

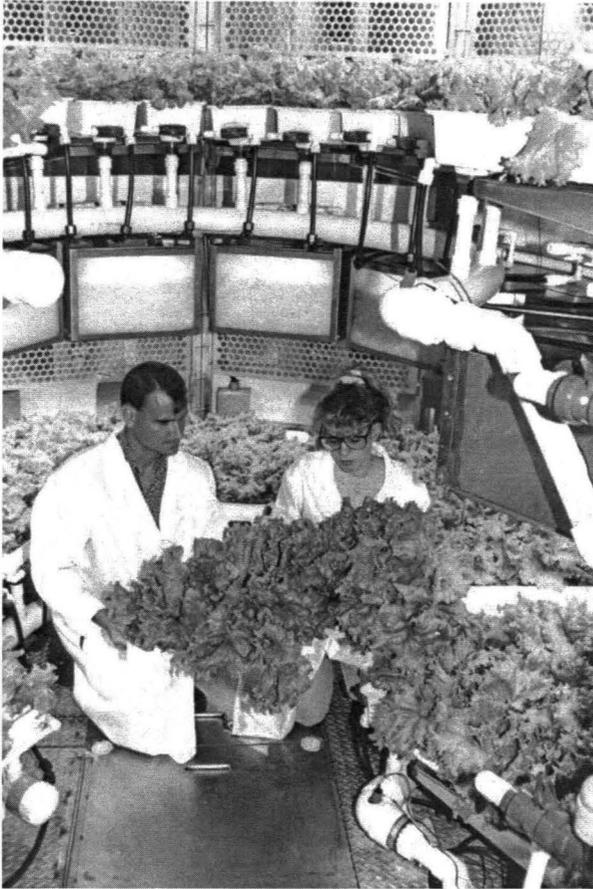
Utilizing Chamber Data for Developing and Validating Climate Change Models

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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.

Chamber Systems



Growth Chamber
KSC



SPAR Chamber
UF



OTC Chamber
KSC

Can chamber data be used to generate data for climate change studies?

Problems with Chamber data

- Environment surrounding plants is altered
 - OTCs vs field : +4⁰C 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 aerodynamic conductance (g_A)



Chamber and Climate Variables

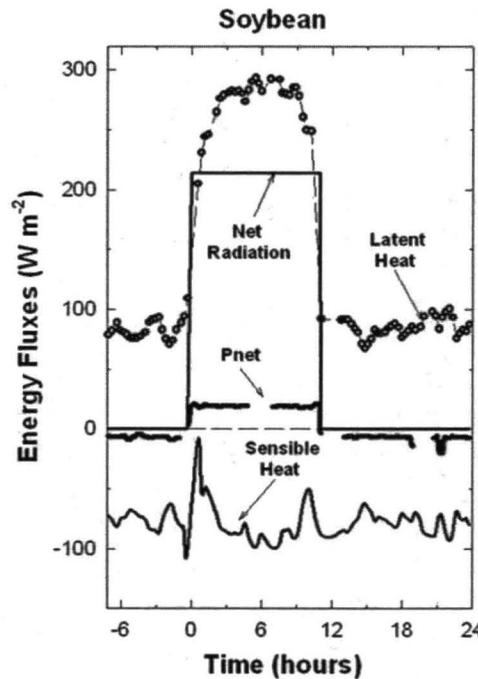
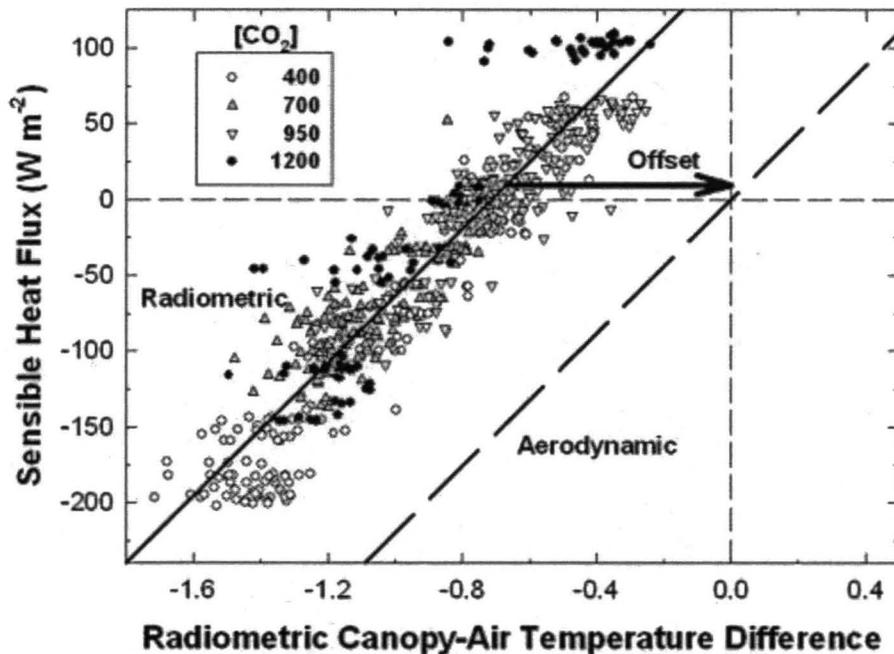
- Constant light – Fixed surface radiation forcing
- Constant T_{air} & RH – Fixed boundary layer forcing
- Chamber humidified during day – boundary layer feedback
- Constant g_A – fixed surface layer feedbacks
- At constant G and constant T_{can} – land surface feedbacks depend on surface conductance G_{surf} . At constant g_A , G_{surf} is dominated by stomatal conductance, G_{can} .

Chamber - advantages

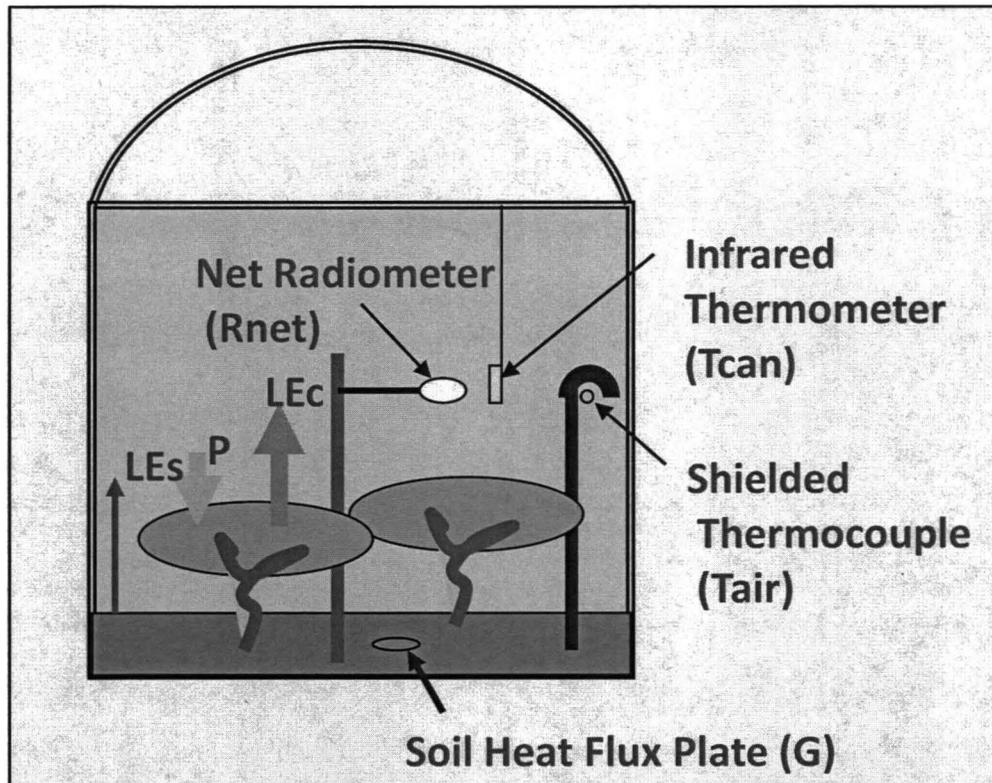
- Control environmental parameters
 - Vary CO_2 at constant PPF, T_{air} , RH, VPD, T_{soil} , soil moisture
- Allow simultaneous measurement of:
 - Energy balance components (R_{net} , P_{net} , LE, H, dT_{can})
 - R_{net} – net radiometer
 - P_{net} – gas exchange system (CO2 fluxes, enclosed)
 - LE – gas exchange system (water vapor fluxes, enclosed)
 - H – solved from $H = R_{\text{net}} - LE - P_{\text{net}} - G$
 - 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



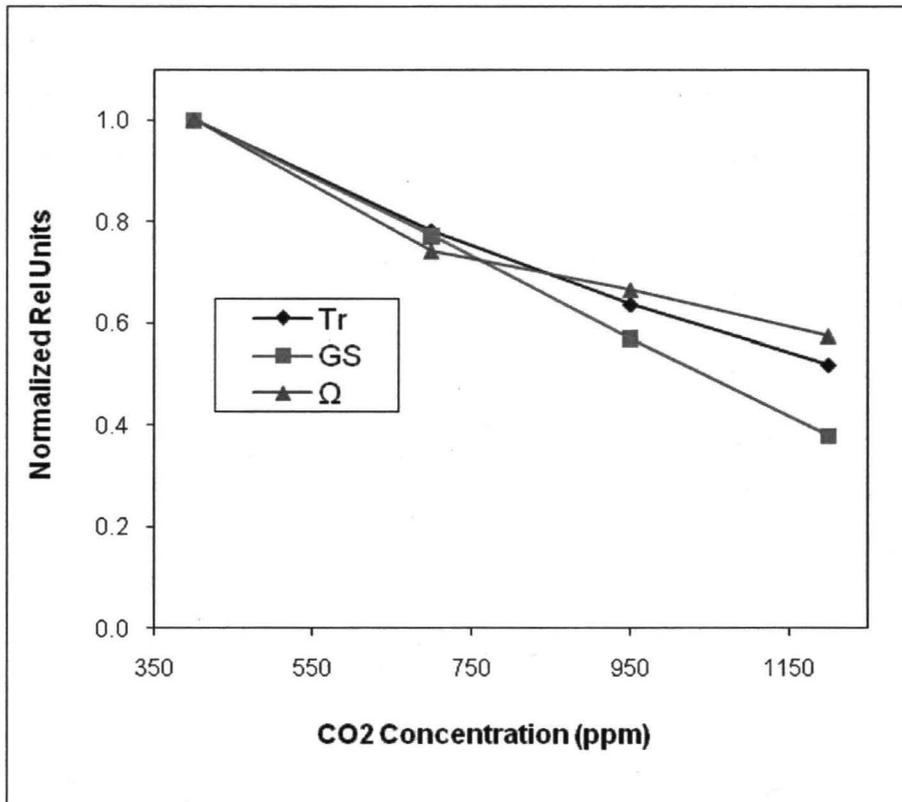
Experimental Apparatus



Experimental setup within OTC.

OTC or SPAR chambers measure CO_2 and water fluxes with gas exchange systems.

G_S & Tr vs CO_2 Concentration



The decoupling coefficient, Ω , 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, ϵ (Jones, 1992).

$$\Omega = (\epsilon + 1) / [\epsilon + 1 + (g_A/G_S)]$$

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

Conclusions

- Chambers alter environment near plants (T_{air} , T_{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 Tr in field settings if the decoupling coefficient is known (i.e. account for boundary layer feedbacks).