

Supplement of Geosci. Model Dev. Discuss., 8, 5809–5871, 2015
<http://www.geosci-model-dev-discuss.net/8/5809/2015/>
doi:10.5194/gmdd-8-5809-2015-supplement
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Supplement of

Variability of phenology and fluxes of water and carbon with observed and simulated soil moisture in the Ent Terrestrial Biosphere Model (Ent TBM version 1.0.1.0.0)

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S. Soil biogeochemistry in the Ent Terrestrial Biosphere Model

The soil biogeochemistry submodel of Ent utilizes a slightly modified version of the CASA' biosphere submodel originally implemented in the NCAR LSM and CSM 1.4 (Bonan, 1996; Randerson et al., 1997; Fung et al., 2005; Doney et al., 2006), which itself is a modified version of the original NASA-CASA biosphere model (Potter et al., 1993). The soil model determines terrestrial soil carbon pools and CO₂ fluxes from microbial respiration.

S.1 CASA structure

The soil biogeochemistry model consists of 3 litter C and N pools and 9 soil C and N pools, as in CASA'. The pools currently are only simulated for the top 30 cm soil depth. This layer accounts for nearly all observable soil respiration fluxes to the atmosphere, but not for full long-term carbon stocks in deeper soil. Down to 100 cm and deeper would allow comparison to existing global datasets of soil carbon and root depths (Batjes, et al., 1996ab; Jackson, et al. 1996). Figure 0-1 shows these 12 pools. Ent has an optional 30-100 cm deeper soil layer that is not run in the current paper.

The various pools currently have fixed C:N ratios and turnover times, listed in Table S1. The pools gain carbon and nitrogen from transfers from other pools, and losses to respiration and transfers to other pools. These transfer and respiration fractions are listed in Table S2.

Soil micrometeorological conditions for the soil layers must be extrapolated from the soil layering scheme of the land surface model. For example the GISS land surface hydrology has a 6-layer soil scheme with geometrically increasing layer thicknesses with depth (Rosenzweig & Abramopoulos, 1997), so soil temperature and moisture for the soil biogeochemistry layers are calculated through a weighted sum for the upper 30 cm.

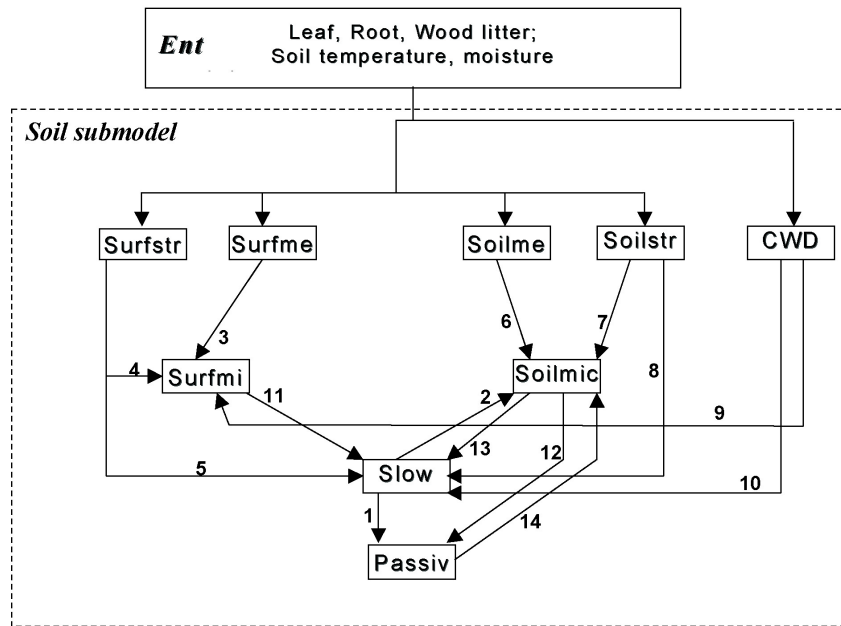


Figure S1. Schematic diagram of soil biogeochemistry submodel of Ent (showing 9 soil C pools only; modified from Potter et al., 1993). Surfstr – surface structural pool; Surfmet – surface metabolic pool; Soilmet – soil metabolic pool (fastest to decompose; 20-day turnover time); Soilstr – soil structural pool; Surfmic – surface microbial pool; Soilmic – soil microbial pool; Slow – slowly decomposing pool; Passiv – very slowly decomposing pool (500-yr turnover time). All pools except for the 3 surf*** pools are assumed to be present in the 2 lower soil layers in addition to the top layer.

Table S1. Values of C pool parameters: cnratio – C:N ratio of all 12 C pools (used only to calculate N pools); $\text{annk}_{\text{soil}}$ – inverse of turnover times of all 9 soil C pools (yr^{-1}).

Pool (see Fig. 1 for definitions)	C:N ratio ¹	$\text{annk}_{\text{soil}}$ ²	~turnover time
Leaf	30	--	(lrage) See
Root	130	--	(lrage)
Wood	55	--	(woodage)
Surfmet	30	14.8	25 d
Surfstr	50	3.9	94 d
Soilmet	25	18.5	20 d
Soilstr	50	4.9	74 d
CWD	135	0.2424	4.1 yr
Surfmic	12.5	6	60 d
Soilmic	12.5	7.3	50 d
Slow	12.5	0.2	5 yr
Passive	8.5	0.002	500 yr

¹from original CASA code (Potter et al., 1993)

²from CASA' code (Doney et al., 2006)

Table S2. Values of respiration pathway coefficients: eff – microbial respiration transfer efficiencies for all 14 pathways; frac_donor – additional respiration efficiencies (both unitless)

Pathway (see Fig. 1)	eff ¹	frac_donor ²
1	0.45	0.003+(0.009*clay frac)
2	0.45	1-frac_donor(1)
3	0.4	1
4	0.4	1-structurallignin(PFT) ³
5	0.7	structurallignin(PFT)
6	0.45	1
7	0.45	1-structurallignin(PFT)
8	0.7	structurallignin(PFT)
9	0.4	1-woodligninfrac ³
10	0.7	woodligninfrac
11	0.4	1
12	0.85-[0.68* (silt+sand fracs)]	0.003+(0.032*clay frac)
13	0.85-[0.68* (silt+sand fracs)]	1-frac_donor(12)
14	0.45	1

¹from CASA code (Potter et al., 1993) for 1–3, others from CASA' code (Doney et al., 2006) ****double check which from which code****

²from original CASA code (Potter et al., 1993)

³derived litter coefficients in both CASA and CASA' codes

In addition to the transfer coefficients in Table S2, three other rate coefficients are used (following Randerson et al., 1997):

$$\text{fact_soilmic} = 1.25;$$

$$\text{fact_slow} = 1.5;$$

$$\text{fact_passive} = 1.5.$$

These are simply decomposition rate adjustment factors for soil microbial, slow, and passive pools (respectively) *for crops only*; their values for all other PFTs is 1.

S.2 Soil module interface with vegetation

Physical inputs to the soil module from the land surface hydrology are volumetric soil moisture, soil temperature, and soil texture (percentage of clay, sand, and silt). Biological inputs consist of leaf, root, and wood litter (Fig. 1). Model outputs are soil C (and N, not used) pools and soil CO₂ flux. Ent calculates litterfall carbon from the leaf area times the specific leaf area,

The relevant plant functional type (PFT)-dependent litter parameters (leaf, fine root, and wood turnover times, litter C:N ratios, specific leaf area, and lignin contents) from Ent are listed in Table C2. In addition to these parameters, a parameter representing the inverse of the residence times of the litter pools, denoted annk_{lit} (in units of yr⁻¹), was calculated as the inverse of lra_{ge} for leaf and root litter or of woodage for wood litter (Potter et al., 1993).

S.3 Temperature and moisture responses of soil respiration

We replaced the CASA' temperature and soil moisture responses of soil respiration with new functions derived from new fits to field data collected by Del Grosso et al. (2005). The Ent TBM **temperature response** of soil respiration is a simple piece-wise linear model that increases up to 30 °C, then flattens. In reality, the response to temperature is exponential up to a certain optimum then declines, but a linear representation was chosen because it reduces the computational time compared to that required for calling an exponential function, and tests on field data show adequate performance for the purpose of predicting respiration fluxes and soil carbon pools (unpublished). At high soil temperatures, soil moisture stress usually occurs also, but because no measurement data were available for respiration at temperatures above 30 °C, the Ent model response does not represent a decline in soil respiration at high temperature. The linear temperature response of soil respiration is:

$$\text{linear } f_{\text{temperature}} = \begin{cases} \text{Intercept} = 0.04607913, T_{\text{soil}} \leq 0^{\circ}\text{C} \\ \frac{(1 - \text{Intercept})}{(30 - 0)} T_{\text{soil}} + \text{Intercept}, 0 < T_{\text{soil}} \leq 30^{\circ}\text{C} \\ 1, T_{\text{soil}} \geq 30^{\circ}\text{C} \end{cases} \quad (1)$$

More realistically, the temperature response is in nature an exponential response, so if there are no computational constraints, the following Q10 function as formulated in the original CASA' should be used:

$$\text{exponential } f_{\text{temperature}} = \text{Q10}^{\frac{T_{\text{soil,C}} - 30.0}{10.0}} \quad (2)$$

where Q10 has a typical value of 2.0.

The Ent TBM **moisture response** of soil respiration is similarly a piece-wise linear model that rises from 0 at zero soil moisture to 1.0 at a relative extractable water content (REW) of 0.7, where REW is the fraction of saturation above the hygroscopic point. Because there are no good functions for calculating hygroscopic point based on soil texture, we estimate the hygroscopic point as half of the wilting point. We note that it would be more precise to model the soil moisture response as an optimality curve, that rises from the soil hygroscopic point (minimum for microbes) rather than wilting point (for plants) to some optimum, then declines as pore space becomes saturated and obstructs the flux of gases. However, lack of good algorithms to calculate the soil hygroscopic point for different soil textures necessitate this version of Ent relying on the wilting point as the point of minimum available soil moisture. We may later introduce a simple linear decline of the soil moisture response with saturation, but at present we have no data on the response to saturated conditions.

$$f_{\text{moisture}} = \begin{cases} 0, & \text{REW} \leq 0 \\ \frac{1}{0.7} \text{REW}, & 0 < \text{REW} \leq 0.7 \\ 1, & \text{REW} \geq 0.7 \end{cases} \quad (3)$$

The linear soil respiration temperature and moisture response functions are plotted in Figure S2 and Figure S3, along with the original CASA' responses, and those of Del Grosso et al. (2005), whose data were re-analyzed to generate the Ent response functions.

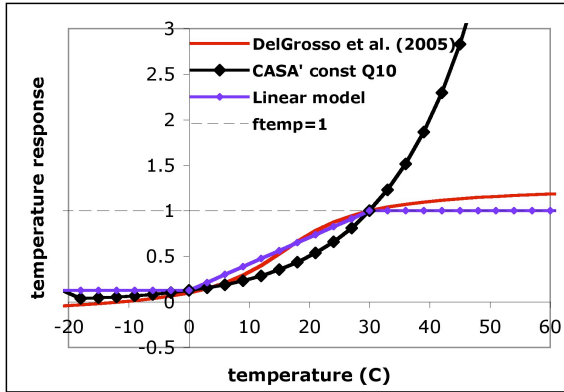


Figure S2. Temperature responses of soil respiration in Del Grosso et al. (2005), CASA', and Ent's piece-wise linear response.

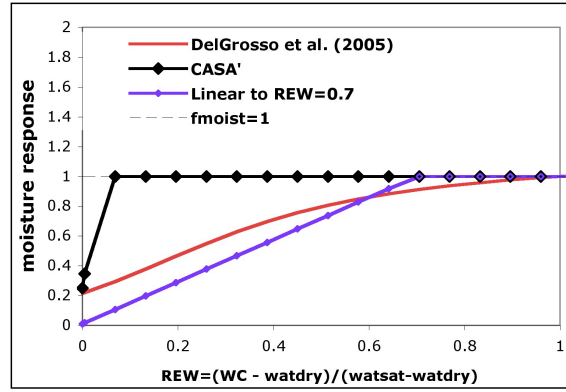


Figure S3. Moisture response of soil respiration in Del Grosso et al. (2005), CASA', and Ent for grassland (Vaira Ranch) soil texture.

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