Day/Night observation operator for DALEC2 model

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The DALEC2 model is a simple process-based model describing the carbon balance of a forest ecosystem [Bloom and Williams, 2015] and is the new version of the original DALEC [Williams et al., 2005]. The model is constructed of six carbon pools (labile (C_{lab}), foliage (C_f), fine roots (C_r), woody stems and coarse roots (C_w), fresh leaf and fine root litter (C_l) and soil organic matter and coarse woody debris (C_s)) linked via fluxes. The aggregated canopy model (ACM) [Williams et al., 1997] is used to calculate daily Gross Primary Production (GPP) of the forest, taking meteorological driving data and the modelled leaf area index (a function of C_f) as arguments. Figure 1 shows a schematic of how the carbon pools are linked in DALEC2.

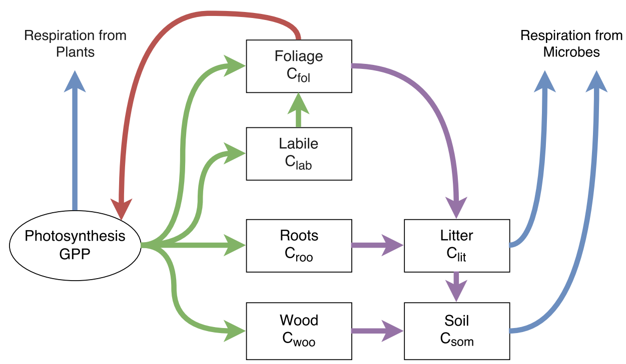

Figure 1: Representation of the fluxes in the DALEC2 carbon balance model. Green arrows represent C allocation, purple arrows represent litter fall and decomposition fluxes, blue arrows represent respiration fluxes and the red arrow represents the influence of leaf area index in the GPP function.

The model equations for the carbon pools at day i are as follows:

$$GPP^i = ACM(C_{fol}^{i-1}, c_{lma}, c_{eff}, \Psi) \tag{1}$$

$$C_{lab}^i = C_{lab}^{i-1} + (1-f_{auto})(1-f_{fol})f_{lab}GPP^i - \Phi_{on}C_{lab}^{i-1}, \tag{2}$$

$$C_{fol}^i = C_{fol}^{i-1} + \Phi_{on}C_{lab}^{i-1} + (1-f_{auto})f_{fol}GPP^i - \Phi_{off}C_{fol}^{i-1}, \tag{3}$$

$$C_{roo}^i = C_{roo}^{i-1} + (1-f_{auto})(1-f_{fol})(1-f_{lab})f_{roo}GPP^i - \theta_{roo}C_{roo}^{i-1}, \tag{4}$$

$$C_{woo}^i = C_{woo}^{i-1} + (1-f_{auto})(1-f_{fol})(1-f_{lab})(1-f_{roo})GPP^i - \theta_{woo}C_{woo}^{i-1}, \tag{5}$$

$$C_{lit}^i = C_{lit}^{i-1} + \theta_{roo}C_{roo}^{i-1} + \Phi_{off}C_{fol}^{i-1} - (\theta_{lit} + \theta_{min})e^{\Theta T^{i-1}}C_{lit}^{i-1}, \tag{6}$$

$$C_{som}^i = C_{som}^{i-1} + \theta_{woo}C_{woo}^{i-1} + \theta_{min}e^{\Theta T^{i-1}}C_{lit}^{i-1} - \theta_{som}e^{\Theta T^{i-1}}C_{som}^{i-1}, \tag{7}$$

where T^{i-1} is the daily mean temperature, Ψ represents the meteorological driving data used in the GPP function and Φ_{on}/Φ_{off} are functions controlling leaf-on and leaf-off. Descriptions for each model parameter used in equations (1) to (7) are included in the appendix in table 1. DALEC2 differs from the original DALEC in that it can be parameterised for both deciduous and evergreen sites with Φ_{on} and Φ_{off} being able to reproduce the phenology of either type of site. The full details of this version of DALEC can be found in Bloom and Williams [2015].

Net Ecosystem Exchange (NEE) is the difference between GPP and ecosystem respiration at any given time. For an observation of total daily (NEE) we have,

$$NEE^i = -(1 - f_{auto})GPP^i(C^i_{fol}, \Psi) + \theta_{lit}C^i_{lit}e^{\Theta T^i} + \theta_{som}C^i_{som}e^{\Theta T^i}. \tag{8}$$

In this work we seek to assimilate observations total daytime NEE and total nighttime NEE in order to increase the number of observations available to us and better partition our modelled estimate of GPP and total ecosystem respiration. As no photosynthesis occurs at night a nighttime observation of NEE is equivalent to an observation of total ecosystem respiration. For total daytime NEE we have,

$$NEE^i_{day} = -GPP^i(C^i_{fol}, \Psi) + r_{a,day}f_{auto}GPP^i(C^i_{fol}, \Psi) + \delta_{day}\theta_{lit}C^i_{lit}e^{\Theta T^i_{day}} + \delta_{day}\theta_{som}C^i_{som}e^{\Theta T^i_{day}} \tag{9}$$

where $r_{a,day}$ is the fraction of autotrophic respiration that occurs during daylight hours, δ_{day} is the day length and T^i_{day} is the mean daytime temperature. For nighttime NEE we have,

$$\begin{aligned} NEE^i_{night} = r_{a,night}f_{auto}GPP^i(C^i_{fol}, \Psi) + \delta_{night}\theta_{lit}C^i_{lit}e^{\Theta T^i_{night}} - \delta_{day}\delta_{night}\theta^2_{lit}C^i_{lit}e^{\Theta T^i_{day}+\Theta T^i_{night}} \\ +\delta_{night}\theta_{som}C^i_{som}e^{\Theta T^i_{night}} - \delta_{day}\delta_{night}\theta^2_{som}C^i_{som}e^{\Theta T^i_{day}+\Theta T^i_{night}} \end{aligned} \tag{10}$$

where $r_{a,night}$ is the fraction of autotrophic respiration that occurs during the night $(r_{a,night} = 1 - r_{a,day})$, δ_{night} is the night length $(\delta_{night} = 1 - \delta_{day})$ and T^i_{night} is the mean nighttime temperature. For Equation (10) $-\delta_{day}\delta_{night}\theta^2_{lit}C^i_{lit}e^{\Theta T^i_{day}+\Theta T^i_{night}}$ and $-\delta_{day}\delta_{night}\theta^2_{som}C^i_{som}e^{\Theta T^i_{day}+\Theta T^i_{night}}$ correspond to the amount of carbon respired during the day, without including these terms we will over predict nighttime respiration. The effect of these terms may be very small and we might find it is not necessary to include them in the nighttime NEE observation operator.

Parameter	Description	Background vector ($\mathbf{x}^b$)	Standard deviation	Range
θ_{min}	Litter mineralisation rate (day^{-1})	9.810×10^{-4}	2.030×10^{-3}	$10^{-5} - 10^{-2}$
f_{auto}	Autotrophic respiration fraction	5.190×10^{-1}	1.168×10^{-1}	$0.3 - 0.7$
f_{fol}	Fraction of GPP allocated to foliage	1.086×10^{-1}	1.116×10^{-1}	$0.01 - 0.5$
f_{roo}	Fraction of GPP allocated to fine roots	4.844×10^{-1}	2.989×10^{-1}	$0.01 - 0.5$
c_{lspan}	Determines annual leaf loss fraction	1.200×10^{0}	1.161×10^{-1}	$1.0001 - 10$
θ_{woo}	Woody carbon turnover rate (day^{-1})	1.013×10^{-4}	1.365×10^{-4}	$2.5 \times 10^{-5} - 10^{-3}$
θ_{roo}	Fine root carbon turnover rate (day^{-1})	3.225×10^{-3}	2.930×10^{-3}	$10^{-4} - 10^{-2}$
θ_{lit}	Litter carbon turnover rate (day^{-1})	3.442×10^{-3}	3.117×10^{-3}	$10^{-4} - 10^{-2}$
θ_{som}	Soil and organic carbon turnover rate (day^{-1})	1.113×10^{-4}	1.181×10^{-4}	$10^{-7} - 10^{-3}$
Θ	Temperature dependance exponent factor	4.147×10^{-2}	1.623×10^{-2}	$0.018 - 0.08$
c_{eff}	Canopy efficiency parameter	7.144×10^{1}	2.042×10^{1}	$10 - 100$
d_{onset}	Leaf onset day (day)	1.158×10^{2}	6.257×10^{0}	$1 - 365$
f_{lab}	Fraction of GPP allocated to labile carbon pool	3.204×10^{-1}	1.145×10^{-1}	$0.01 - 0.5$
c_{ronset}	Labile carbon release period (days)	4.134×10^{1}	1.405×10^{1}	$10 - 100$
d_{fall}	Leaf fall day (day)	2.205×10^{2}	3.724×10^{1}	$1 - 365$
c_{rfall}	Leaf-fall period (days)	1.168×10^{2}	2.259×10^{1}	$10 - 100$
c_{lma}	Leaf mass per area (gCm^{-2})	1.285×10^{2}	6.410×10^{1}	$10 - 400$
C_{lab}	Labile carbon pool (gCm^{-2})	1.365×10^{2}	6.626×10^{1}	$10 - 1000$
C_{fol}	Foliar carbon pool (gCm^{-2})	6.864×10^{1}	3.590×10^{1}	$10 - 1000$
C_{roo}	Fine root carbon pool (gCm^{-2})	2.838×10^{2}	2.193×10^{2}	$10 - 1000$
C_{woo}	Above and below ground woody carbon pool (gCm^{-2})	6.506×10^{3}	7.143×10^{3}	$100 - 10^{5}$
C_{lit}	Litter carbon pool (gCm^{-2})	5.988×10^{2}	5.450×10^{2}	$10 - 1000$
C_{som}	Soil and organic carbon pool (gCm^{-2})	1.936×10^{3}	1.276×10^{3}	$100 - 2 \times 10^{5}$

Table 1: Parameter values and standard deviations for background vector used in experiments.

References

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