Utilizing Chamber Data for Developing and Validating Climate Change Models

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Abstract

• Controlled environment chambers (e.g. growth chambers, SPAR chambers, or open-top chambers) are useful for measuring plant ecosystem responses to climatic variables and CO₂ that affect plant water relations.
• However, data from chambers was found to overestimate responses of C fluxes to CO₂ enrichment.
• Chamber data may be confounded by numerous artifacts (e.g. side-lighting, edge effects, increased temperature and VPD, etc) and this limits what can be measured accurately.
• Chambers can be used to measure canopy level energy balance under controlled conditions and plant transpiration responses to CO₂ concentration can be elucidated. However, these measurements cannot be used directly in model development or validation.
• The response of stomatal conductance to CO₂ will be the same as in the field, but the measured response must be recalculated in such a manner to account for differences in aerodynamic conductance, temperature and VPD between the chamber and the field.
Can chamber data be used to generate data for climate change studies?
Problems with Chamber data

• Environment surrounding plants is altered
  – OTCs vs field: +4°C higher Temperature, 0.8 kPA higher VPD, lower total irradiance, altered diffuse radiation.
  – Side-lighting – edge effects overestimate yields
  – Higher ventilation – increased coupling to bulk air exaggerates changes in stomatal conductance
  – Restrict pathogen and insect migration
• Result: overestimate future global yields

Mitigating Problems with Chambers

- Use controls wisely
  - i.e. CO₂ enriched & ambient OTCs exposed to higher temperatures, VPD, lower total irradiance, and diffuse radiation.
- Guard rows – prevent side-lighting effects
- Measure chamber aero-dynamic conductance ($g_A$)
Chamber and Climate Variables

- Constant light – Fixed surface radiation forcing
- Constant Tair & RH – Fixed boundary layer forcing
- Chamber humidified during day – boundary layer feedback
- Constant gA – fixed surface layer feedbacks
- At constant G and constant Tcan – land surface feedbacks depend on surface conductance Gsurf. At constant gA, Gsurf is dominated by stomatal conductance, Gcan.

Chamber - advantages

• Control environmental parameters
  – Vary CO₂ at constant PPF, T_{air}, RH, VPD, T_{soil}, soil moisture
• Allow simultaneous measurement of:
  – Energy balance components (R_{net}, P_{net}, LE, H, dT_{can})
    • R_{net} – net radiometer
    • P_{net} – gas exchange system (CO₂ fluxes, enclosed)
    • LE – gas exchange system (water vapor fluxes, enclosed)
    • H – solved from H = R_{net} – LE – P_{net} - G
    • dT_{can} – Canopy-to-air temperature difference (IR)
Chamber - advantages

- Allow calculation of $g_A$ from $H$ & $dT_{can}$
  - $g_A = \text{slope of } H \text{ vs } dT_{can}$ and several CO$_2$ concentrations
- Allow calculation of $G_{surface}$ from LE & VPD
- Allow calculation of $G_S$ from $G_{surface}$ & $g_A$
Experimental Apparatus

Experimental setup within OTC.
OTC or SPAR chambers measure CO2 and water fluxes with gas exchange systems.
The decoupling coefficient, $\Omega$, was calculated from $g_A$, $G_S$, and the ratio of the increase of latent heat content to the increase of sensible heat content of saturated air, $\varepsilon$ (Jones, 1992).

$$\Omega = \frac{\varepsilon + 1}{\varepsilon + 1 + (g_A/G_S)}$$

At constant $g_A$: Transpiration rate (Tr), stomatal conductance ($G_S$) and $\Omega$ decrease with increasing $[CO_2]$. 
Conclusions

• Chambers alter environment near plants ($T_{\text{air}}$, $T_{\text{can}}$, VPD, and $g_A$).
• Problems due to side-lighting and ventilation can be mitigated.
• Chambers simplify fix most forcing and feedbacks – useful for calibrating climate change models (e.g. measure $G_s$ response to $CO_2$).
• $G_s$ measured in chambers can be converted to $T_r$ in field settings if the decoupling coefficient is known (i.e. account for boundary layer feedbacks).