Automated Chambers for Measuring Soil and Canopy Respiration

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Fig. 1. A hot-wire system was used to protect the chambers while allowing the cattle to graze in the sample plot. Measurements of intercepted photosynthetically active radiation as well as routine visual inspections indicated no difference between the vegetation inside and outside the plot area. Clipped leaves were observed inside the plots, indicating that the cattle successfully grazed in the area encompassed by the soil frame despite the presence of the chamber system.

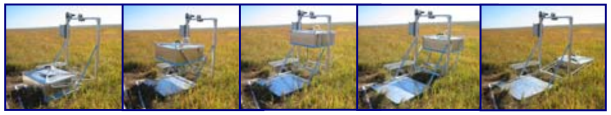

Fig. 2. Rectangular opaque chambers (0.85 m x 0.85 m x 0.25 m) were automatically deployed at 2 or 4 hourly intervals using a four-arm linkage and 12V-winch. When idle, the chambers rested on a parking platform north of the sample plot; thus, the plot microclimate was not affected.

Introduction and Objectives

A multiplexed automated chamber system was developed to monitor ecosystem respiration (J_R) from unplowed tallgrass prairie near Manhattan, Kansas. Chambers were deployed in the source area of eddy covariance towers for one year in annually burned grazed and ungrazed pastures. J_R was determined from CO_2 vs. time curves using a non-steady-state measurement as follows:

$$J_R = \rho_m \frac{V}{A} \frac{dCO_2}{dt}$$

where J_R is in μmol m^{-2} s^{-1}, V is chamber volume in m^3, A is chamber area in m^2 and ρ_m is the molar density of air (mol m^{-3}). The rate change in CO_2, dCO_2/dt, was estimated from a polynomial-based algorithm following the methods of Ham et al. (2004). Gaps in the data were filled using the diurnal mean method and a 13-day gliding window as described by Falge et al. (2001), except during a winter ice storm, where an exponential temperature model was used.

Data from these chambers were used to:

1. Characterize patterns of ecosystem respiration in grazed and ungrazed tallgrass prairie,
2. Address the effect of sampling frequency on calculations of J_R and
3. Determine the efficacy of using temperature to model J_R for gap filling purposes.

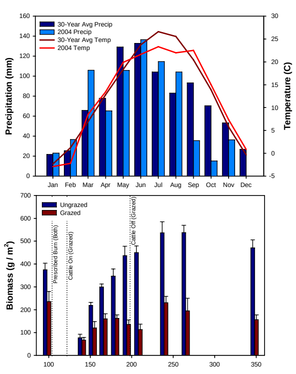

Fig. 3. *Top.* Annual and 30-year average regional temperature and precipitation. Total 2004 precipitation was 779 mm, compared to 884 mm, the 30-year average. *Bottom.* Biomass at the sites. Leaf area index correlated well with biomass from Day of Year 120-220.

Ecosystem Respiration from Grazed and Ungrazed Prairie

Automated chambers were operated for 12 months in Grazed and Ungrazed pastures to evaluate the effect of grazing on the amount of CO_2 lost to the atmosphere. Over the course of one year, the Ungrazed site lost 18 % more CO_2 (5940 g CO_2 m^{-2}, 1621 g C m^{-2}) than the Grazed site (5025 g CO_2 m^{-2}, 1371 g C m^{-2}). Most of this difference occurred during the summer months and coincided with grazing activity. Cattle were stocked on the grazed site from early May to mid July at a rate of 0.8 ha per steer (i.e., intensive early stocking).

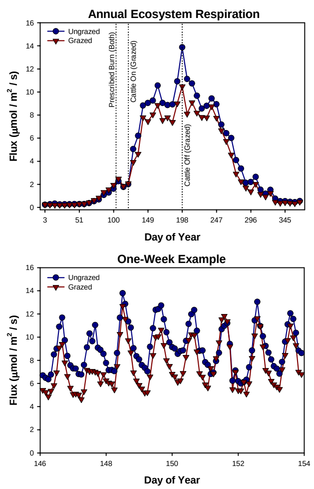

Fig. 4. *Top.* Ecosystem respiration from Jan through Dec 2004. At both sites, fluxes increased dramatically shortly following the prescribed burn in April and declined sharply through October. The Grazed and Ungrazed sites had nearly identical fluxes until cattle were placed on the Grazed site. After this point, J_R at the Ungrazed site was higher than at the Grazed site. Annual ecosystem respiration was 15 % less in the Grazed site compared to the Ungrazed pasture. *Bottom.* An example of fluxes at the Grazed and Ungrazed sites at the end of May. Flux at the Grazed site was 82 % that at the Ungrazed site, on average. Interestingly, fluxes were approximately equal on both sites during the 13.5 mm precipitation on Day 151-152.

Temperature Modeling as a Gap Filling Strategy

Most long-term studies are faced with periods of incomplete or missing data. Weather conditions (e.g., high wind speeds or rain), mechanical failures, or operator errors will inevitably create gaps in the data record. An average diurnal mean (Falge et al., 2001) is a good gap filling technique in many cases. However, improved estimates of missing data can be obtained by developing simple relationships between flux and temperature using measurements made immediately prior to and after the data gap. Model equations for predicting J_R were developed based on five days of near-continuous data using an exponential model (e.g., Lloyd and Taylor, 1994):

$$\ln(J_R) = m(T - T_{avg}) + b$$

where J_R is ecosystem respiration in μmol m^{-2} s^{-1}, m and b are constants, T is temperature, and T_{avg} is the average temperature during the span of time the data were collected, both in degrees Celsius. Air temperature resulted in relatively high R^2 values (0.70 to 0.91), suggesting that this method of gap-filling is adequate to fill small gaps in the data (i.e. less than a day). An Arrhenius model was also used with nearly identical results. However, equations generated using data from one season or stage of canopy phenology may not be suitable for gap filling at other times of year. Additionally, blocks of data spanning times during which precipitation occurred resulted in poor fit of the data. This suggests that adding a soil water content parameter would improve results. This was also proposed by Bremer et al. (1998), based on research at a nearby site.

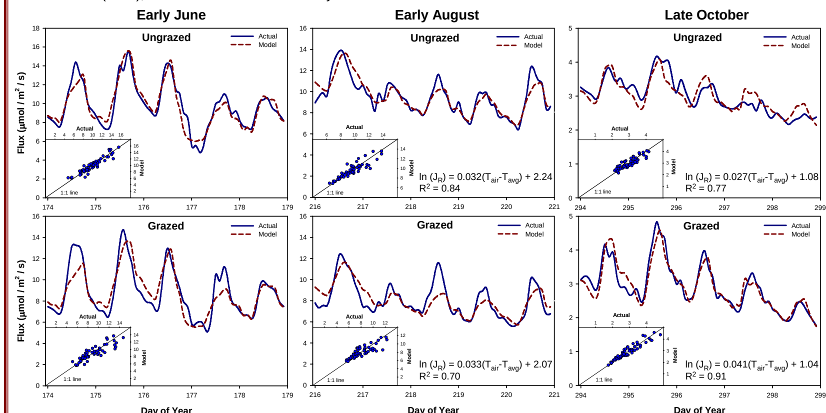

Fig. 5. Actual and modeled fluxes. Relationships were developed as described above. Most modeled points fell within ± 2 μmol of the actual flux. ***Left.*** June. The canopy was growing rapidly. Cattle were placed on the Grazed site 30 days previous. ***Center.*** August. The Ungrazed site had a mature canopy at this time. Cattle were removed from the Grazed site about 20 days previous, and the canopy was recovering. ***Right.*** October. The canopy had senesced at both sites, and fluxes were low.

Sampling Interval

It is desirable to operate chambers no more often than is necessary to reduce their impact on the surface microclimate, to lower system energy requirements and to prevent unnecessary mechanical wear on the instruments. To determine the sampling interval required to collect adequate data, the chambers at the Ungrazed site were operated on an hourly basis for several months. Average fluxes calculated using the 1-hr data were compared to fluxes calculated after assuming the chamber measurements were made at hypothetical sample intervals of 2, 4, 6, 8 and 12 hr. Another interval was calculated assuming the chambers operated only at the times of maximum and minimum flux (1300 and 0600 LST, respectively). The recommended interval between samples depends on error tolerance; in this case, error was < 2% when chambers were operated at up to a 4 hr interval.

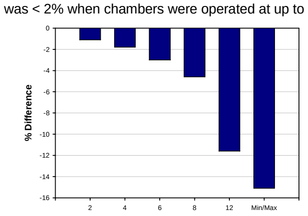

Fig. 6. The percent difference in flux for various intervals compared to an hourly sampling regime.

References

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