 - H_d)/(RT_1)])} \quad (\text{E.2})$$

CLM4 model uses the form of temperature dependence of $V_{c,max}$ and J_{max} as shown in Eq. S4-S5, where the leaf temperature is $T_l(K)$ and the parameters included; $H_d = 220000 \text{ J mol}^{-1}$ and $S_v = 710 \text{ J mol}^{-1} \text{ K}^{-1}$.

Temperature sensitivities of $V_{c,max}$ as described in Eq. E.1-E.2 has been simulated in some studies (e.g. [Collatz et al. 1991](#), [Sellers et al. 1996](#)).

b) *Temperature response function two* (TRF2)

TRF2 is adapted from Leuning ([2002](#)), who uses the temperature dependence of $V_{c,max}$ and J_{max} as shown in Eq. E.4; however, the mean parameters that he used across all of the

species were the following: For $V_{c,max25}$, $H_a = 73637 \text{ J mol}^{-1}$, $H_d = 149252 \text{ J mol}^{-1}$ and $S_v = 486 \text{ J mol}^{-1} \text{ K}^{-1}$, and for J_{max25} , $H_a = 50300 \text{ J mol}^{-1}$, $H_d = 152044 \text{ J mol}^{-1}$ and $S_v = 495 \text{ J mol}^{-1} \text{ K}^{-1}$.

c) *Temperature response function three* (TRF3)

TRF3 is a temperature dependence of $V_{c,max}$ which is based on the formulation and parameterization as in Medlyn et al. (2002a) but further modified by Kattge & Knorr (2007) to make the temperature optima a function of growth temperature (T_g ; °C).

$$V_{c,max}(T_1, T_g) = V_{c,max25} \frac{(1 + e^{[(a+bT_g)T_0 - H_d]/(RT_0)}) e^{[(H_a/RT_0)(1 - T_0/T_1)]}}{1 + e^{[(a+bT_g)T_1 - H_d]/(RT_1)}} \quad (\text{E.3})$$

where $V_{c,max25}$ is the value of $V_{c,max}$ at the reference temperature ($T_0 = 298.15\text{K}$), H_a (J mol^{-1}) is energy of activation, H_d (J mol^{-1}) is the energy of deactivation, the entropy term; S_v ($\text{J mol}^{-1} \text{ K}^{-1}$) is now a function of temperature (Medlyn et al. 2002a), following Kattge & Knorr (2007): $S_v = a + bT_g$, where a and b are acclimation parameters for S_v and were held constants, R is the universal gas constant ($8.314 \text{ J mol}^{-1} \text{ K}^{-1}$) and the leaf temperature is $T_1(\text{K})$. The values of the acclimation parameters (a and b), H_a and H_d were adapted from Table 3 of Kattge & Knorr (2007), which were fixed across our data set.

A similar equation is used to describe the temperature dependence of J_{max} and corresponding values of the acclimation parameters (a and b), H_a and H_d were taken from Table 3 of Kattge & Knorr (2007), which were also fixed across our data set.

d) *Temperature response function four* (TRF4)

Following Farquhar et al. (1980) and Leuning (1997), the temperature dependence of $V_{c,max}$ is described using a modified Arrhenius equation which allows for the decrease in $V_{c,max}$ above an optimum temperature, namely:

$$V_{c,max}(T_1) = V_{c,max25} \frac{(1+e^{[(S_v T_0 - H_d)/(RT_0)])} e^{[(H_d/RT_0)(1-T_0/T_1)]}}{1+e^{[(S_v T_1 - H_d)/(RT_1)]}} \quad (\text{E.4})$$

where $V_{c,max25}$ is the value of $V_{c,max}$ at the reference temperature ($T_0 = 298.15\text{K}$), H_a (J mol^{-1}) is energy of activation, H_d (J mol^{-1}) is the energy of deactivation, S_v ($\text{J mol}^{-1} \text{K}^{-1}$) is an entropy term, R is the universal gas constant ($8.314 \text{ J mol}^{-1} \text{ K}^{-1}$) and the leaf temperature is T_1 (K). A similar equation is used to describe the temperature dependence of J_{max} .

TRF4 is implemented in CLM4.5 by Oleson et al. (2013), who uses the form of temperature dependence of $V_{c,max}$ and J_{max} as shown in Eq. E.1, where S_v is a function of the plant growth temperature (t_{growth}) that considers limited temperature acclimation, where $S_v = 668.39 - 1.07 * \min(\max(t_{growth}, 11), 35)$. Other parameters CLM4.5 uses include, $H_a = 72000 \text{ J mol}^{-1}$ and $H_d = 200000 \text{ J mol}^{-1}$.

Temperature sensitivities of $V_{c,max}$ as described in Eq. E.4 has been simulated in many studies (e.g. Medlyn et al. 2002a, Kattge and Knorr 2007, Walker et al. 2014). A similar equation is used to describe the temperature dependence of J_{max} with the corresponding S_v equation (that considers limited temperature acclimation). The values of the acclimation parameters (a and b), were taken from Table 3 of Kattge & Knorr (2007), which were also fixed across our data set. The same values of a and b are used by CLM4.5. We used the remaining parameter values as in CLM4.5 that included, $H_a = 50000 \text{ J mol}^{-1}$ and $H_d = 200000 \text{ J mol}^{-1}$.

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