

Constraining Simulated Respiration Fluxes with Component Measurements in a Dry Eucalypt Forest

Nam Jin Noh¹, Alexandre Renchon¹, Jinquan Li¹, Anne Griebel¹, Catriona MacDonald¹, Vanessa Haverd², Eric Davidson³, Stefan Arndt⁴, Mark Tjoelker¹, Craig Barton¹, and Elise Pendall¹

¹Western Sydney University

²CSIRO Canberra

³University of Maryland

⁴School of Ecosystem and Forest Sciences, The University of Melbourne

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Abstract

Isolating significant signals from temporal variations in autotrophic and heterotrophic components of ecosystem respiration (Reco) is required to better quantify the temperature sensitivity of the land carbon cycle processes. Here we present diurnal and seasonal patterns in field and model-based components of respiration and investigate their responses to environmental conditions at a dry eucalypt forest, the Cumberland Plain SuperSite of the Australian Terrestrial Ecosystem Research Network. We conducted measurement campaigns of total CO₂ flux from the soil surface (R_{soil}), soil microbial respiration (R_{microbe}), root respiration (R_{root}), litter respiration (R_{litter}), and stem respiration (R_{stem}) in 2018. In total, six infrared gas analyzers with closed, dynamic auto-chambers and six forced diffusion auto-chambers were used for periodic campaigns. Further, Reco and its components were simulated using the Community Atmosphere-Biosphere Land Exchange model (CABLE), constrained by eddy covariance measurements and chamber measurements of R_{soil}. A new version of CABLE was implemented with the Dual Arrhenius Michaelis Menten (DAMM) formulation to assess the importance of substrate availability for simulating R_{microbe}. We found that respiration rates showed similar diurnal patterns among the components, showing diurnal hysteresis between respiration components and temperature. In this dry ecosystem, the respiratory components were more responsive to seasonally increasing temperature in wet than in dry periods, and the responses were dependent on atmospheric relative humidity affecting the litter layer moisture content. The temperature sensitivity was significantly higher in R_{stem} than in other components. Based on observed fluxes of R_{microbe} in trenched plots and R_{soil} in intact soil plots, the mean contribution of R_{root} to R_{soil} was less than 20 % for the dry seasons, while mean R_{stem} was two times greater than mean R_{soil} suggesting that R_{stem} should be not overlooked in ecosystem flux estimations. This study highlights that partitioning the respiratory components and accounting for their different temperature-responses will be necessary to reduce uncertainty in modelling carbon-climate feedbacks.

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Vanessa Haverd², Eric A. Davidson³, Stefan Arndt⁴, Mark G. Tjoelker¹, Craig Barton¹, Elise Pendall¹
(Contact: n.noh@westernsydney.edu.au)

1. Hawkesbury Institute for the Environment, Western Sydney University, Penrith, NSW, Australia
2. CSIRO, Oceans and Atmosphere, Canberra, Australia
3. University of Maryland Centre for Environmental Science, Frostburg, MD, USA
4. School of Ecosystem and Forest Sciences, The University of Melbourne, Richmond, Australia



Introduction and objectives

- Isolating significant signals from temporal variations in autotrophic and heterotrophic components of ecosystem respiration (R_{eco}) is required to better quantify the temperature sensitivity (Q_{10}) of the land carbon (C) cycle processes.
 - Here we present temporal patterns in field and model-based components of respiration (R) at a dry eucalypt forest of the Cumberland Plain SuperSite, the Australian Terrestrial Ecosystem Research Network (TERN).
- We investigate the seasonal and diurnal dynamics of component R and their responses to temperature (T) and soil moisture (θ).
 - We evaluate temperature sensitivity of autotrophic and heterotrophic R components and quantify contributions of the R components to R_{eco} .



Fig 1. (a) Cumberland Plain flux tower near Sydney, Australia, where R_{eco} is greater than GPP in summer, leading to net C loss and (b) auto-chambers at EucFACE site near the flux tower.

Study site and measurements

- We conducted measurement campaigns of total CO_2 flux from the soil surface (R_{soil}), soil microbial R (R_m), root R (R_{root}), litter R (R_{litter}), and stem R (R_{stem}) in 2018.

Table 1. Methods of autotrophic and heterotrophic R components measurements

Measurements	Methods	Equipment
Heterotrophic R	<ul style="list-style-type: none"> R_{soil} R_m (= $R_{trenched\ plot}$) R_{litter} (= $R_{soil} - R_{litter\ removed\ plot}$) 	<ul style="list-style-type: none"> Force diffusion auto-chambers (EosFD, Eosense Inc., Canada) (n=3) and closed, dynamic auto-chambers (LI-8100A-104, LICOR Inc., USA) (n=6)
Autotrophic R	<ul style="list-style-type: none"> R_{stem} [ground area basis] R_{root} (= $R_{soil} - R_m - R_{litter}$) or detached R_{root} R_{leaf} 	<ul style="list-style-type: none"> EosFD (n=3) and a survey chamber (LI-8100-102 and 103) Static chambers with NDIR CO_2 sensors CABLE model output (2014–2017)
Eddy flux	<ul style="list-style-type: none"> R_{eco} estimated by eddy covariance observations (Cumberland Plain flux tower) and neural network gap-filling 	
Modelled R	<ul style="list-style-type: none"> R_{eco_DAMM}, R_{soil_DAMM} and R_{m_DAMM}, simulated by Dial Arrhenius Michaelis Menten (DAMM) model combining an Arrhenius function of temperature sensitivity with substrate availability [S], based on Michaelis-Menten theory ($R = \alpha \times e^{-Ea/RT} \times [S] / (K_m + [S])$) R_{eco_CABLE} (2014–2017) predicted using a new version of the Community Atmosphere-Biosphere Land Exchange model (CABLE) with DAMM model incorporated 	
Meteorological data	<ul style="list-style-type: none"> T (air, soil, stem), θ, precipitation (sourced from HIEV, https://hie.v.uws.edu.au/) 	

Discussion and conclusions

- In this dry eucalypt ecosystem, the temperature sensitivity was variable among the heterotrophic and autotrophic R components. Q_{10} of R_{eco} was between those of R_{soil} and R_{stem} . The temperature responses of R components were dependent on soil water availability (Fig 4, Table 2).
- R_{stem} should be not overlooked in ecosystem flux estimations when considering its large contribution to R_{eco} (ca. 23–50%) (Fig 7).
- Partitioning the R components and accounting for their different T-responses dependent on θ will be necessary to better constrain daily and seasonal R_{eco} estimates.
- Our further study will access the importance of substrate availability for accurately simulating the R components using the CABLE with the DAMM formulation to reduce uncertainty in modelling C-climate feedbacks.

Result 1. Temporal dynamics of R components

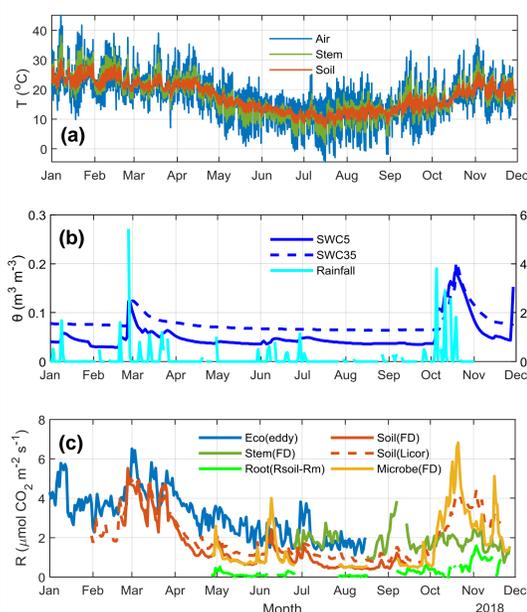


Fig 2. Seasonal variations in (a) T, (b) θ and precipitation, (c) daily mean R for the components and (d) mean R and T by monthly measurement campaigns.

- Similar trends, but large variability in wet periods, responding to rainfall pulse (Fig 2b,c).
- Seasonal variation in R_{eco} was explained by heterotrophic R_m while its diurnal variation was explained by autotrophic R_{stem} (Fig 3).

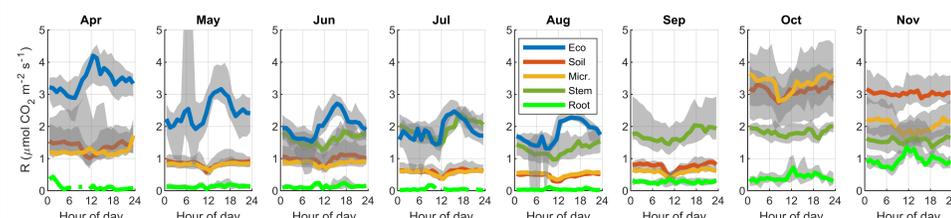


Fig 3. Diurnal variations (median (line) and quartiles (shade)) in R components according to months using half-hourly bins.

Result 2. Responses of R to T and θ

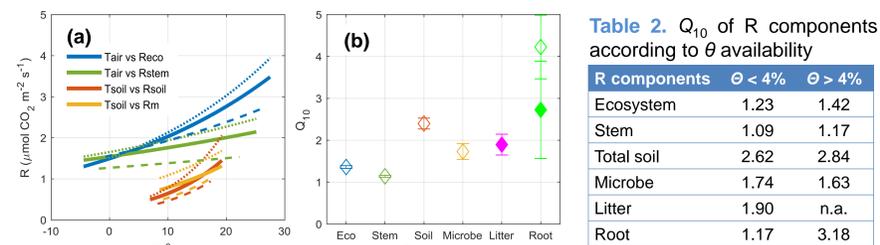


Fig 4. (a) Responses of R_{eco} , R_{stem} , R_{soil} , and R_m to T under different θ levels (Dotted and dashed lines indicate the responses of R to T at < and > median θ , respectively). (b) Q_{10} for all R components (Vertical bars indicate 95% confidence bounds). Half-hourly data measured using FD chambers were used only for May to August (dry winter) when all R data were available. The Q_{10} for R_{litter} and $R_{detached\ root}$ (closed \blacklozenge) in (b) were calculated by the data from monthly campaigns.

- All R components increased with T, and the R are more responsive to T in high θ due to very dry soil condition in winter in this ecosystem. The Q_{10} varied among the components (1.09 ~ 3.18) (Fig 4, Table 2).
- The DAMM model (combining T and θ) accounts for 19% and 84% of R_{eco} and R_{soil} , respectively, while a Q_{10} model explains 60% of R_{stem} (all $p < 0.001$, Fig 5). Our on-going study will identify a hypothesis that aboveground phenology (e.g. leaf area, stem growth) is related to seasonal patterns of R_{stem} that are not adequately accounted for by temperature alone.

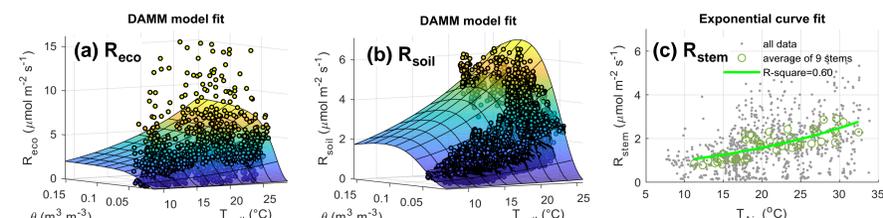


Fig 5. (a) R_{eco} and (b) R_{soil} fitted to DAMM model which captures interactions between T and θ at half-hourly scale, and (c) exponential fitting to T for R_{stem} (monthly campaigns).

Result 3. Estimates of R components & their contributions to R_{eco}

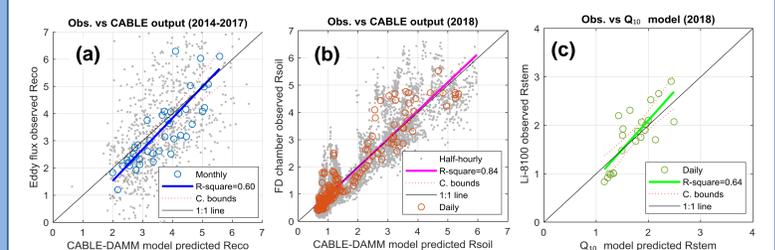


Fig 6. Comparisons of simulated R with observed component R. (a) R_{eco} , (b) R_{soil} and (c) R_{stem} . The dots in (a) and (b) indicate half-hourly data.

- DAMM model predicted daily and monthly R_{eco} well, while it predicted R_{soil} well at daily and half-hourly scale (Fig 6).
- R_m contributed the most to R_{eco} (32–63%), while R_{stem} contributed 23% to 50%. R_{root} contributed only ~ 10% to R_{eco} potentially due to issues of trenching method. R_{leaf} and R_{litter} are nearly constant seasonally (Fig 7).

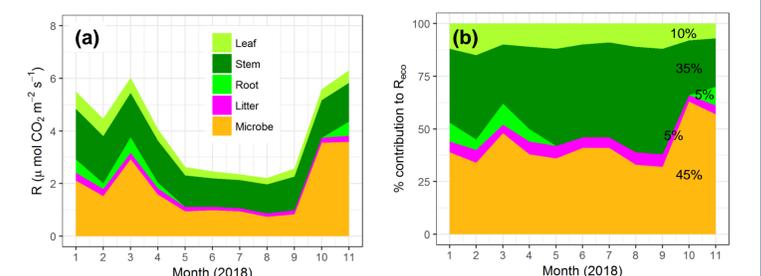


Fig 7. Estimates of seasonal (a) component R and (b) their contributions to R_{eco} (sum of R components). The percentage values in (b) indicate the average contribution for each components during the measurement period.