Appendix A

Brief Model Description of TRIPLEX-FLUX

TABLE A1. Variables and parameters used in TRIPLEX-FLUX for simulating old black spruce of boreal forest in Canada.

Symbol	Unit	Description	Equation and Value	Reference
A	$\mu mol \cdot m^{-2} \cdot s^{-1}$	net CO_2 assimilation rate for big leaf	$A = \min(V_c, V_j) - Rd$ $A = g_s(C_a - C_i)/1.6$	Farquhar et al. (1980), Leuning (1990), Sellers et al. (1996)
A_{canopy}	$\mu mol \cdot m^{-2} \cdot s^{-1}$	net CO_2 assimilation rate for canopy	$A_{canopy}=A_{sun}LAI_{sun}+A_{shade}LAI_{shade}$	Norman, (1982)
A_{shade}	$\mu mol \cdot m^{-2} \cdot s^{-1}$	net CO_2 assimilation rate for shaded leaf		
A_{sun}	$\mu mol \cdot m^{-2} \cdot s^{-1}$	net CO_2 assimilation rate for sunlit leaf		
Γ	Pa	CO_2 compensation point without dark respiration	$\Gamma = 1.92 * 10^{-4}\ O_2\ 1.75^{(T-25)/10}$	Collatz et al. (1991) and Sellers et al. (1992)
C_a	Pa	CO_2 concentration in the atmosphere	Input variable	
C_i	Pa	Intercellular CO_2 concentration		
f(N)	-	nitrogen limitation term	$f(N) = N/N_m = 0.8$	Bonan (1995)
f(T)	-	temperature limitation term	$f(T) = (1+\exp((-220{,}000 +710(T+273))/(R_{gas}(T+273))))^{-1}$	Bonan (1995)
g_s	$m \cdot mol \cdot m^{-2} \cdot s^{-1}$	stomatal conductance	$g_s = g_o + m100A\ r_h/Ca$	Ball et al. (1988)
g_o	-	initial stomatal conductance	57.34	Cai and Dang (2002)
m	-	coefficient	Optimizable	7.43 by Cai and Dang (2002)
J	$\mu mol \cdot m^{-2} \cdot s^{-1}$	electron transport rate	$J = J_{max}\ PPFD/(PPFD + 2.1\ J_{max})$	Farquhar and von Caemmerer (1982)
Jmax	$\mu mol \cdot m^{-2} \cdot s^{-1}$	light-saturated rate of electron transport in the photosynthetic carbon reduction cycle in leaf cells	$J_{max} = 29.1 + 1.64\ V_m$ Optimizable	Wullschleger (1993)
K	Pa	function of enzyme kinetics	$K = K_c\ (1 + O_2 / Ko)$	Collatz et al. (1991) and Sellers et al. (1992)
K_c	Pa	Michaelis–Menten constants for CO_2	$K_c = 30 * 2.1^{(T - 25)/10}$	Collatz et al. (1991) and Sellers et al. (1992)
K_o	Pa	Michaelis–Menten constants for O_2	$K_o = 30000 * 1.2^{(T - 25)/10}$	Collatz et al. (1991)

M	kg C·m^{-2}·day^{-1}	biomass density of each plant component	0.4 for leaf 0.28 for sapwood 1.4 for root	Gower et al. (1977) Kimball et al. (1997) Steel et al. (1997)
N	%	leaf nitrogen content	1.2	Based on Kimball et al. (1997)
N_m	%	maximum nitrogen content.	1.5	Bonan (1995)
O_2	Pa	oxygen concentration in the atmosphere,	21,000	Chen et al. (1999)
PPFD	µmol·m^{-2}·s^{-1}	photosynthetic photon flux density	Input variable	
Q_{10}	-	temperature sensitivity factor	Optimizable	2.0 by Goulden et al. (1998)
R_a	kg C·m^{-2}·day^{-1}	autotrophic respiration	$R_a = R_m + R_g$	
r_a	-	carbon allocation fraction	0.4 for root 0.6 for leaf and sapwood	Running and Coughlan (1988)
R_d	µmol ·m^{-2}·s^{-1}	leaf dark respiration	$R_d = 0.015V_m$	Collatz et al. (1991)
R_e	kg C·m^{-2} ·day^{-1}	ecosystem respiration	$R_e = R_a + R_h$	
R_g	kg C·m^{-2}·day^{-1}	growth respiration	$R_g = r_g\, r_a$ GPP	Ryan (1991)
r_g	-	growth respiration coefficient	0.25 for root, leaf and sapwood	Ryan (1991)
R_{gas}	m^3·Pa·mol^{-1}·K^{-1}	molar gas constant	8.3143	Chen et al., 1999
r_h	%	relative humidity	Input variable	
R_h	kg C·m^{-2}·day^{-1}	heterotrophic respiration	$R_h = R_{10}Q_{10}^{(Ts-Tb)/10}$	van't Hoff, 1898
R_m	kg C·m^{-2}·day^{-1}	maintenance respiration	$R_m = M\, r_m\, Q_{10}^{(T-To\,)/10}$ T_o=20^{o}C	Running and Coughlan (1988), Ryan (1991)
r_m	-	maintenance respiration coefficient	0.002 at 20^{o}C for leaf 0.001 at 20^{o}C for stem 0.001 at 20^{o}C for root	Kimball et al. (1997)
T	^{o}C	air temperature	Input variable	
V_c	µmol·m^{-2}·s^{-1}	Rubisco-limited gross photosynthesis rates	$V_c = V_m (C_i - \Gamma)/(C_i - K)$	Farquhar et al. (1980)
V_j	µmol·m^{-2}·s^{-1}	Light-limited gross photosynthesis rates	$V_j = J (C_i - \Gamma)/(4.5C_i + 10.5\Gamma)$	Farquhar and von Caemmerer (1982)
V_{max}	µmol·m^{-2}·s^{-1}	maximum carboxylation rate	$V_{max} = V_{m25}0.24(T - 25)f_{(T)}f_{(N)}$ Optimizable	Bonan (1995)
V_{m25}	µmol·m^{-2}·s^{-1}	V_m at 25°C, variable depending on vegetation type	Included in optimized V_{max}	45 by Cai and Dang (2002)

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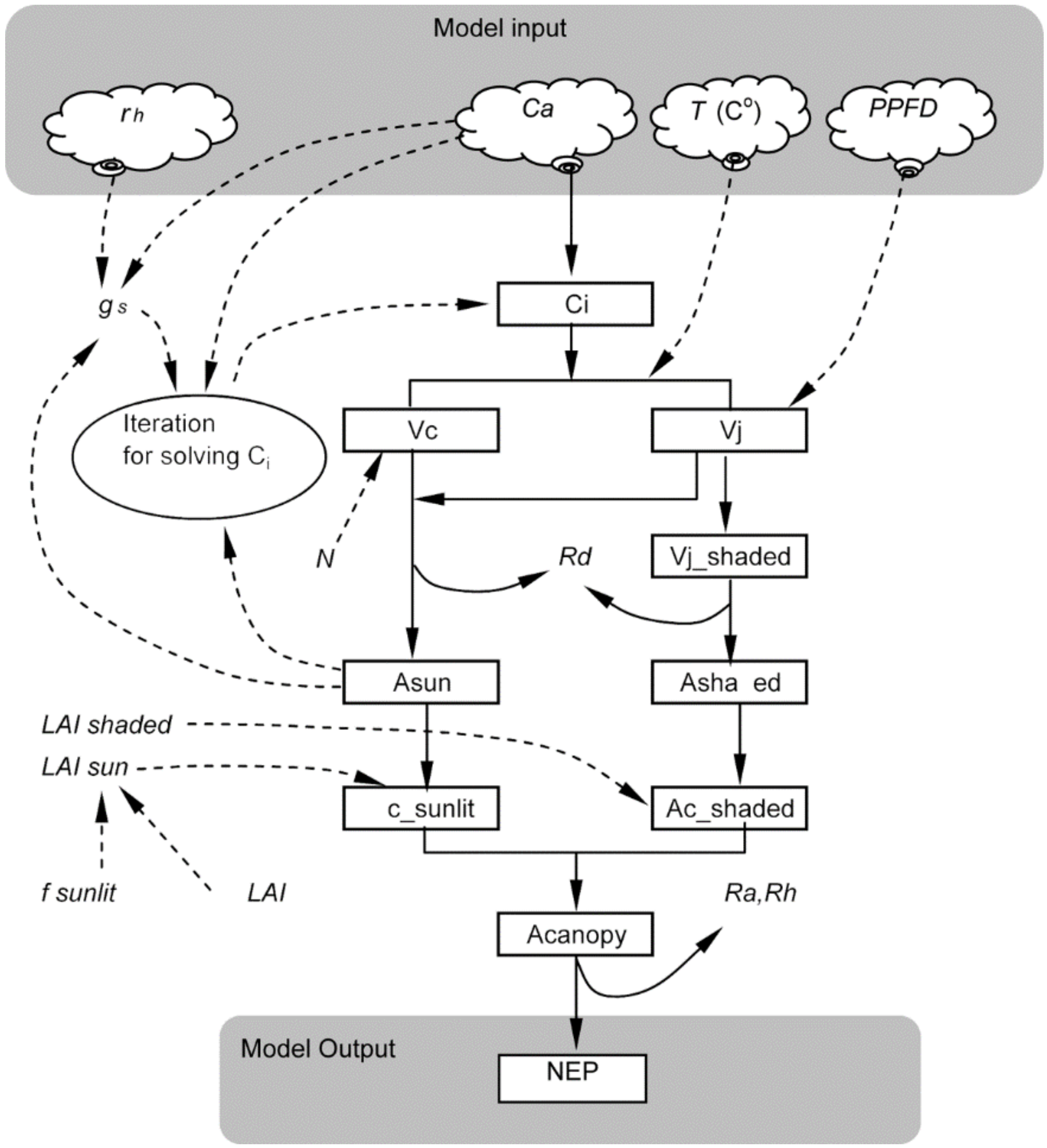

FIG. A1. The model structure diagram of TRIPLEX-FLUX. Solid lines represent carbon flows and the fluxes between the forest ecosystem and external environment; dashed lines denote control and effects of environmental variables; rectangles express state variables; the ellipse is a process of iteration. All symbols are expressed in Table A1.