Forest Ecophysiological Responses Will Influence Regional Water Supplies due to Atmospheric Conditions in the Near Future

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Outline

1. The problem: Global atmospheric chemistry is changing

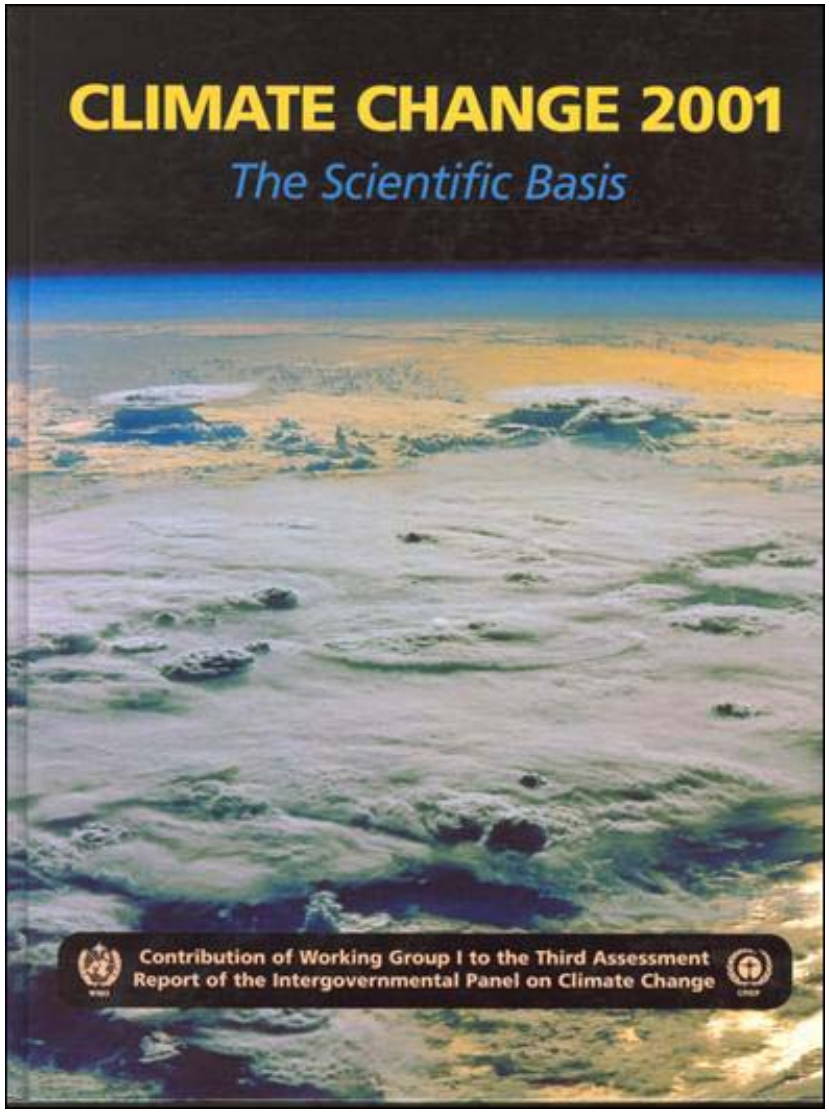
2. Tree growth and physiological responses will influence forest hydrologic cycling: Hypotheses

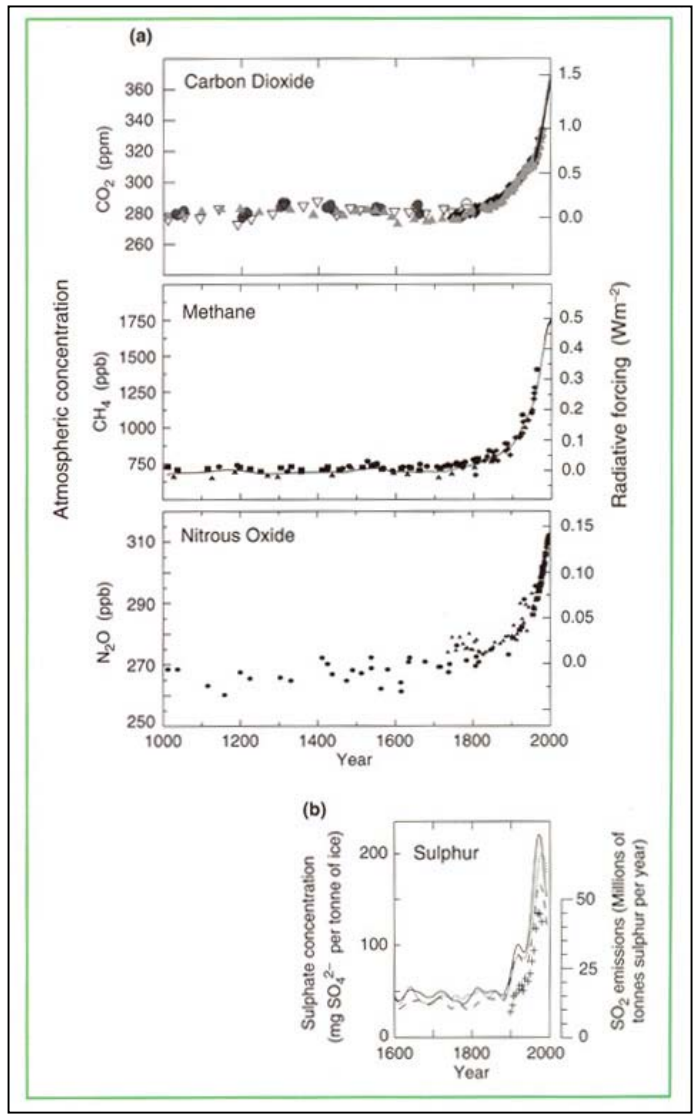
3. The Aspen FACE Water Cycling Project

4. Progress to Date

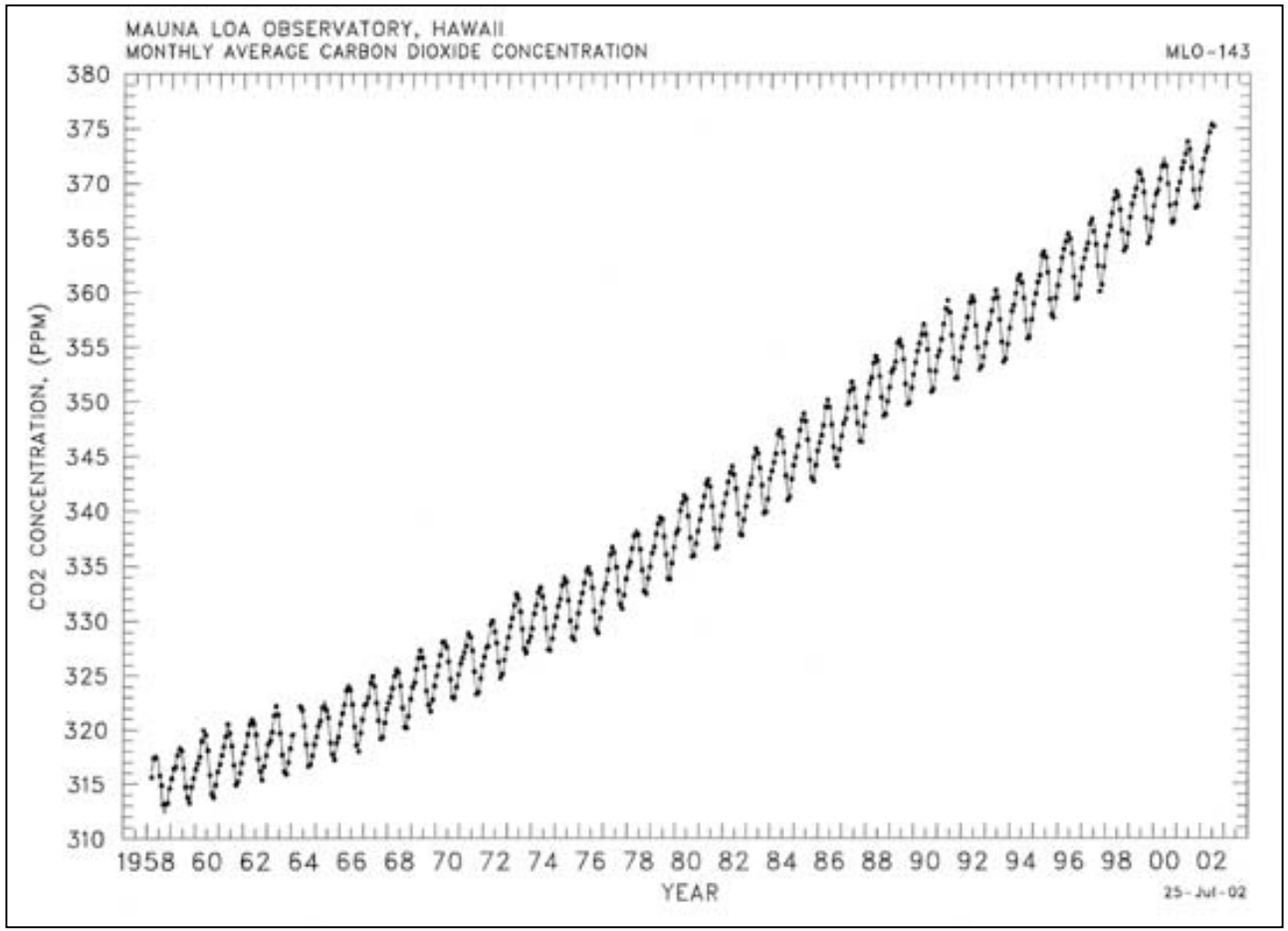
5. Impacts and Outputs

1. Global atmospheric chemistry is changing





The Keeling Curve



Courtesy of the American Institute of Physics

Tropospheric O_3 is also rising

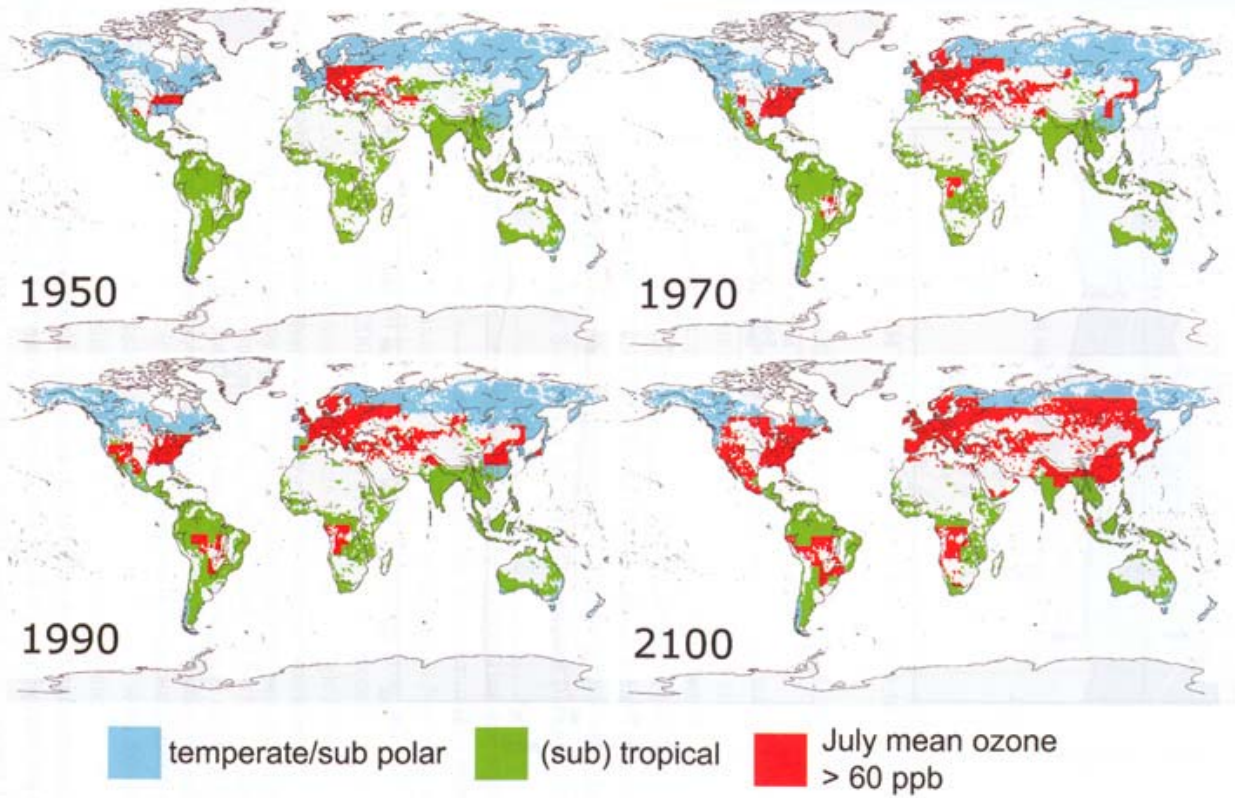
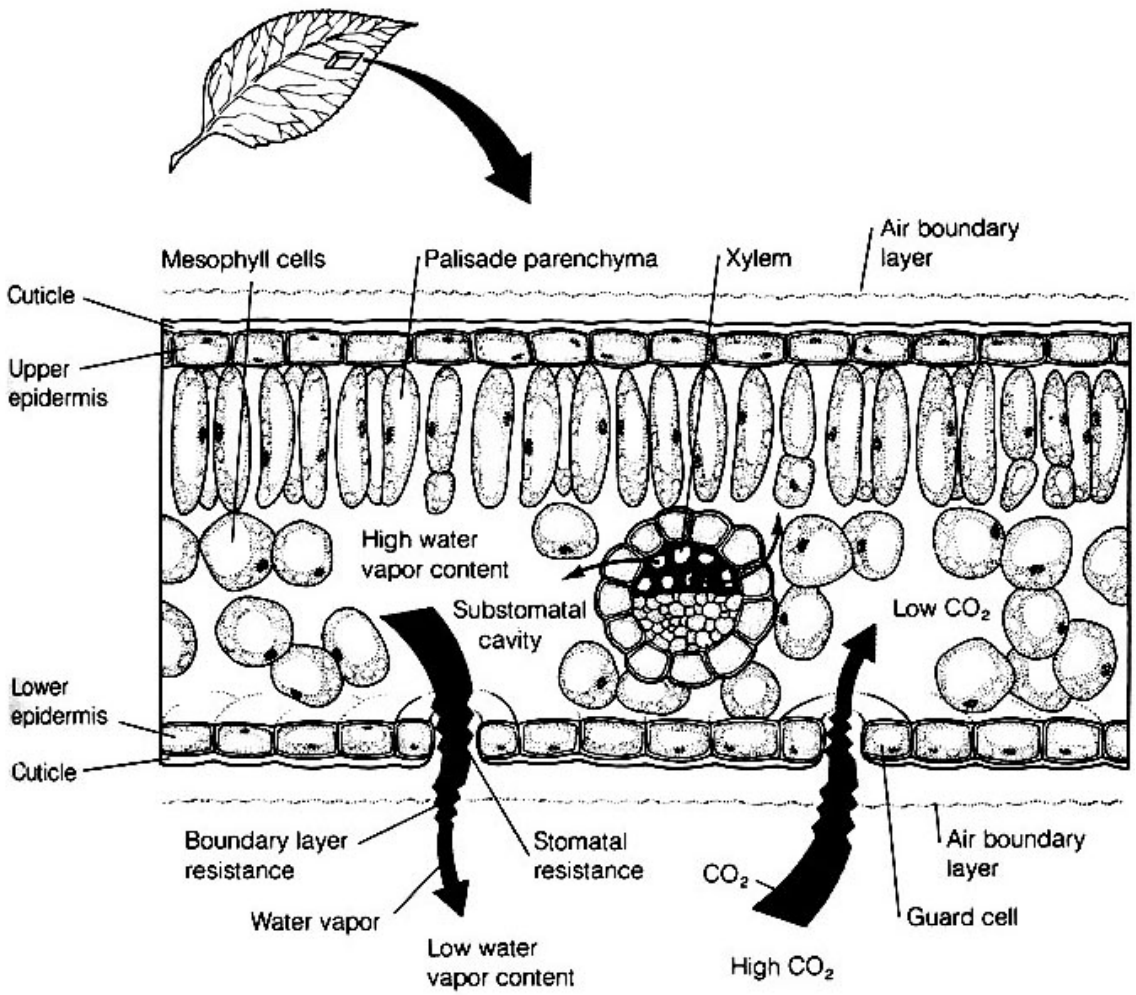


Figure 2. Global forest area where July peak surface O_3 concentration exceeds 60 ppb (from Fowler et al., 1999).

Shriner and Karnosky 2003

2. Tree growth and physiological responses will influence forest hydrologic cycling



From Taiz and Zeiger, 1991

Plant responses to elevated CO_2 and O_3

- Elevated CO_2 decreases leaf-level stomatal conductance to water vapor, but increases leaf area development

- Chronic exposure to elevated O_3 can impair stomatal function, decreasing leaf-level control over water loss. However,O_3 also decreases leaf area development

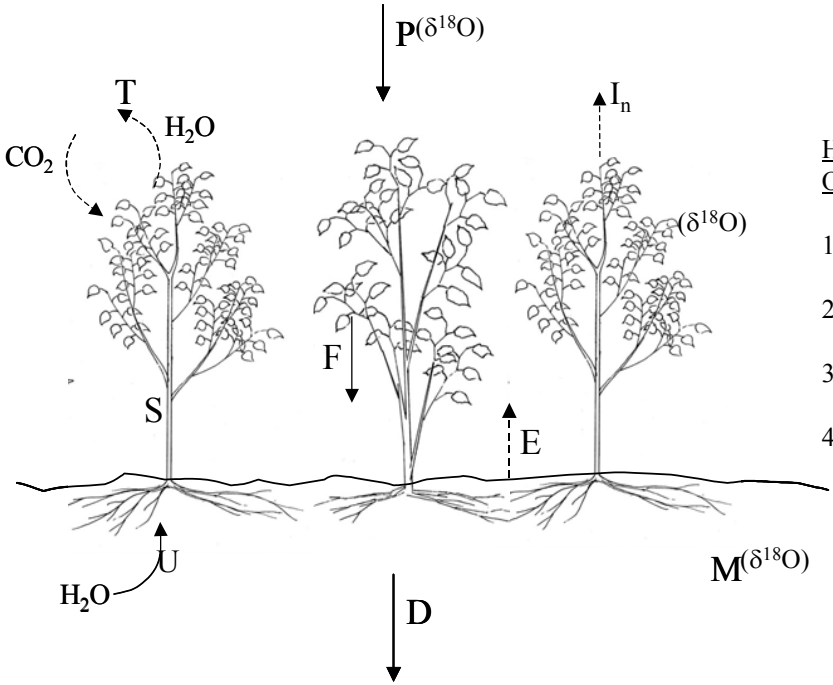
- The outcome of these two opposing drivers of canopy water loss is unknown, but when scaled to the landscape will influence regional water

- Differences in leaf area development also influence surface energy balance (albedo and shading effects)

Hypotheses

<u>Hypothesized Elevated CO_2 Responses</u>

1. ↓ g_s > ↑ LAI ⇒ ↑ M
2. ↑ roots ↑ U ⇒ ↑ resilience
3. ↑ LAI ⇒ ↓ E + ↑ I_n
4. ↑ roots ⇒ ↑ depth U



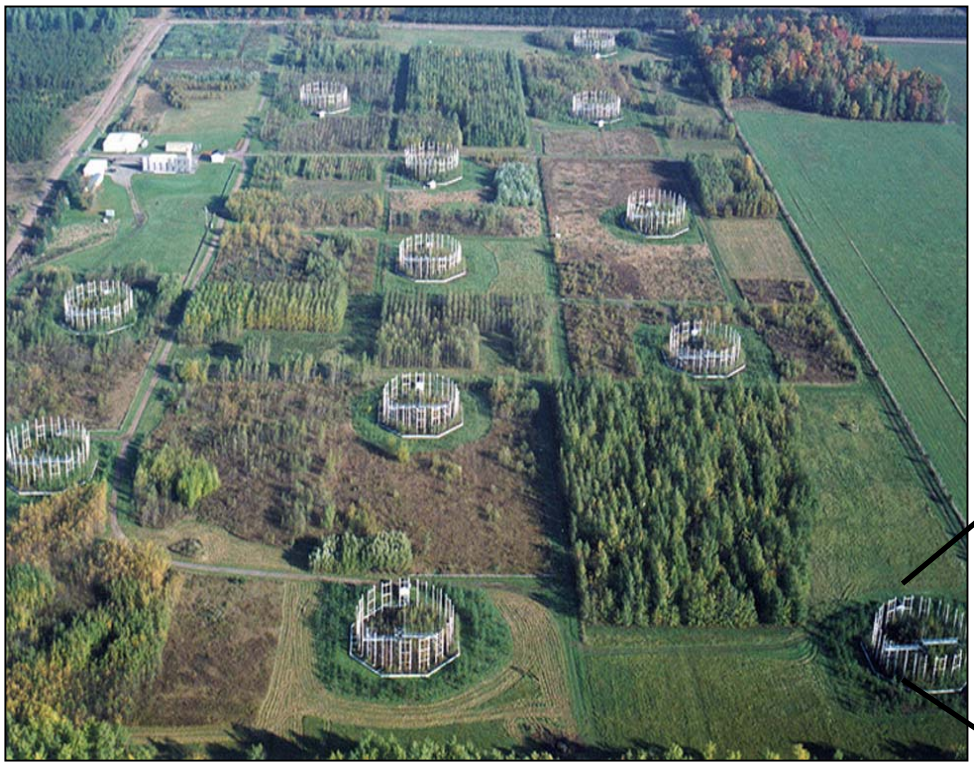
<u>Hypothesized Elevated O_3 Responses</u>

1. ↓ LAI ↓ T ⇒ ↑ M
2. ↑ g_s + ↓ roots ⇒ ↓ resilience
3. ↓ LAI ⇒ ↑ E + ↓ I_n
4. ↓ roots ⇒ ↓ depth U

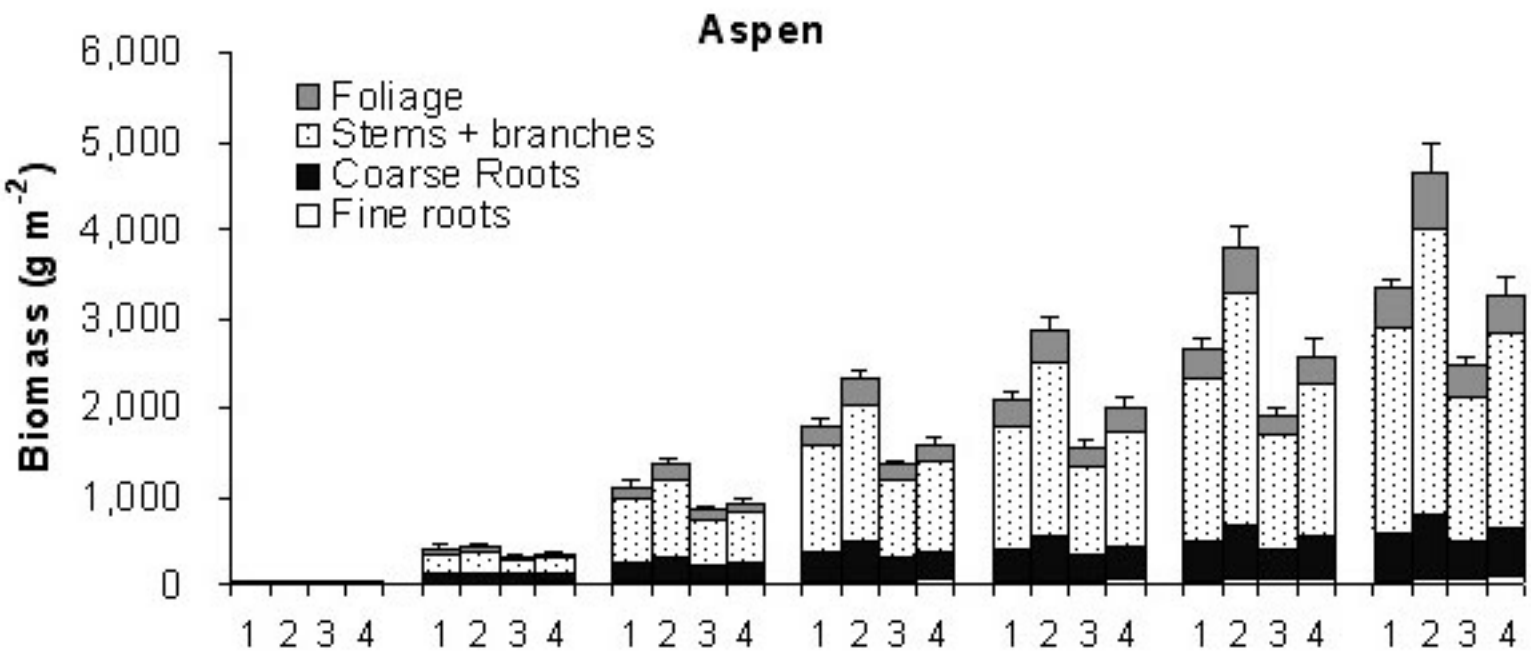
Conceptual model and hypotheses of ecosystem water balance as affected by elevated atmospheric CO_2 and O_3 at the FACTS-II Aspen FACE Project, Rhinelander, WI. The study will be conducted in aggrading forest stands and will determine how responses from the leaf/root and plant levels scale to the ecosystem to influence the overall ecosystem water balance. Hypotheses are explained below. Figure legend in alphabetical order: D – drainage, E – forest floor evaporation, g_s – stomatal conductance, F – through fall, I_n – net interception, LAI – leaf area index, M – soil water content, δ^{18}O – isotopic signature for ^{18}O, P – total precipitation, S – stem flow, T – transpiration, U – water uptake. Individual tree drawings by B. Ketchum.

3. The Aspen FACE Water Cycling Project

(www.aspenface.mtu.edu)



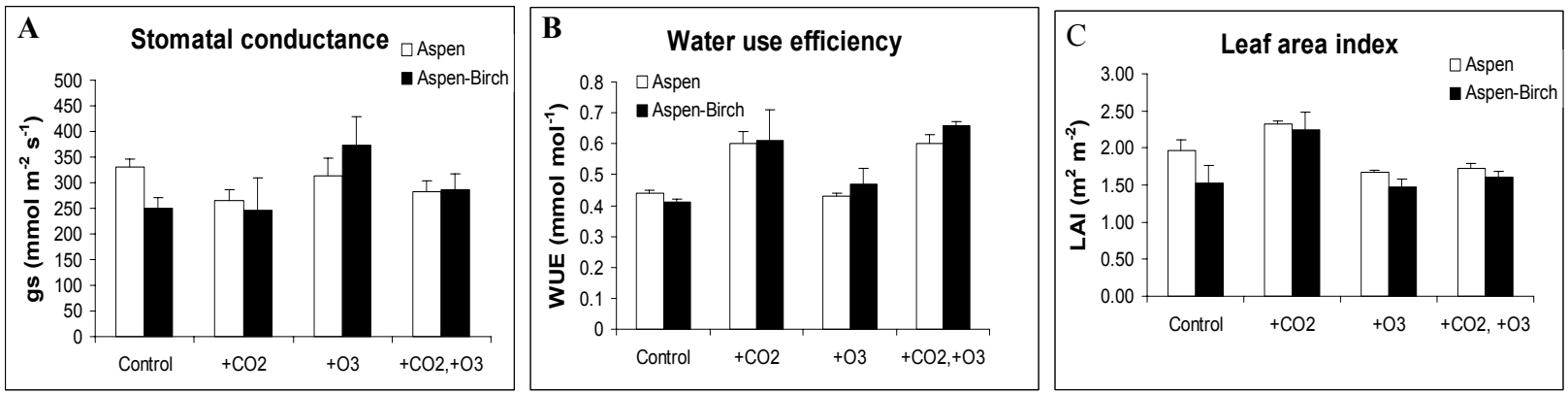
Aspen FACE Growth Response



Treatments: 1) Control, 2) +CO_2, 3) +O_3 4) +CO_2, +O_3

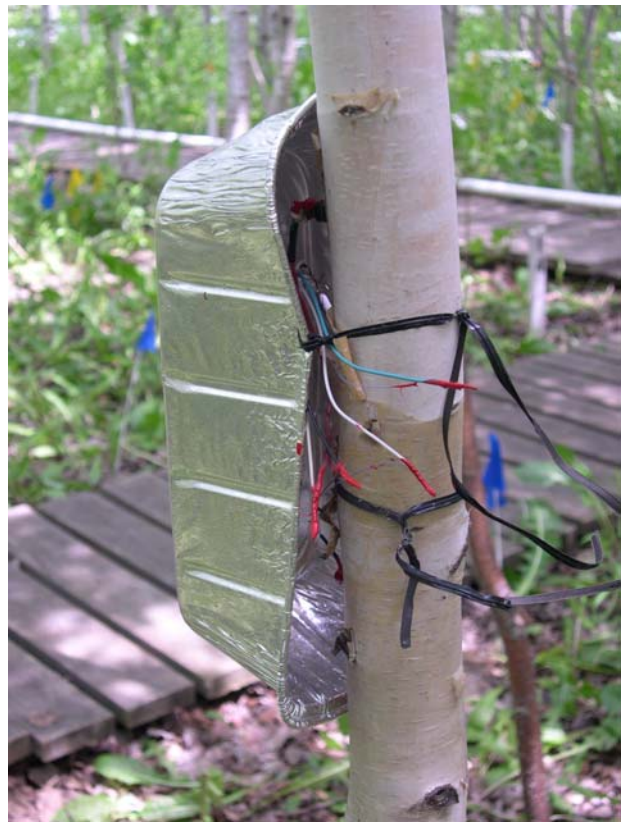
King et al. 2005

Preliminary data from Aspen FACE Project hinted that the stands altered water cycling in response to CO_2/O_3



Influences of elevated CO_2 and O_3 concentrations on stomatal conductance (A), leaf water use efficiency (B), and leaf area index (C) in aspen and aspen-birch communities at FACTS-II, The Aspen FACE Project in Rhinelander, Wisconsin. Values are means and standard errors.

Stand level water balance studies ($Pt = E + T + D + R + In + \Delta M$) combined with ecophysiology will allow us to test our hypotheses



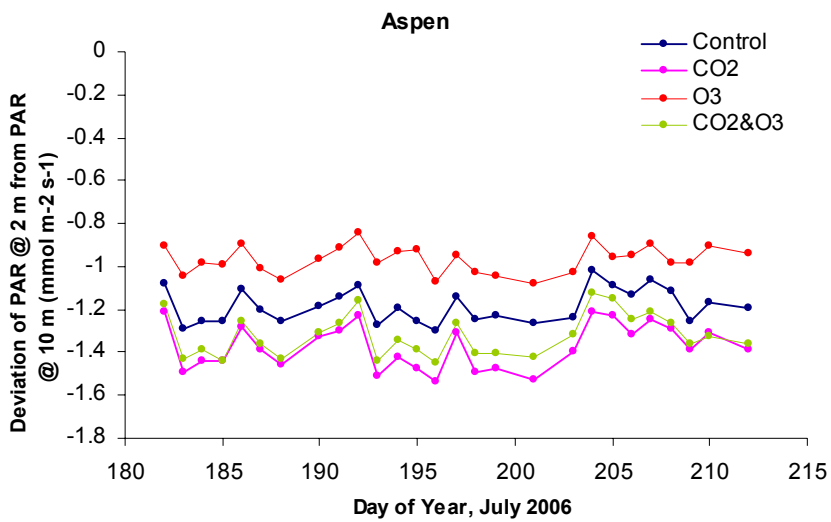
4. Progress to Date

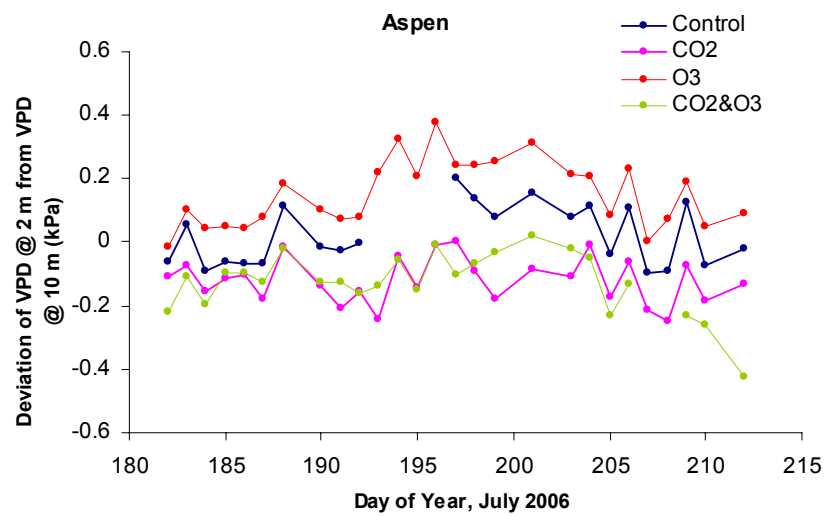
- Fall 2004/Winter 2005
  - Received award
  - Recruited post-doc (Dr. Nick Saliendra, USFS)

- Spring/Summer 2005
  - Moved from MTU to NCSU, transferred award
  - Purchased equipment
  - Recruited undergraduate summer field technicians
  - Above- and below-ground micromet installation, root harvest
  - QA/QC sensor operation

- 2005-2006
  - Shipped soil cores (frozen) from WI to NC
  - Recruited undergraduate lab technicians, processing cores for root characteristics (biomass, length, root length density, depth distribution)
  - Completed first year of logging daily micromet data (2×10^6 measurements!)
  - Continued data QA/QC and developing automated DACQ,QA/QC (in collaboration with Brookhaven National Lab, Dr. John Nagy)
  - Recruited new PhD student at NCSU (Lee Rhea)
  - Collaborate with scientists performing sap flow studies (Ellsworth, Uddling)

- 2007 and Beyond
  - Data collection, analysis, and synthesis are in early stages and will continue for next 2 years
  - We will continue to improve micromet monitoring
    - Soil surface evaporation and direct measurements of drainage
    - Replacement of faulty sensors
    - Automated data collection, QA/QC
    - Continued monitoring of sap flow, if resources allow

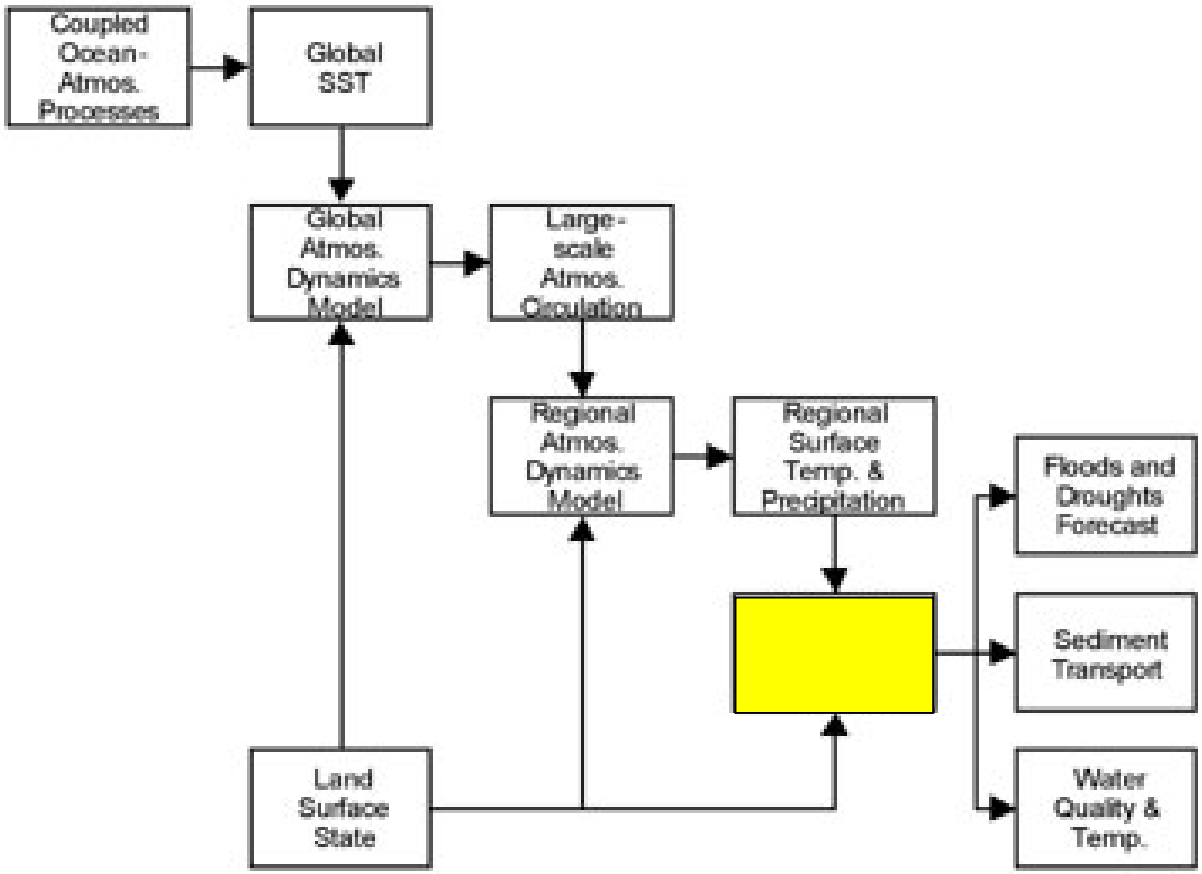




Mean difference in mid day photosynthetically active radiation (PAR) and vapor pressure deficit (VPD) above and below aspen forest canopies exposed to elevated CO_2 and tropospheric O_3 at the Aspen FACE Project (n = 3).

5. Expected Impact and Outcomes

- This project has high educational value
  - 6 undergraduate technicians, 1 PhD student, and 1 Post-Doc have been supported to date
- The water cycling project is filling a key gap in the mission of the Aspen FACE Project
  - Micro-met monitoring, plant water relations, hydrologic cycle
  - Strong leveraging of university, USDA CSREES, and USDA Forest Service resources
- The primary outputs will be disseminated in peer-reviewed publications, scientific meetings, and the world wide web, e.g.

King JS, ME Kubiske, KS Pregitzer, GR Hendrey, EP McDonald, CP Giardina, VS Quinn, DF Karnosky (2005) Tropospheric O_3 compromises net primary production in young stands of trembling aspen, paper birch and sugar maple in response to elevated atmospheric CO_2. New Phytologist 168:623-636.

Data from the proposed research will be important for validating the coupled hydrology & ecosystem models, especially with respect to incorporating effects due to the changing atmosphere in the Upper Midwest region. Adapted from *A Plan for a New Science Initiative on the Global Water Cycle*, report to the USGCRP from the Water Cycle Study Group (2001).