

# **Impacts of Environmental Variation on Photosynthetic Enhancement in a Forest Exposed to Atmospheric CO<sub>2</sub> Enrichment**

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**The Oak Ridge Experiment on CO<sub>2</sub> Enrichment of Sweetgum**

# Oak Ridge Experiment on the CO<sub>2</sub> Enrichment of Sweetgum (FACE)

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**Research supported by the U.S. Department of Energy, Office of Science, Biological and Environmental Research (PER and TCP)**

## Expectations in CO<sub>2</sub> research:

- CO<sub>2</sub> enrichment increases photosynthesis
  - means: +45 to +65%
- CO<sub>2</sub> enrichment decreases stomatal conductance
  - means: ns to ! 30% (a note of uncertainty!)

## Continuing uncertainties:

- Will large trees respond the same as seedlings?
- Will responses be sustained?
- What are the sources of variability?
  - **Environmental variation / stress**

# Oak Ridge Experiment on CO<sub>2</sub> Enrichment of Sweetgum



## Experimental design:

- *Liquidambar styraciflua*
  - Planted in 1988
  - Plots 25 m diameter
  - Trees now 15 m tall
  - Exposure began in 1998
- 2 elevated CO<sub>2</sub> plots -
  - 560 ppm CO<sub>2</sub>
- 3 control plots-
  - ~360 ppm CO<sub>2</sub>

# Oak Ridge Experiment: CO<sub>2</sub> Enrichment of Sweetgum

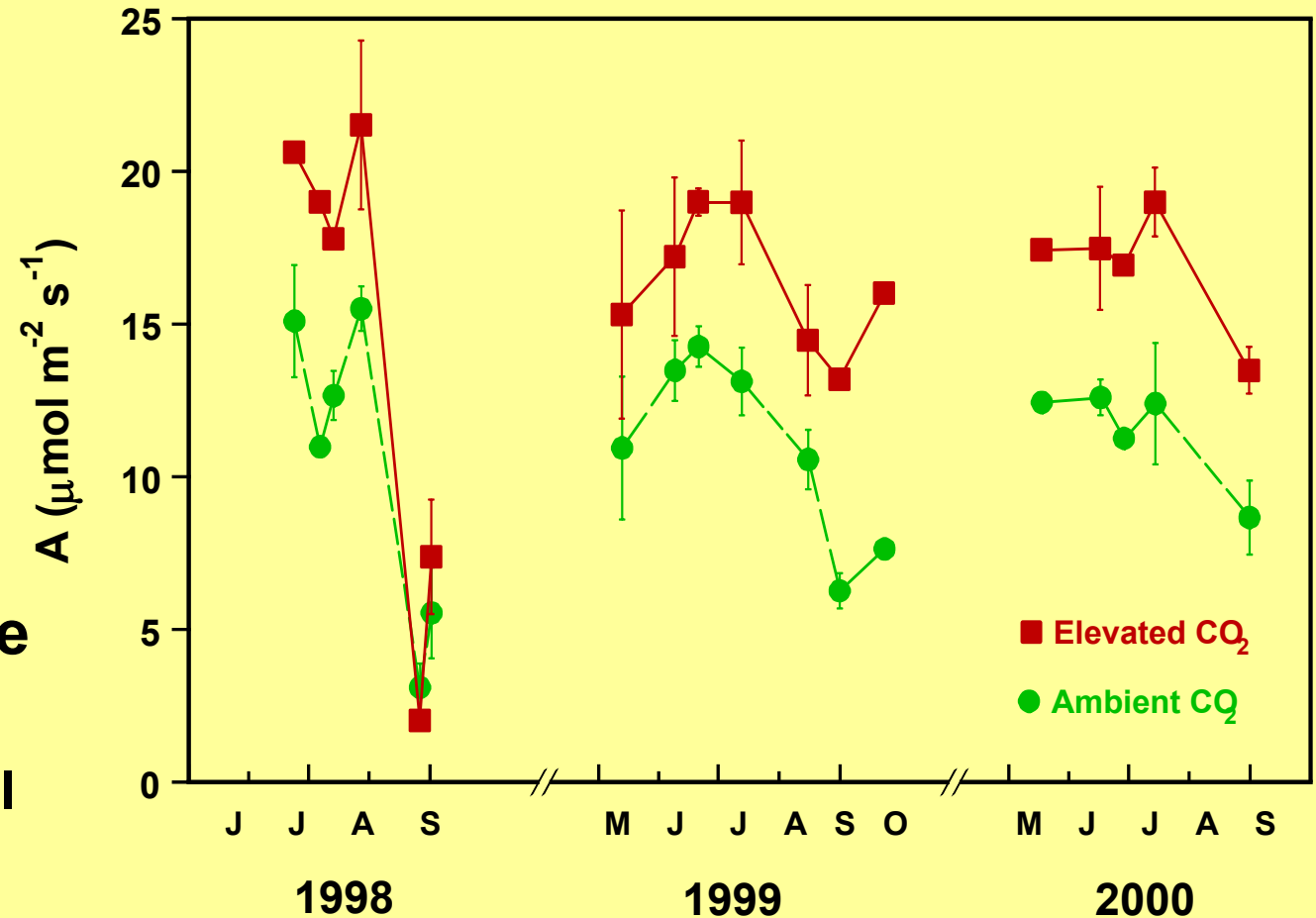
- Gas exchange:**
- Light-saturated
  - 360 or 560 ppm CO<sub>2</sub>
  - LI-COR LI-6400
    - Red-Blue LED



- Upper canopy for 3 years; mid-canopy added in year 3
- Prevailing atmospheric and soil conditions
  - VPD, temperatures, natural rainfall
  - (soil moisture monitored by TDR)

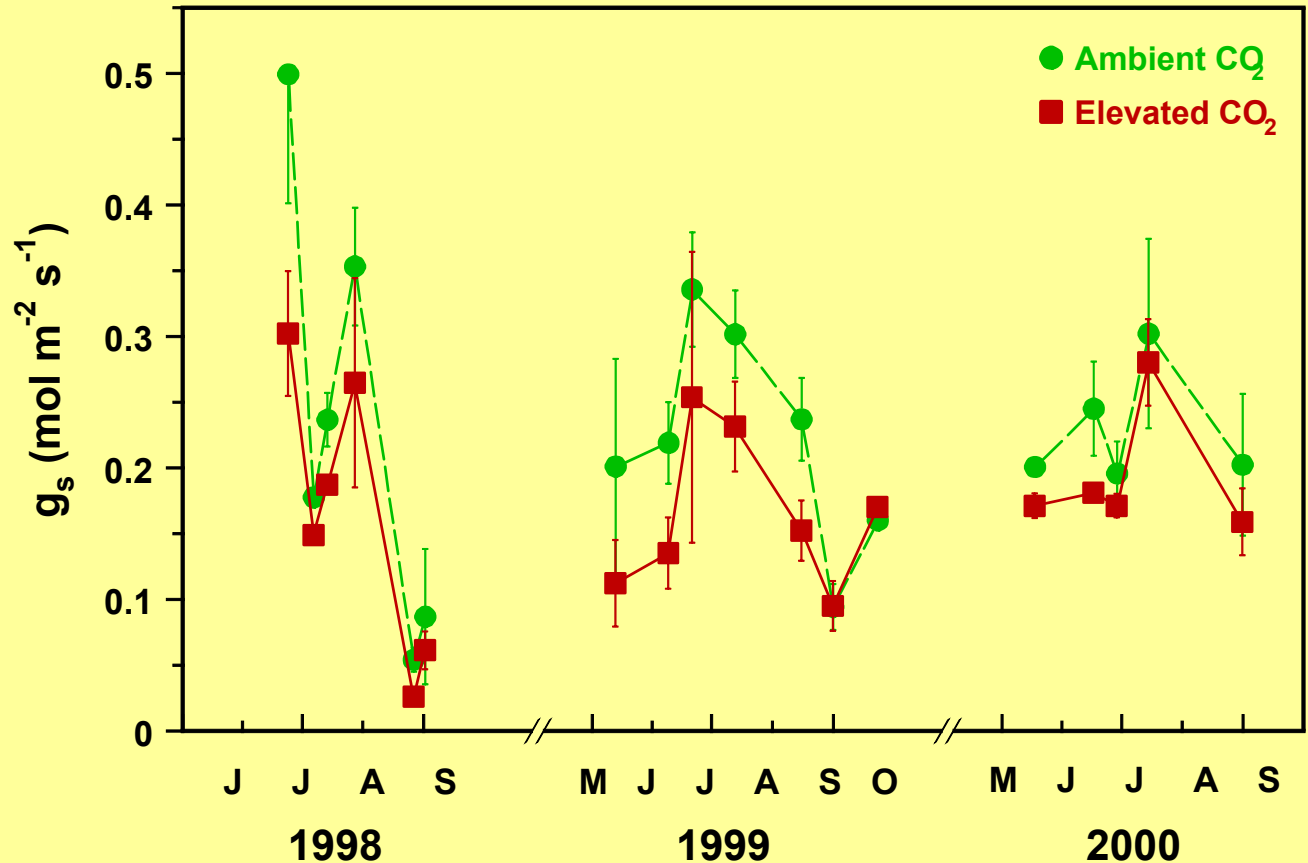
# Photosynthesis remained higher in elevated CO<sub>2</sub>

- Averaged 46% higher
- Effect persisted—no decline over time
- More variation late in season
  - Low rainfall
  - Dry air
  - High T?

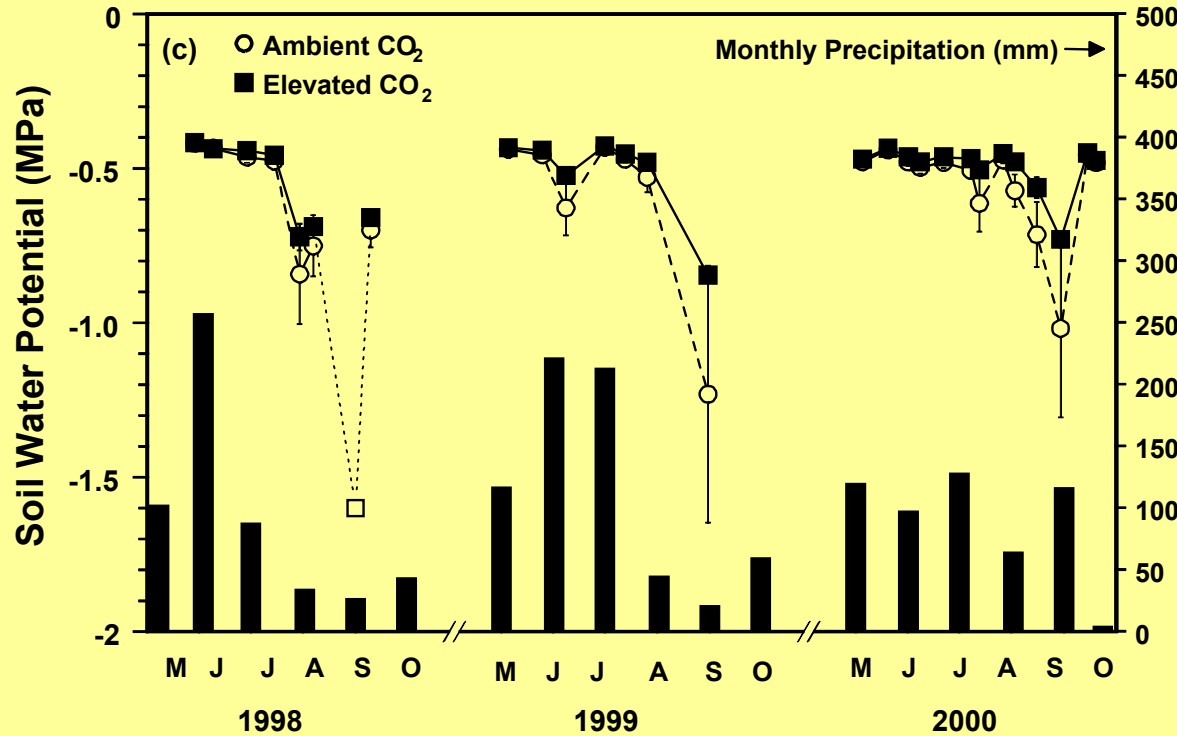
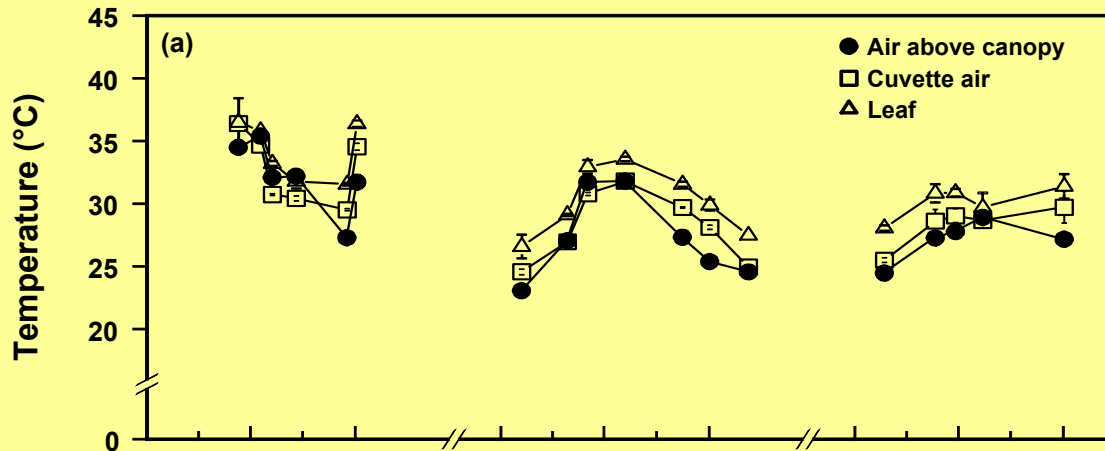


# Differences in stomatal conductance with CO<sub>2</sub> were smaller, and more variable

- Averaged 24% lower
  - often ns
- No decline over time
- Responses often muted (variable) late in season







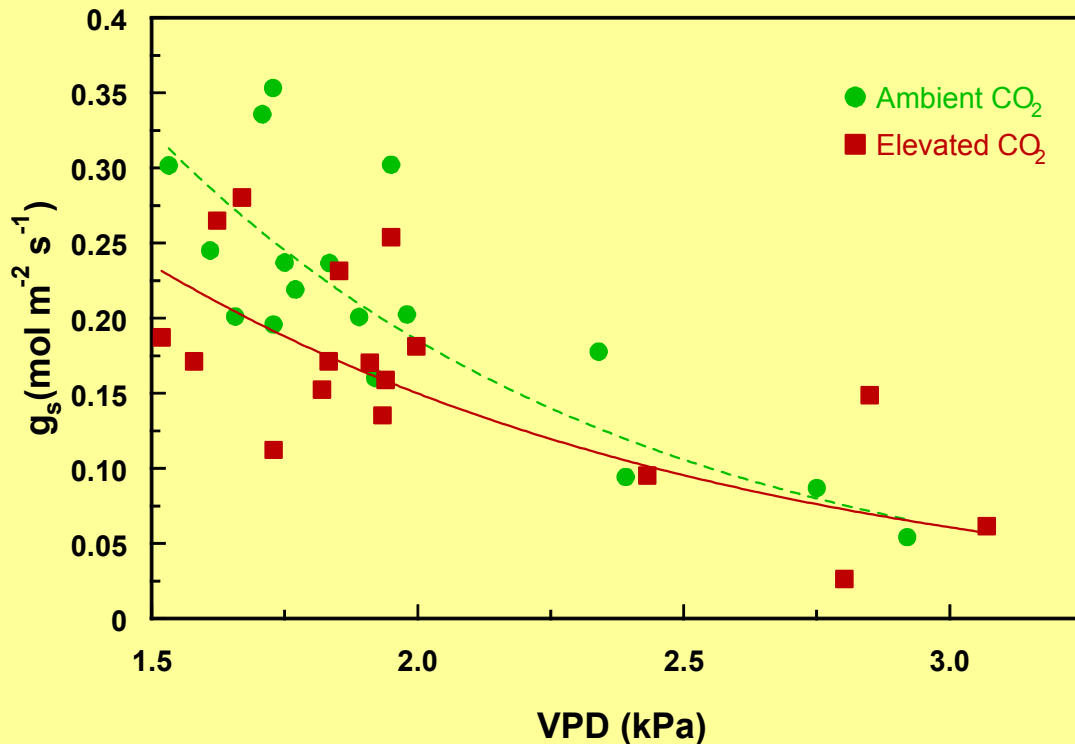
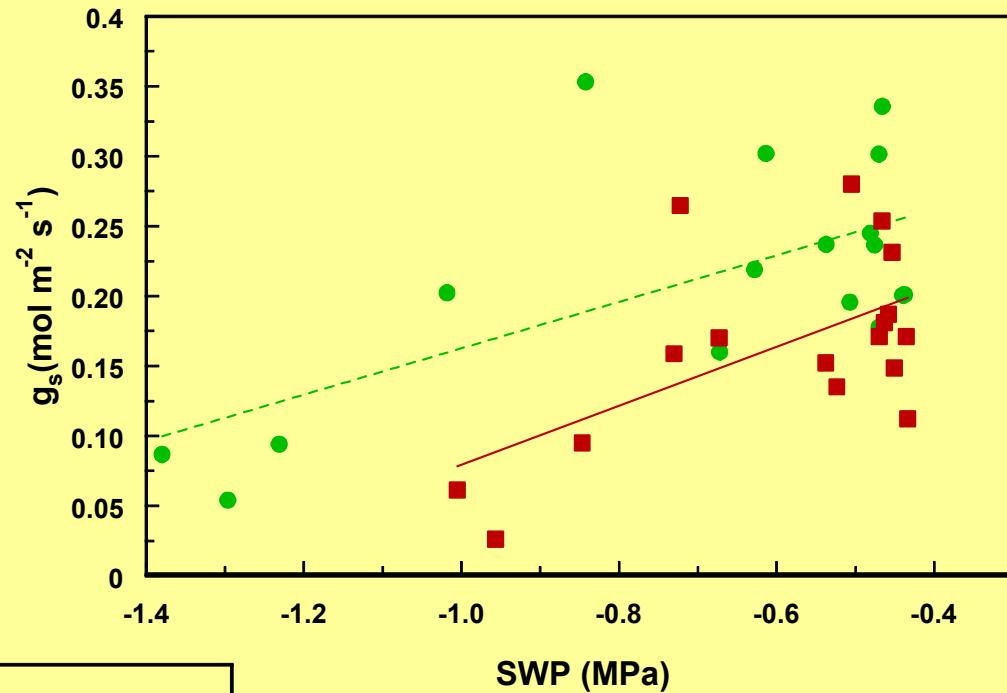
- Atmospheric conditions (temperature, VPD) varied seasonally

- Late season droughts developed in 1998 & 1999

- How did environmental variation impact CO<sub>2</sub> effects?

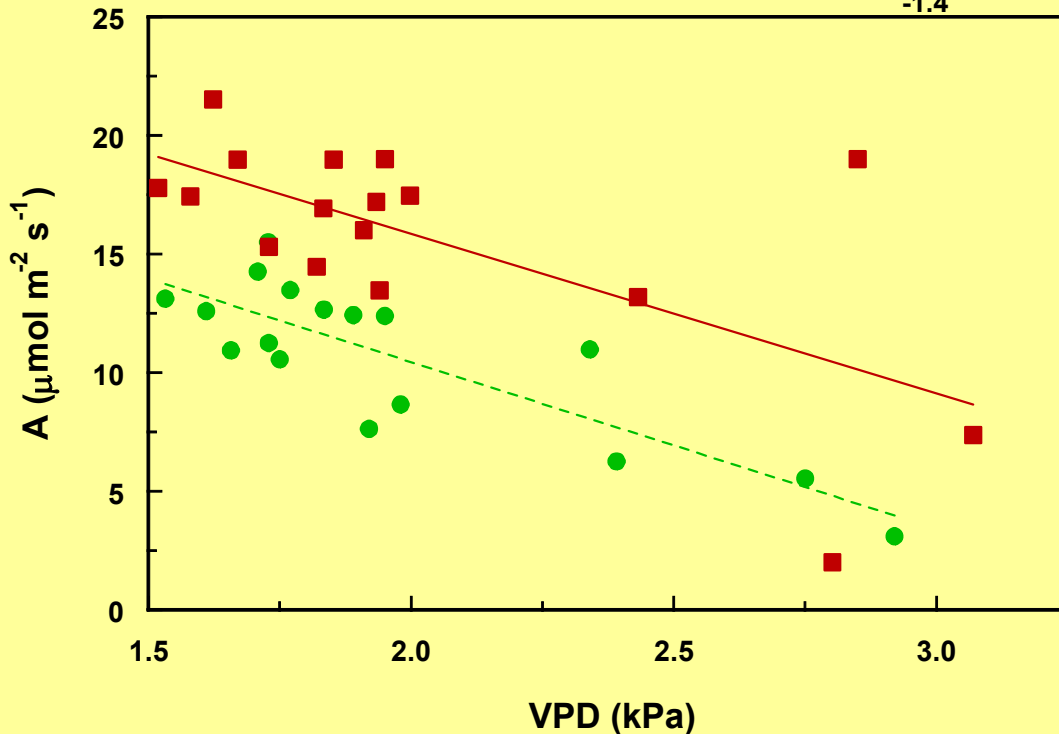
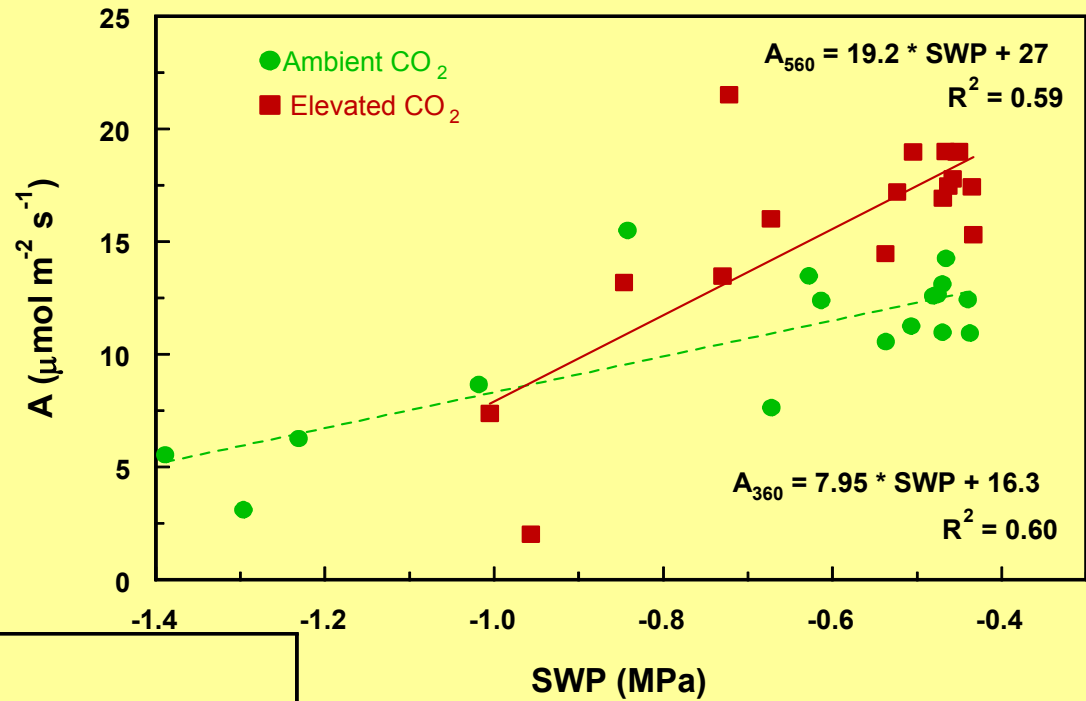


In both CO<sub>2</sub> treatments, g<sub>s</sub> decreased in response to drought and high VPD



The absolute effect of CO<sub>2</sub> on g<sub>s</sub> was larger at low VPD  
–disappeared at high VPD

In both CO<sub>2</sub> treatments, A decreased in response to drought and high VPD



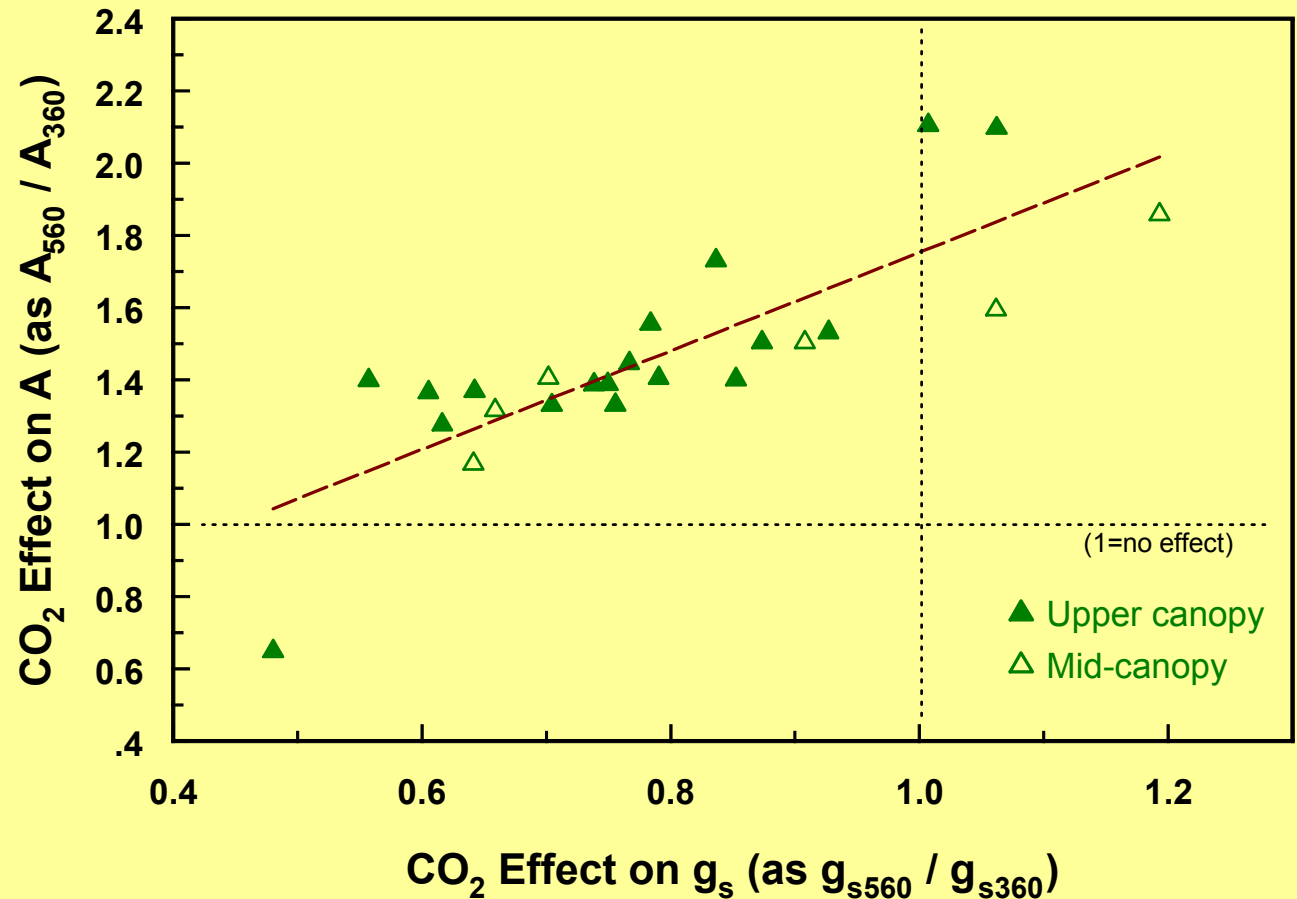
The effect of CO<sub>2</sub> on A was more variable under stress. In very dry soil there was a difference in the *absolute effect* (treatment *difference*)

# Which environmental factors were *most* important? (Multiple regression)

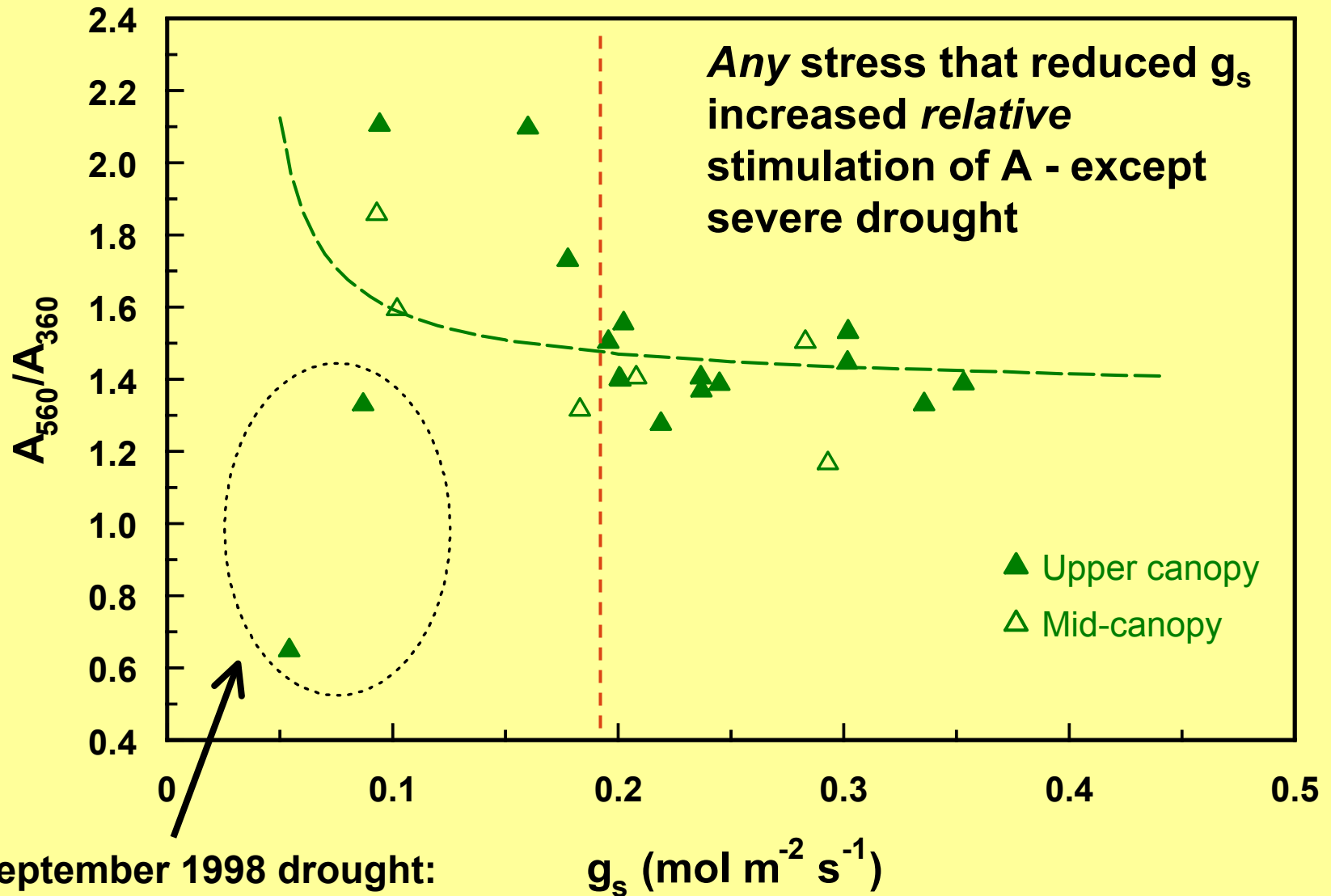
- Variation in VPD most significant
  - $g_s$  &  $A_{Amb}$  (within treatment; negative relationships)
  - Absolute CO<sub>2</sub> effects: Elevated - Ambient -- negative relationship with  $g_s$
- SWP - significant for  $A_{EL}$  and  $A_{Elevated}$   $A_{Ambient}$  (positive)
- Leaf Temperature
  - Increased  $A_{Amb}$ ,  $g_s$  (within trt) after accounting for VPD
  - No relationship with CO<sub>2</sub> effects
- **No** factors significant for *relative* CO<sub>2</sub> effects
  - (Elevated / Ambient)--- **Highly variable under stress**

# When CO<sub>2</sub> reduced stomatal conductance the most, photosynthetic enhancement was limited

- Inverse relationship between CO<sub>2</sub> effects on  $g_s$  and A (as EI/Amb)
- Similar throughout the canopy



# What influenced *relative* CO<sub>2</sub> effects on A?



September 1998 drought:  
non-stomatal limitations

# Summary--

- **CO<sub>2</sub> effects on A and g<sub>s</sub> were sustained for 3 years in a closed canopy deciduous stand**
- **Moisture stresses (high leaf:air VPD, drought) limited stomatal effects of CO<sub>2</sub>**
  - (Because stomata were already closed)
- **All stresses that closed stomata (below a threshold) tended to increase the *relative* stimulation of A, unless drought induced biochemical limitations**

# Broader Implications--

- In mesophytic ecosystems, seasonal environmental stresses may have transitory impacts on CO<sub>2</sub> effects, limiting carbon gain during the stress event, but will not impact long-term photosynthetic stimulation.
- *Absolute* CO<sub>2</sub> effects may be more pertinent than *relative* effects when scaling up to issues of stand level carbon gain or water losses