Patterns of CO_2 Efflux from Woody Stems in a Red Oak (Quercus rubra) Chronosequence

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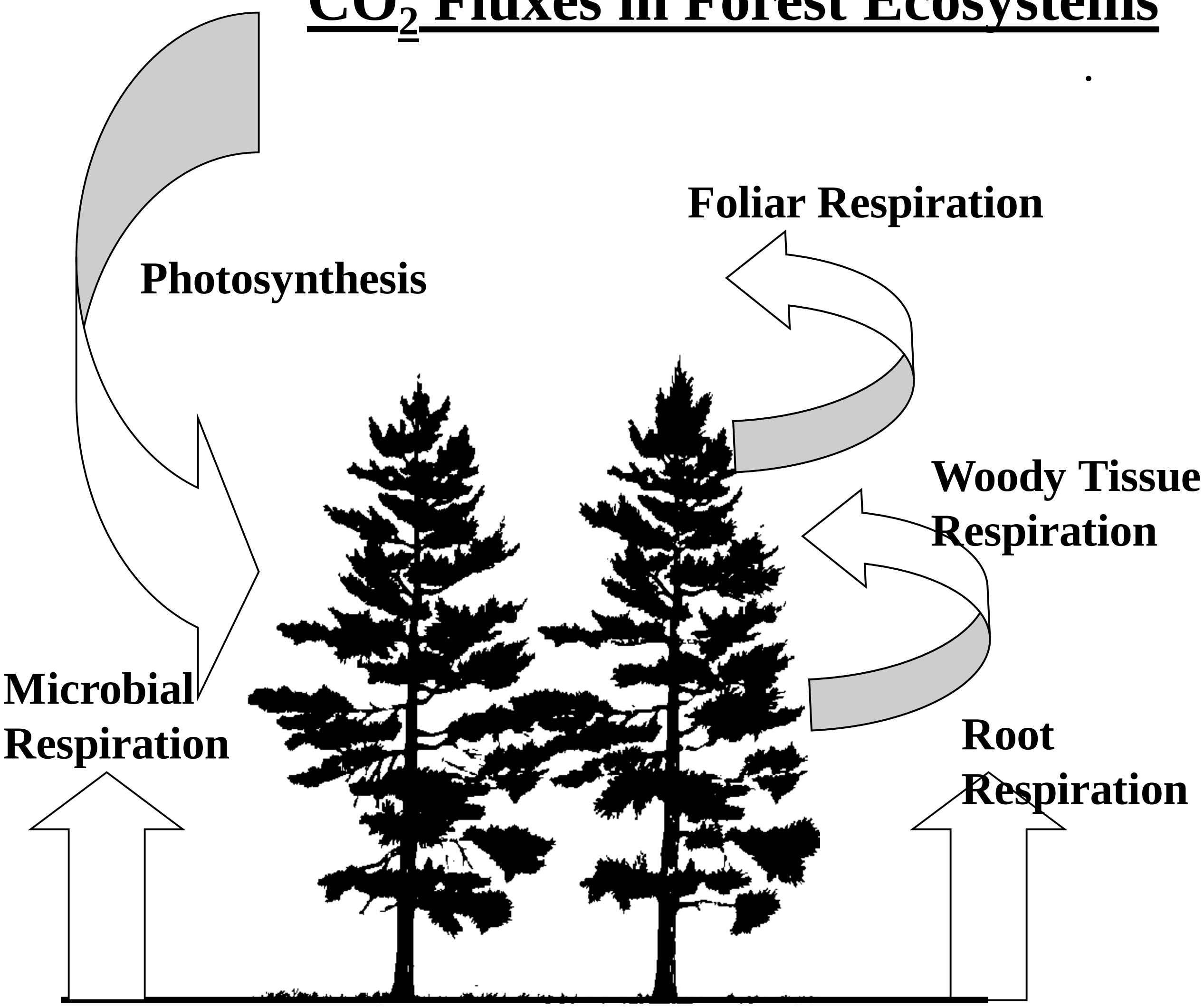
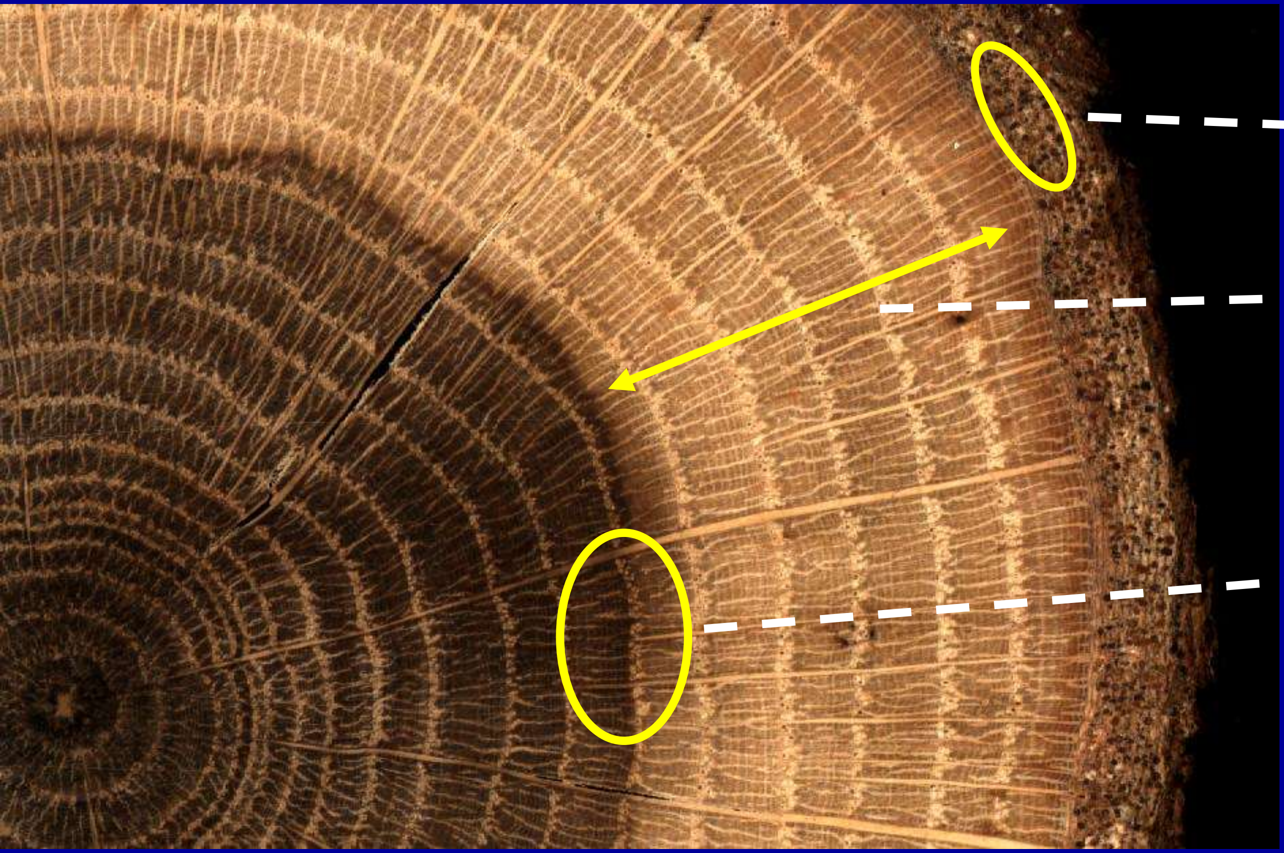
Respiration in stems and branches is an important, but poorly understood, component of forest carbon budgets.

CO_2 Fluxes in Forest Ecosystems



- 50-70% of carbon assimilated by photosynthesis is released back to atmosphere by plant respiration

Woody Tissue Respiration Background: Sources of Respiratory CO_2 Within Stems



Inner Bark

Sapwood Parenchyma

Sapwood-Heartwood Boundary

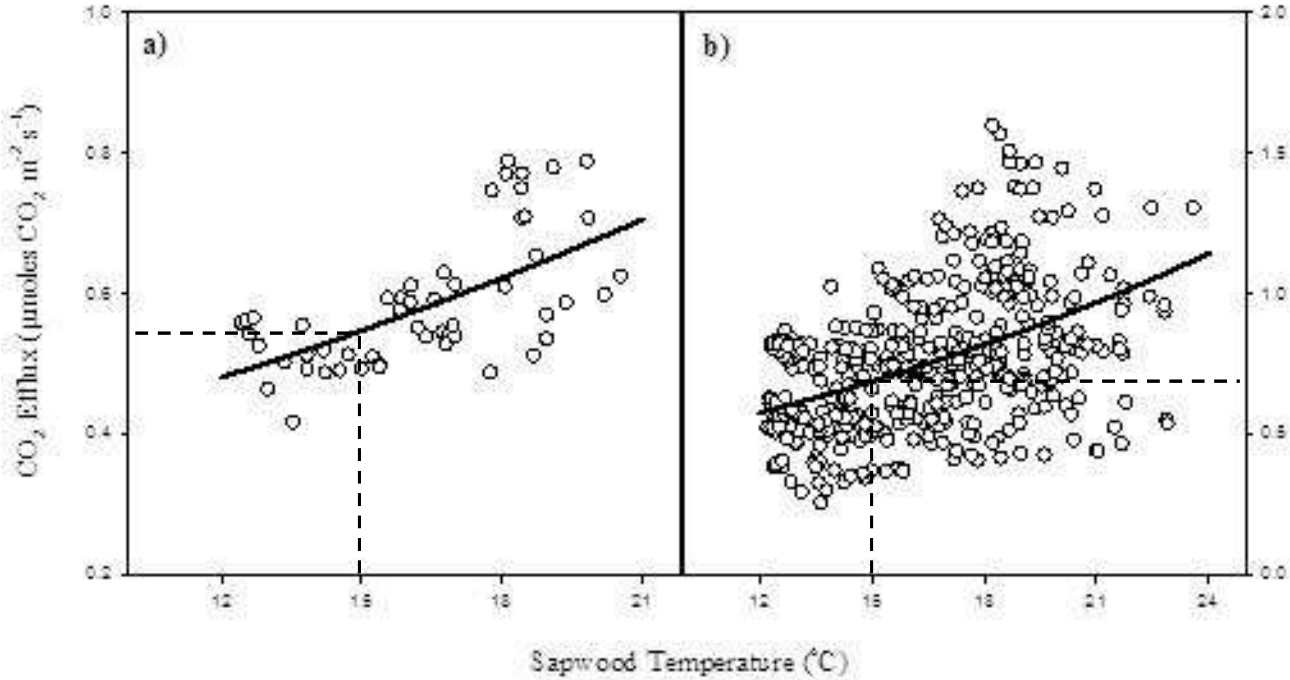
Woody Tissue Respiration Background: CO_2 Efflux-Temperature Response

- Equations to describe CO_2 Efflux-Temperature plots are typically similar to:

$R=R_o*e^{(Eo/Rg)*(1/To-1/Ta)}$

or

$R=R_o*Q_{10}^{((T-To)/10)}$



Woody Tissue Respiration Background:

Recent evidence suggests that sap flow in tree stems strongly influences the rate of CO_2 efflux to the atmosphere (McGuire and Teskey 2002; Teskey and McGuire, 2004; Bowman et al, in prep).

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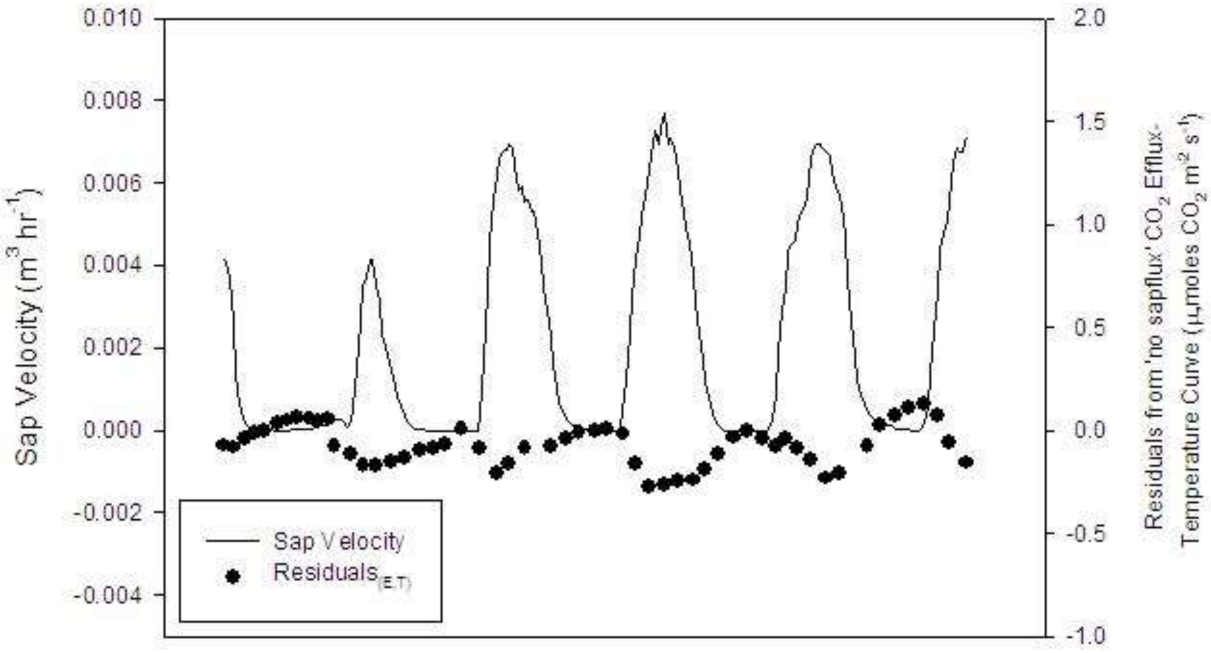
•Residuals tended to become more negative, i.e. there was less CO_2 efflux than would be predicted from sapwood temperature alone, in the late morning. This decline in the magnitude of residuals corresponded to the onset of sap flow.



- **This study aims find consistent linkages between amount of respiratory CO_2 within stems, the transpirational and anatomical barriers to CO_2 diffusion to the atmosphere, and the actual CO_2 diffusing from tree stems.**

<u>Study Site:</u> A chronosequence of *Q. rubra* stands located in Black Rock Forest (Cornwall, NY)

Black Rock Forest:

- Q. *rubra* and Q. *prinus* account for ~60% of forest basal area. *Acer rubrum* comprises 8% of basal area
- 1,500 ha scientific preserve
- located in Hudson Highlands province
- 41° 24′ N 74° 01 ′ W
- Elevation 110 – 450 above sea level

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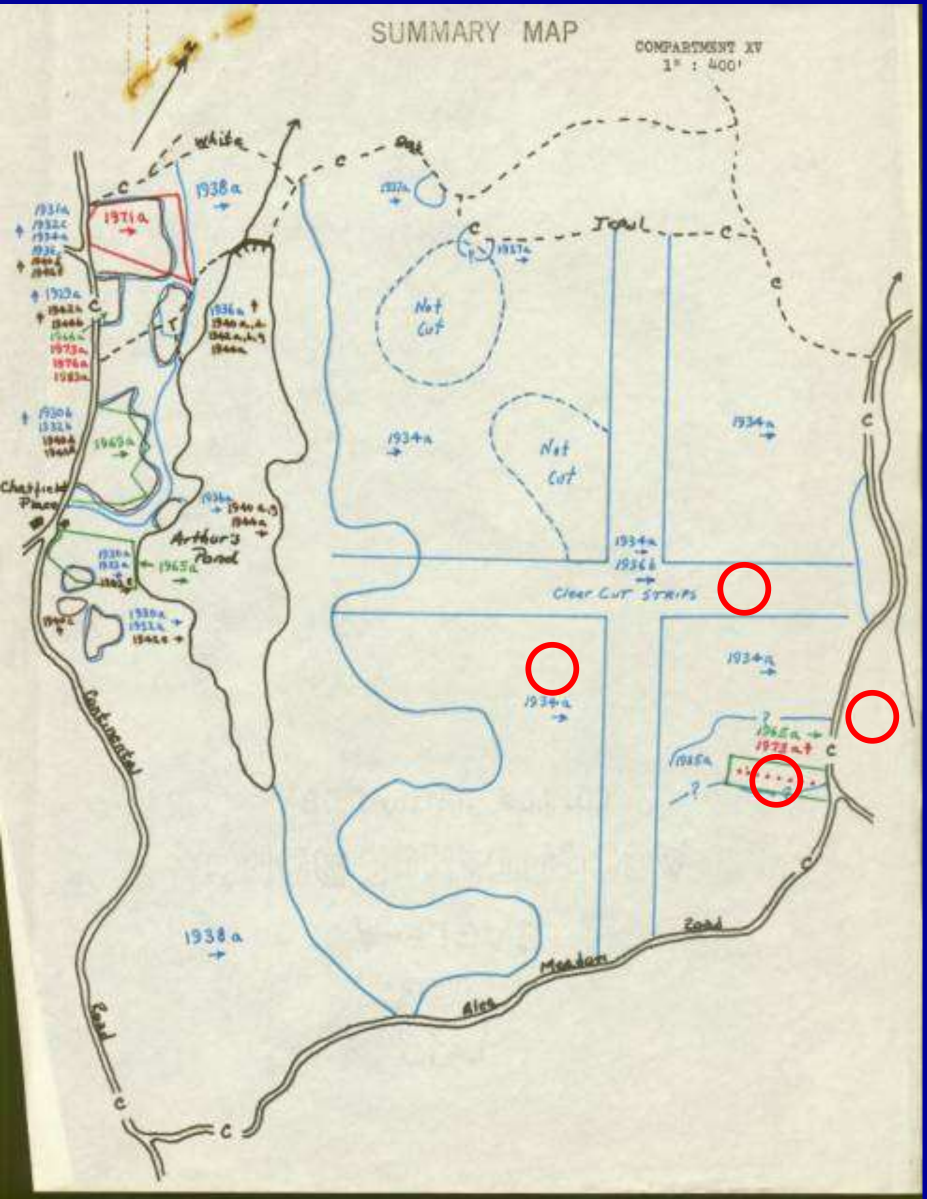

- Detailed records of logging at BRF enabled identification of four stands ranging in age from 35-130 yrs.

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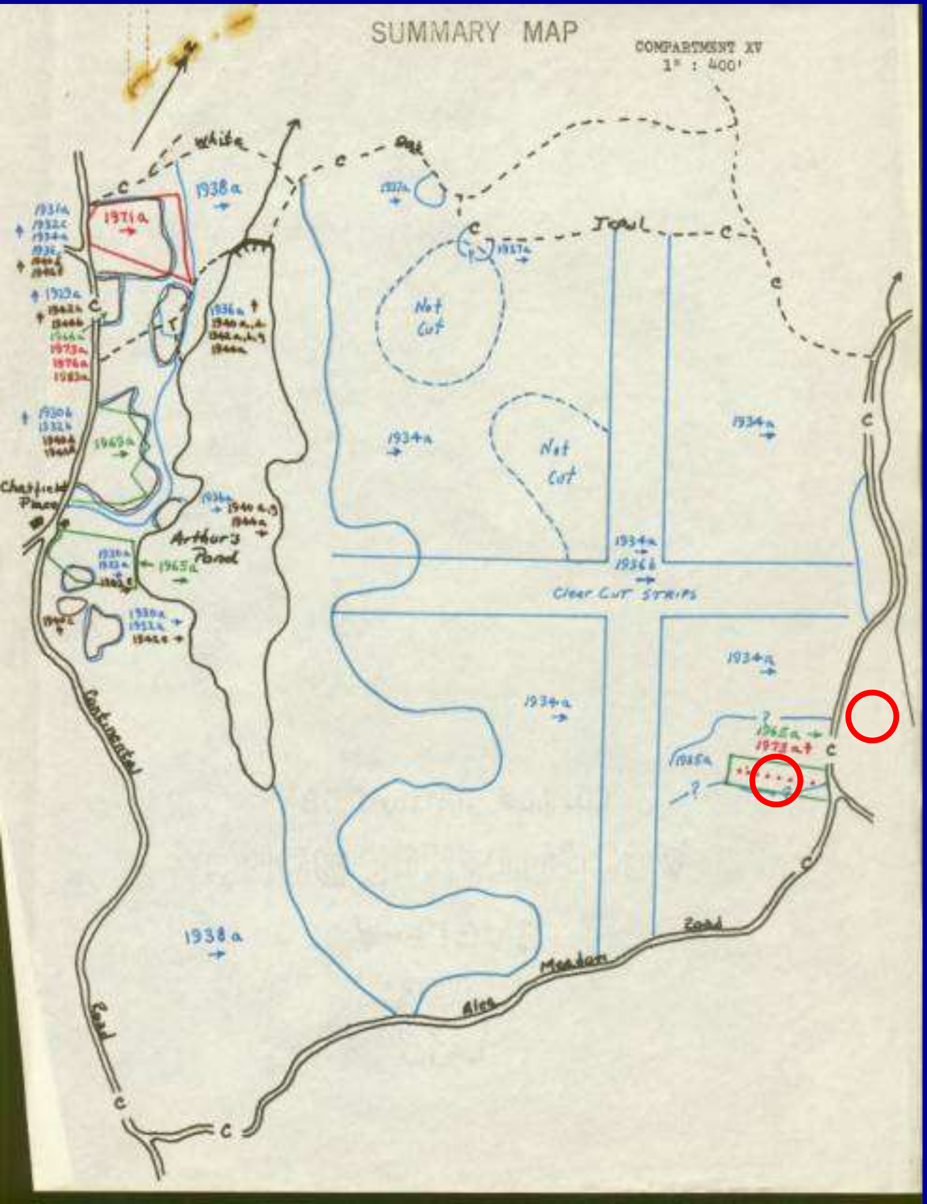
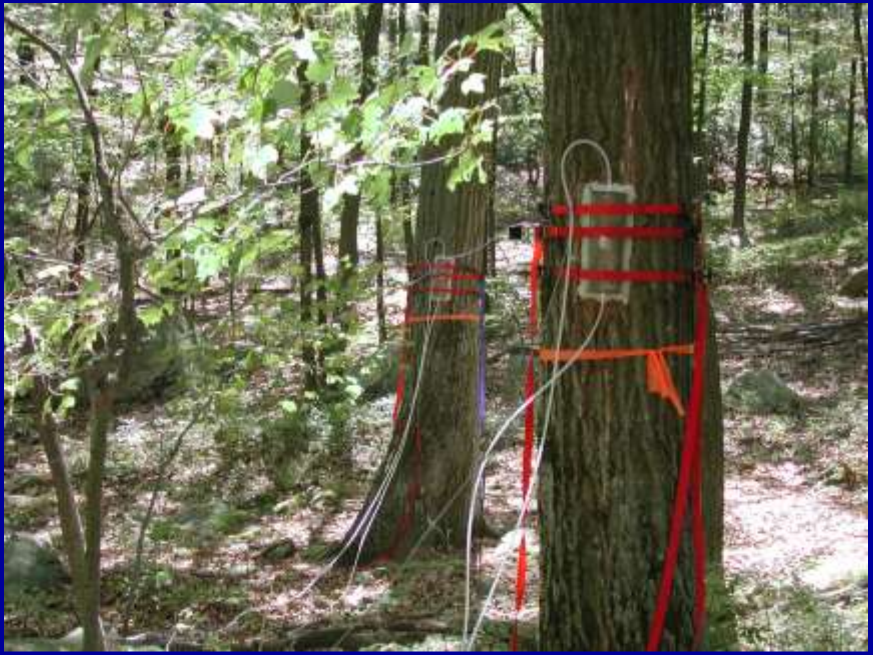


• Data was collected in two of these stands between mid June and late July 2004.

Age (Yrs)	DBH (cm ± SD)	Height (m ± SD)	Stand LAI (m^2/m^2)
37	14.84 (± 0.97)	14.01 (± 0.67)	2.15
91	38.28 (± 1.71)	19.92 (± 0.73)	2.67

Study Methods:

•Continuous measurements of CO_2 efflux were made in 8 *Q. rubra* trees from each stand for 7-10 days.



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•Physiological and anatomical characteristics that 1) represent the amount of CO_2 within the stem or 2) may influence diffusion of CO_2 from the stem were also measured:

- •Sap Velocity
- •CO_2 concentration within the xylem

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- •Sap Velocity
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- •Respiratory potential of excised inner bark and sapwood tissues
- •Diameter Growth Rate
- •Bark Thickness and Sapwood Density

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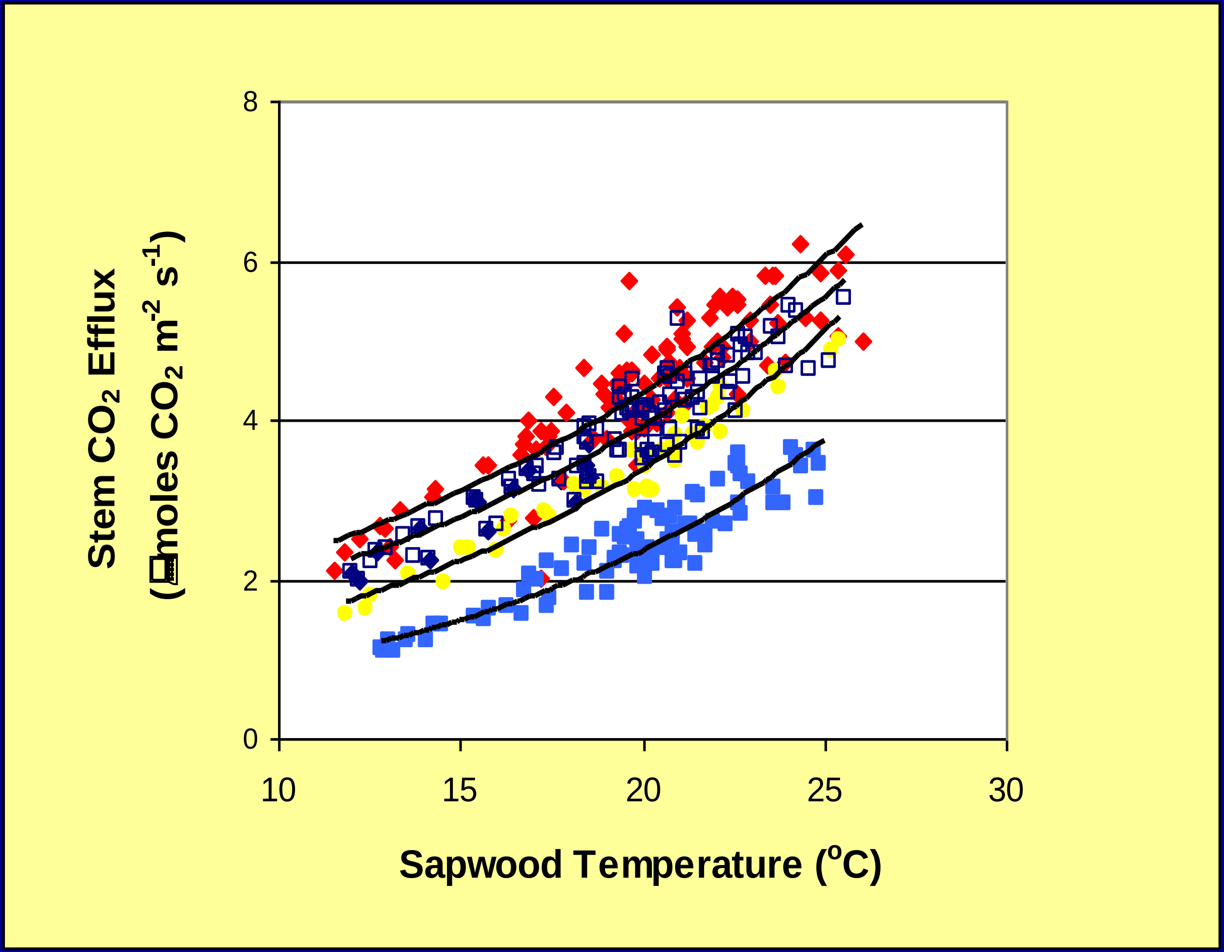
- Physiological and anatomical characteristics that 1) represent the amount of CO_2 within the stem or 2) may influence diffusion of CO_2 from the stem were also measured.
- 'Concentration Gradient' framework for stem CO_2 efflux involving processes that influence either 1) the magnitude of the concentration gradient between the stem interior and the atmosphere or 2) the resistance to CO_2 diffusion across this gradient

Results:

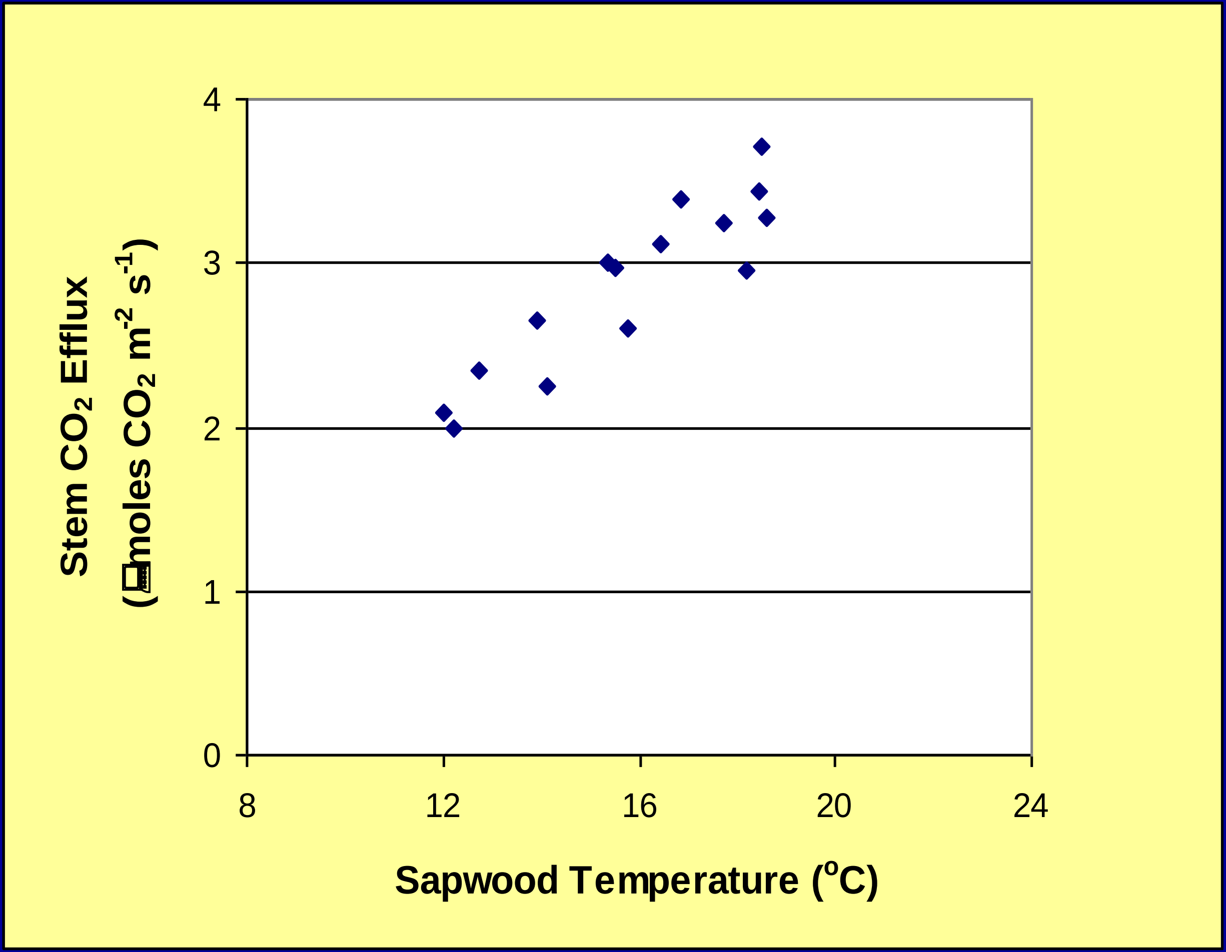
•CO_2 efflux was strongly related to temperature in all sampled trees.

•CO_2 efflux rates were not significantly different between 30- and 90-yr old stands.



Results:

•A diel hysteresis in the CO_2 efflux data was commonly observed in both stands.



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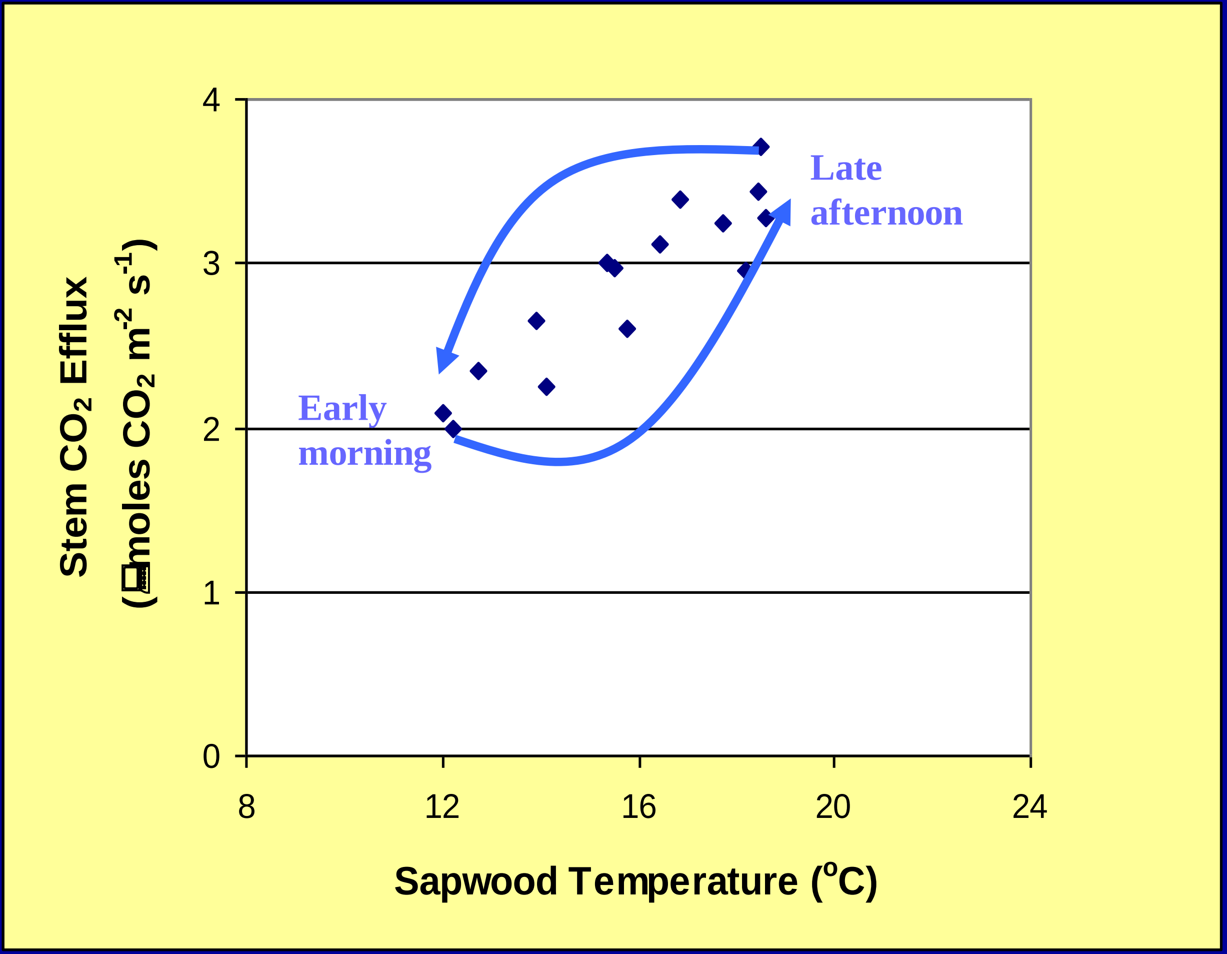
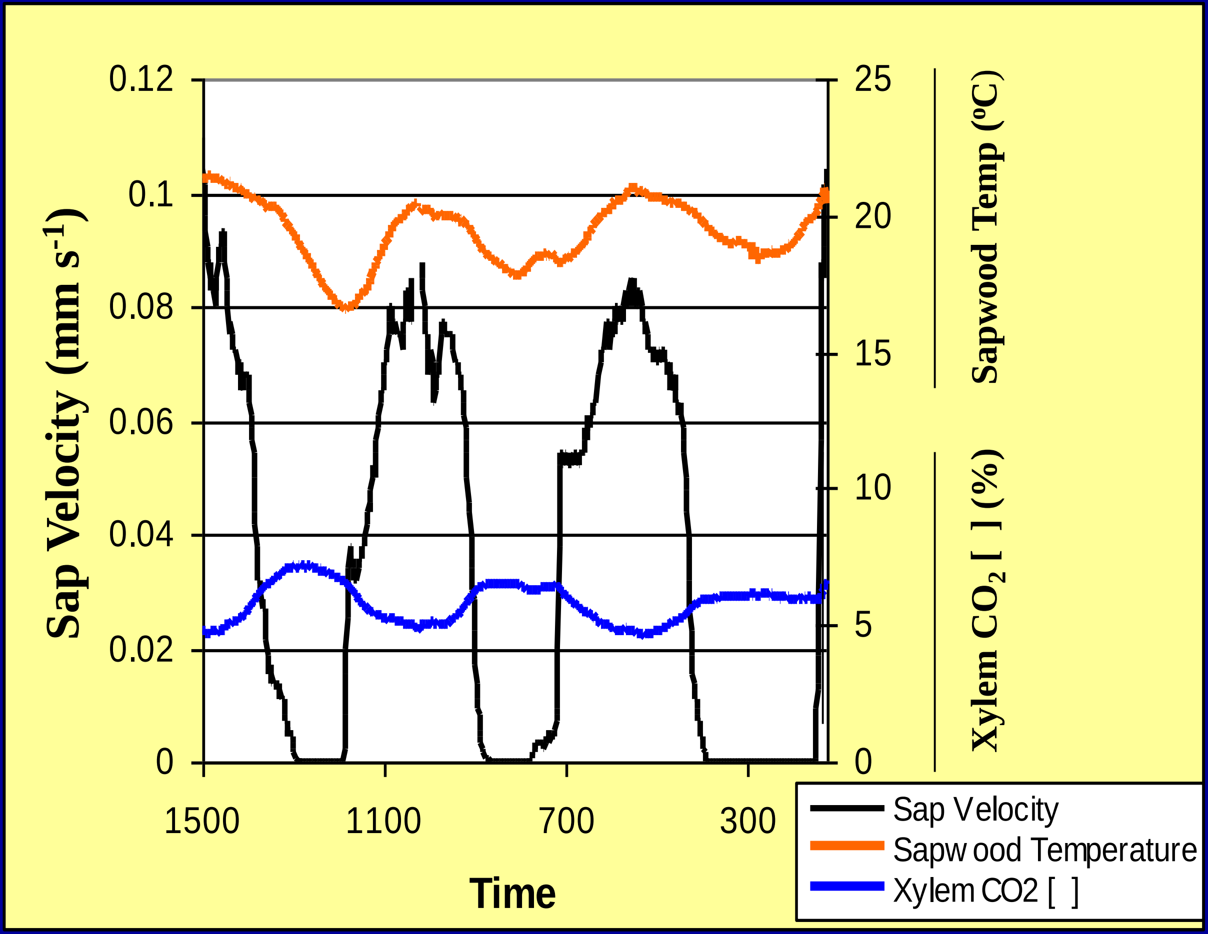


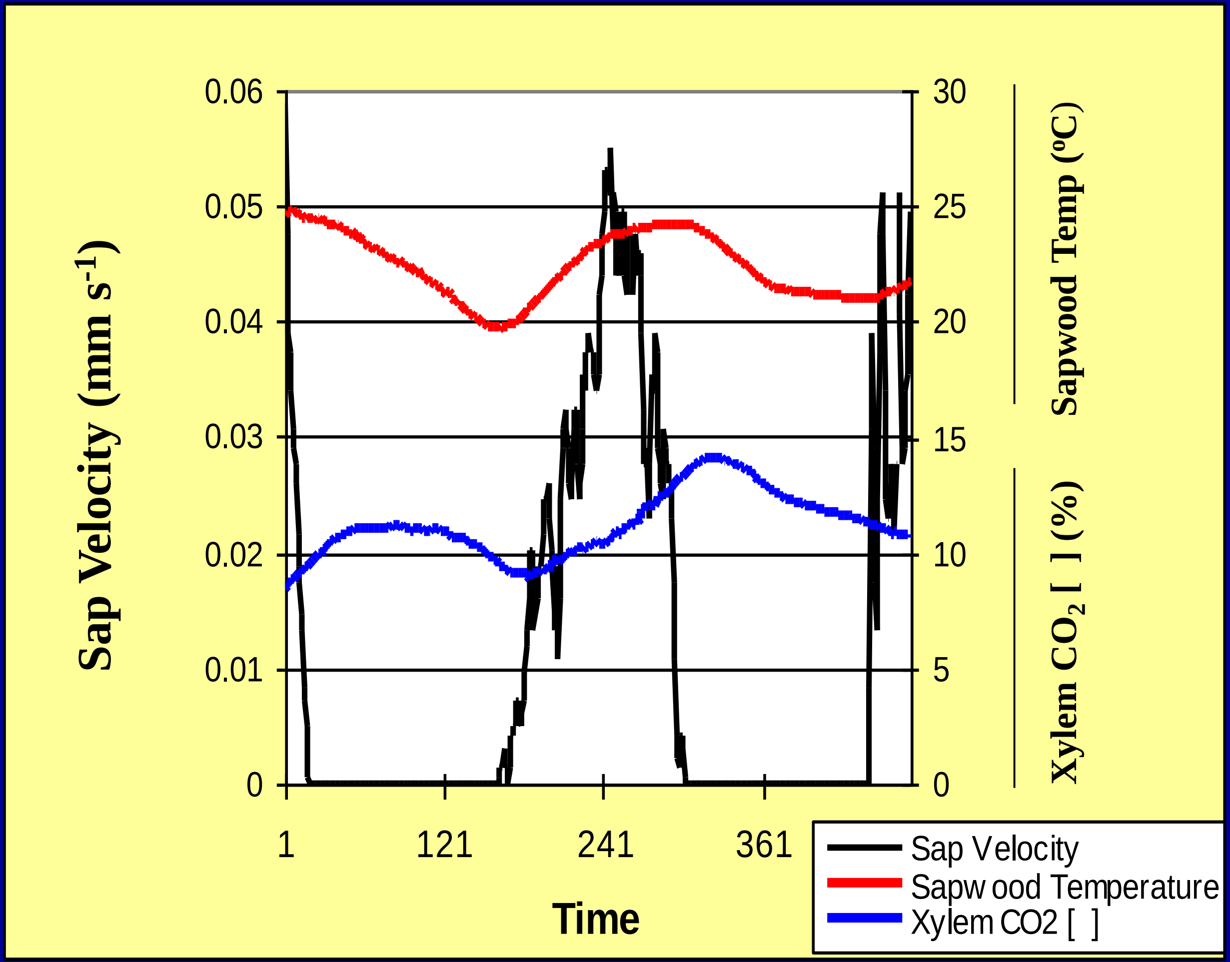
Results:

- The internal CO_2 [ ] in the xylem exhibited a diel pattern caused by sap flow. This pattern indicates that dissolved respiratory CO_2 is transported to upper portions of the tree in the transpiration stream.
- Avg. maximum sap velocity and avg. internal CO_2 [ ] were calculated for comparisons with stem CO_2 efflux



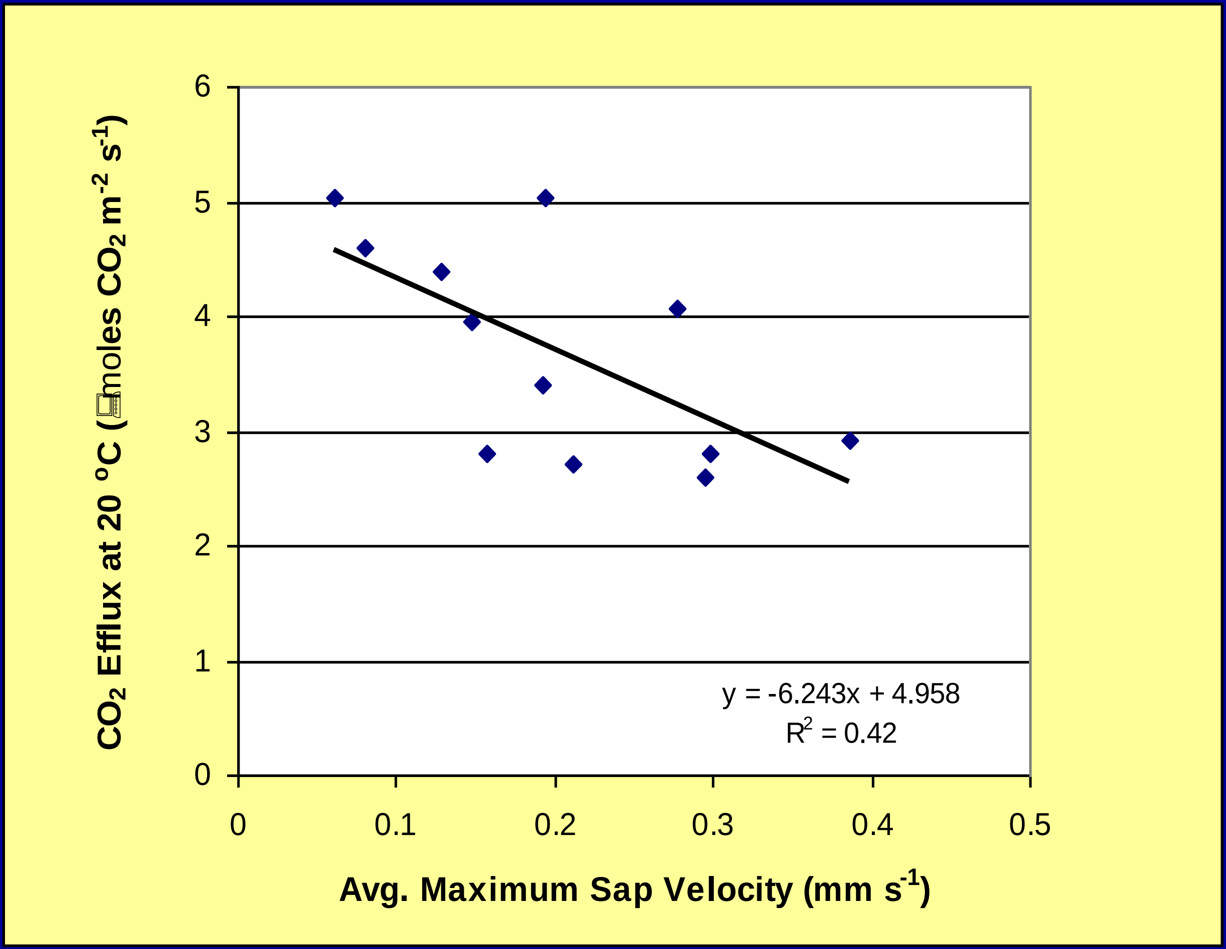
Results:

•Occasionally, the internal CO_2 [ ] in the xylem more closely followed stem sapwood temperature. This was only seen in the younger trees.



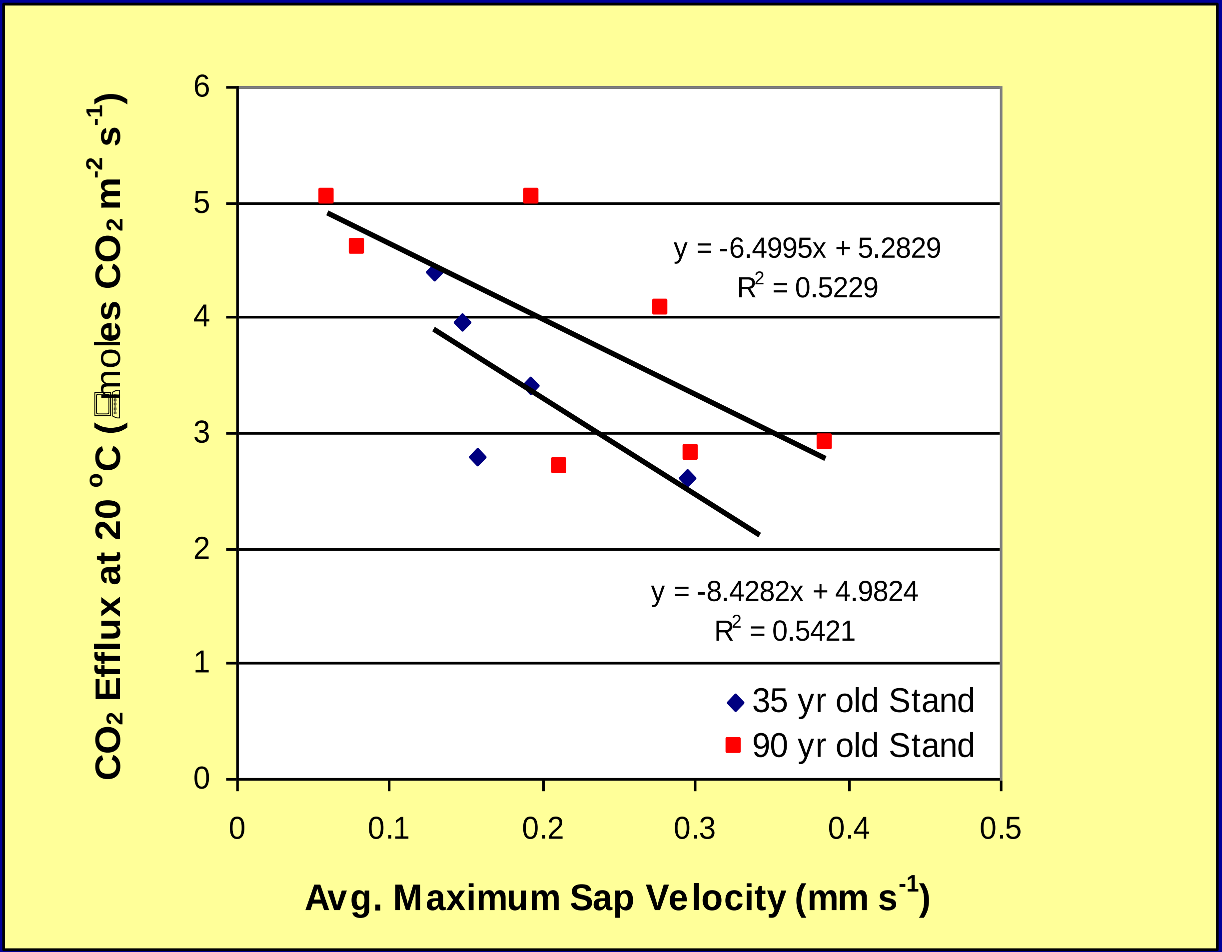
Results:

•CO_2 efflux rates were negatively correlated to average maximum sap flow rates. This is also consistent with the transport of respiratory CO_2 in the transpiration stream.



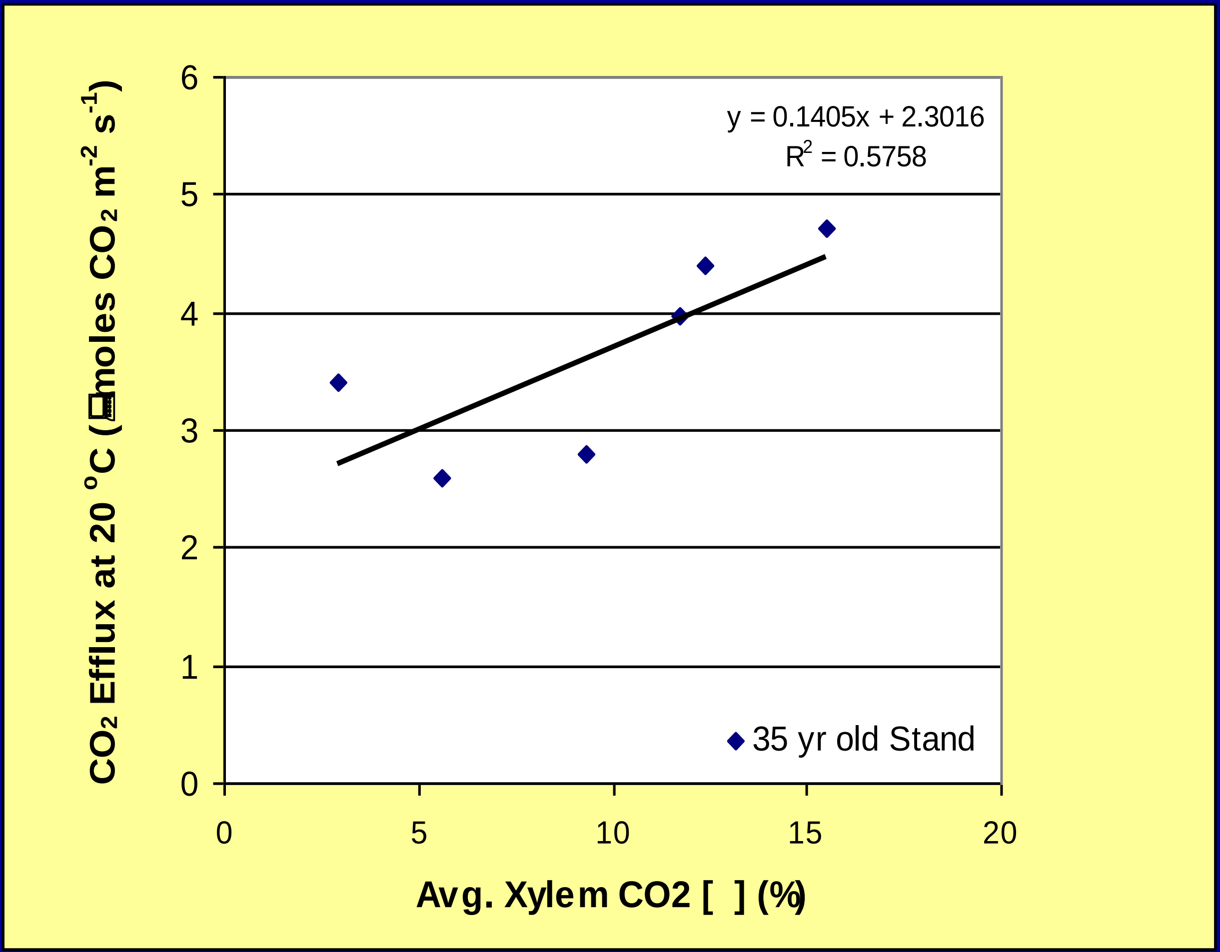
Results:

•This trend was observed in both 35- and 90-yr old tree stands.



Results:

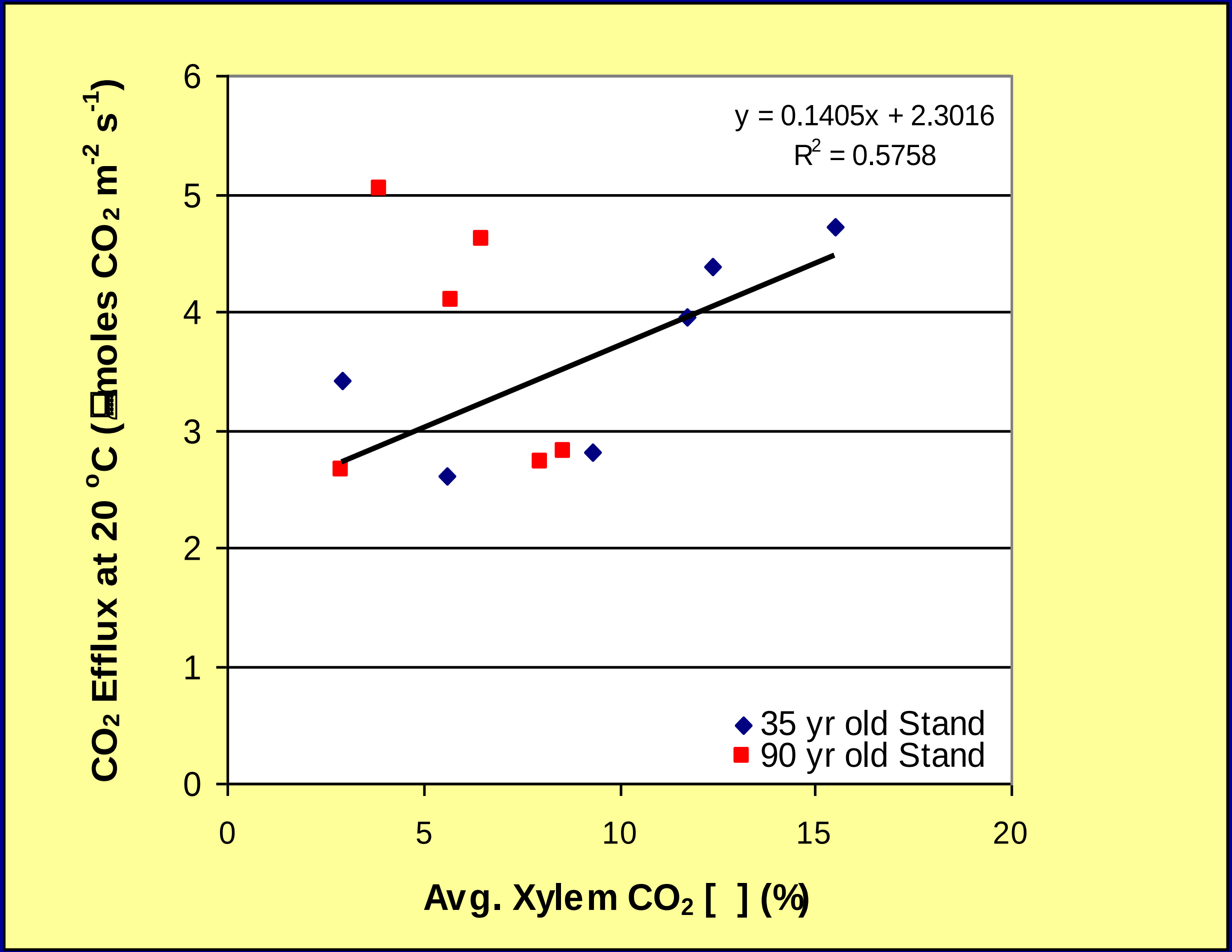
- CO_2 efflux was positively correlated to the xylem CO_2 [ ] in the 35 yr old stand.



Results:

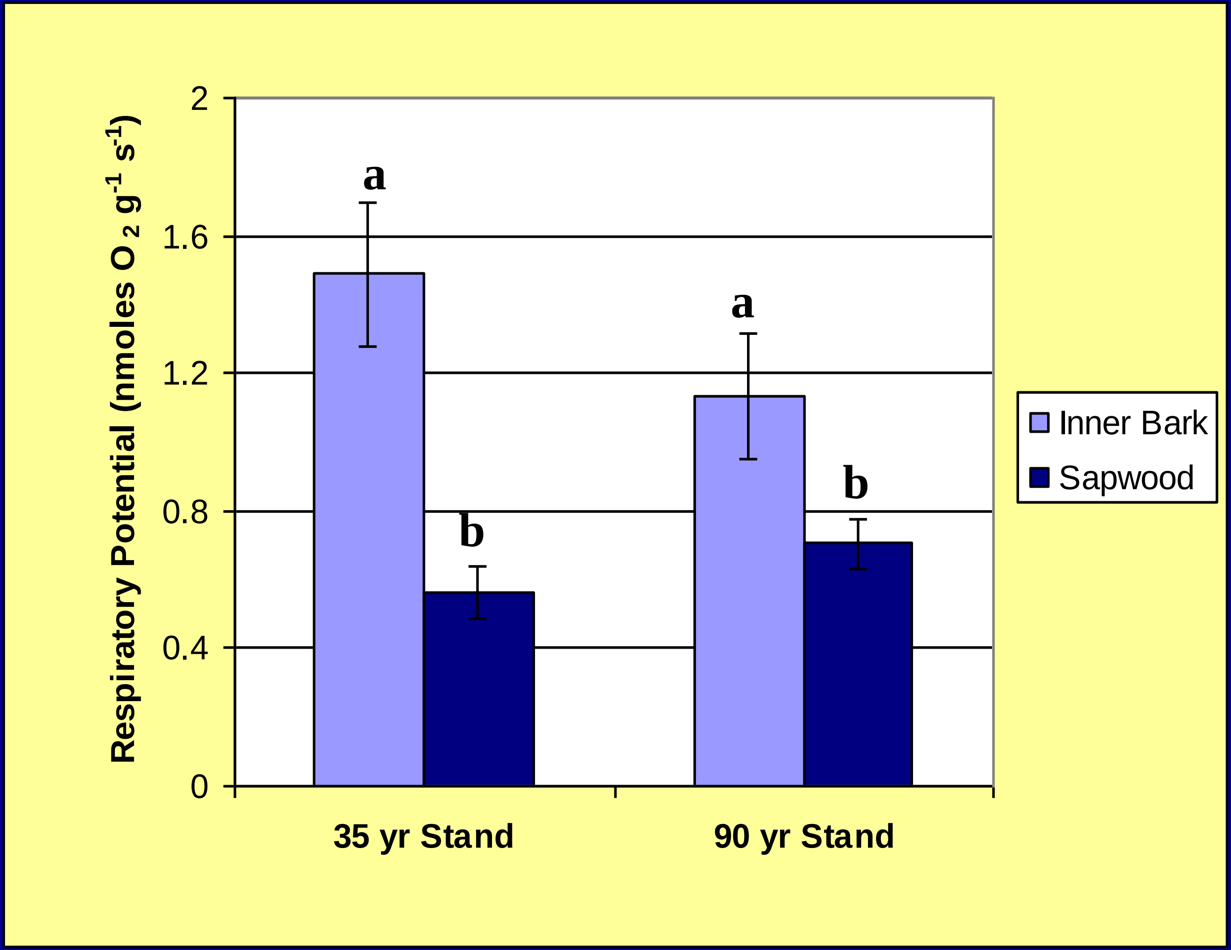
•As hypothesized, CO_2 efflux was positively correlated to the xylem CO_2 [ ] in the 35 yr old stand.

…but not in the 90 yr old stand.



Results:

•Respiratory potential of extracted wood was significantly ($p < .05$) higher in inner bark compared to sapwood. No differences were observed between the stands and no correlations were found with stem CO_2 efflux or internal CO_2 [ ].



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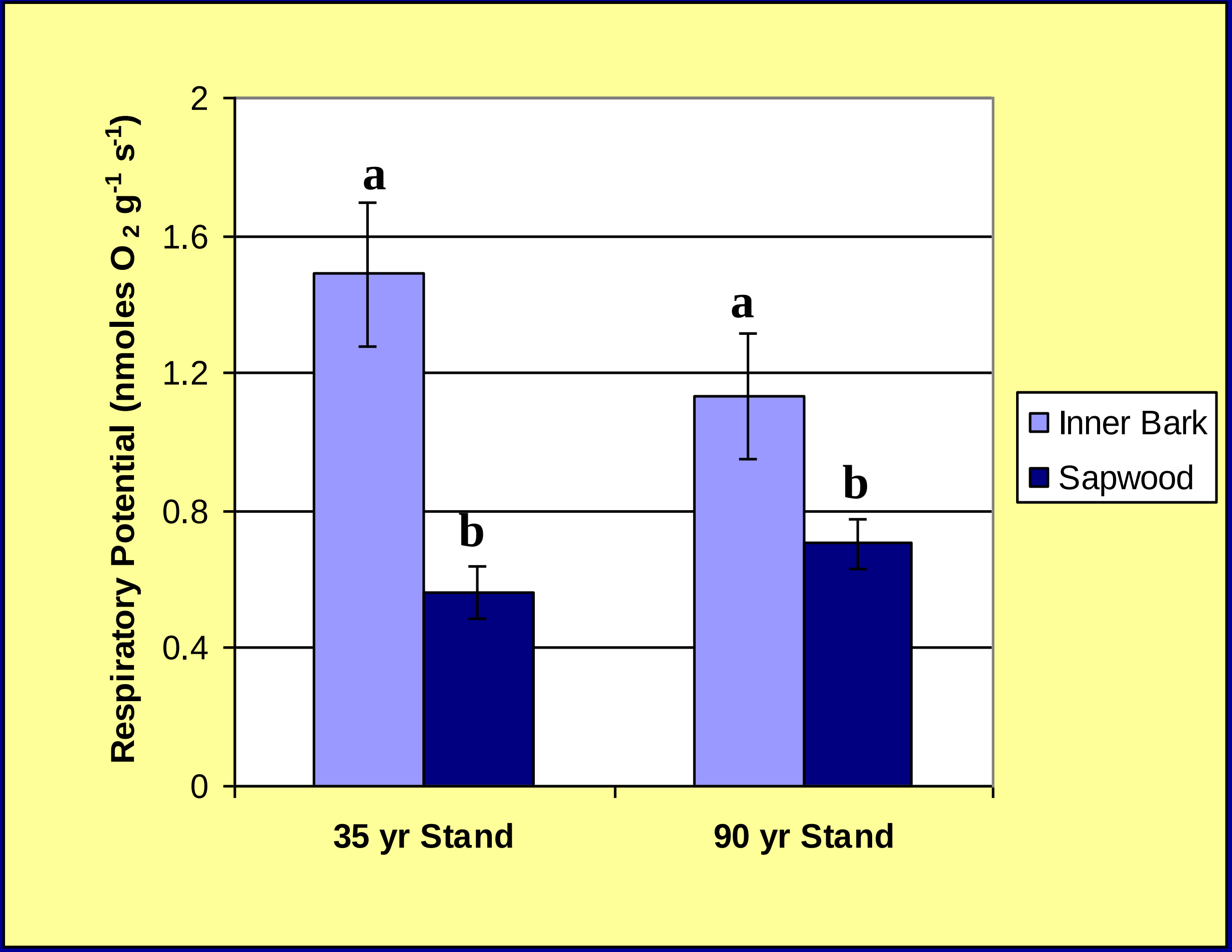
•Also, no correlations were observed between stem CO_2 efflux rate and diameter growth or the anatomical traits of wood (bark thickness, wood density).



General Conclusions:

•Stem CO_2 efflux was negatively correlated with sap velocity in both stands. This finding, along with other recent studies, suggests that interactions between CO_2 efflux and stem hydraulics are commonplace in forest trees.

•The internal CO_2 [ ] of xylem was also predictive of CO_2 efflux in the younger tree stand, but not in the older stand. Perhaps, this indicates that CO_2 efflux in young (with thin bark) trees is driven by the magnitude of the concentration gradient between the tree's interior and the atmosphere. While in older trees (with thick bark), CO_2 efflux may also be heavily influenced by factors that dictate the permeability of wood to CO_2 diffusion.

•These interactions between CO_2 efflux and sap velocity create great uncertainty about the sources and destinations of respiratory CO_2 with unknown ramifications for whole-tree carbon budgets.

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