# The SCIENCE behind the Story

## FACE-ing a High-$CO_2$ Future

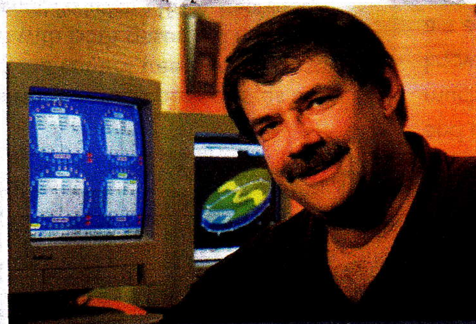
Can fumigating trees with carbon dioxide tell us what to expect from global climate change? Hundreds of scientists think so, and are testing plants' responses to atmospheric change at unique outdoor Free-Air $CO_2$ Enrichment (FACE) facilities.

Our civilization is radically altering Earth's carbon cycle by burning fossil fuels and deforesting landscapes. Today the atmosphere contains 35% more carbon dioxide ($CO_2$) than it did just two centuries ago, and the amount is rapidly increasing. Rising $CO_2$ concentrations are warming our planet, and global climate change brings many unwelcome consequences (Chapter 18).

Plants and other autotrophs remove carbon dioxide from the atmosphere to use in photosynthesis, and all organisms add $CO_2$ to the atmosphere by cellular respiration (p. 32). Will more $CO_2$ mean more plant growth, and will more plants be able to absorb and store much of the extra $CO_2$? Perhaps, but before we rely on forests and phytoplankton to save us from our own emissions, we'd better be sure they can do so.



Historically, if a researcher wanted to measure how plants respond to increased carbon dioxide, he or she would alter gas levels in a small enclosure like a lab or a greenhouse. But can we really scale up results from such small indoor experiments and trust that they will show how entire forests will behave? Many scientists thought not, and so they pioneered Free-Air $CO_2$



Aspen FACE site researcher Dr. Mark Kubiske of the U.S. Forest Service

Enrichment. In FACE experiments, ambient levels of $CO_2$ encompassing areas of forest (or other vegetation) outdoors are precisely controlled. With their large scale and open-air conditions, FACE experiments include most factors that influence a plant community in the wild, such as variation in temperature, sunlight, precipitation, herbivorous insects, disease pathogens, and competition among plants. By measuring how plants respond to changing gas compositions in such real-world conditions, we can better learn how ecosystems may change in the carbon-dioxide-soaked world that awaits us.

Dozens of organizations have sponsored FACE facilities—36 sites in 17 nations so far, including U.S. sites in Arizona, California, Illinois, Minnesota, Nevada, North Carolina, Tennessee, Wisconsin, and Wyoming. The sites cover a variety of ecosystems, from forests to grasslands to rice paddies, and the plots range in size from 1 m to 30 m (3–98 ft) in diameter.

To understand how a typical FACE study works, let's visit the Aspen FACE Experiment at the Harshaw Experimental Forest (where aspen trees are common) near Rhinelander, Wisconsin. Here, tall steel and plastic towers and pipes ring 12 circular plots of forest 30 m (98 ft) in diameter (**see photo**). The pipes release $CO_2$, bathing the plants in an atmosphere 50% richer in $CO_2$ than today's (equal to what is expected for the year 2050). Sensors monitor wind conditions, and computers control for the influence of wind by adjusting $CO_2$ releases, keeping ambient concentrations stable within each plot.

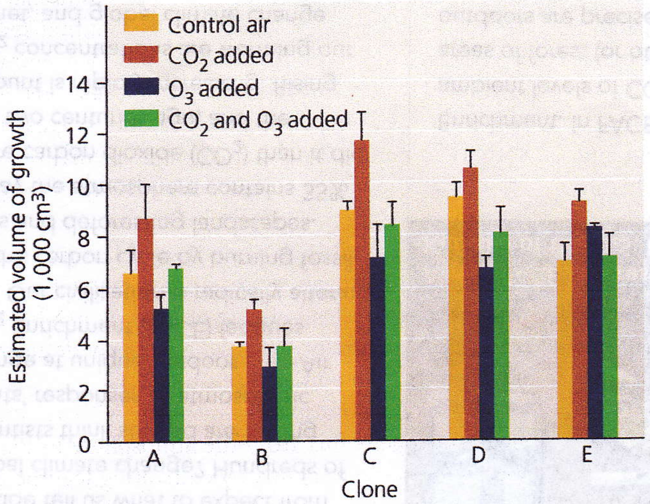
The pipes at the Aspen plots also release tropospheric ozone ($O_3$, a major pollutant in urban smog; p. 477), and researchers study how this gas and $CO_2$ affect plant growth, leaf and root conditions, soil carbon content, and much more. Pipes at some plots release normal air, serving as controls for the treatment plots.

Researchers using the Aspen FACE facility have been asking whether forest trees will sequester more carbon as $CO_2$ levels rise, whether this will change as trees grow, how $CO_2$ interacts with ozone, and how these gases affect trees' interactions with insects and diseases. They have learned a number of things so far, among these:

- Insects and diseases that attack aspen and birch trees increase as atmospheric levels of ozone and $CO_2$ rise.

At the Aspen FACE facility in Wisconsin, tall towers and pipes control the atmospheric composition around selected patches of trees.

- High $CO_2$ concentrations delay aspen leaf aging, which makes some aspens vulnerable to frost damage in winter.
- Elevated $CO_2$ levels increase photosynthesis and tree growth—but moderate levels of ozone offset this increased growth (**see graph**).




Data from five clones of aspens show that during the study period trees supplied with carbon dioxide grew more than did the control trees, while those supplied with ozone grew less. Trees supplied with both gases did not grow differently from the controls. SOURCE: *Environmental Pollution* 115 (3), Isebrands, J.G., et al, Growth responses of *Populus tremuloides* clones to interacting elevated carbon dioxide and tropospheric ozone, 359–371, Fig 2, © 2001, with permission from Elsevier. http://www.sicnedirect.com/science/journal/02697491.

Because many modelers have not taken ozone into account when estimating how much carbon trees can sequester, the Aspen FACE data suggest that their models may overestimate the amount of $CO_2$ that trees will pull out of the air.

Together, such results indicate that rising carbon dioxide levels could have a variety of negative impacts on trees and forests. Thus, the old expectation that more $CO_2$ makes for happier plants appears to be an oversimplification. Indeed, research from other FACE sites is showing that increased growth from enhanced $CO_2$ is often temporary and that growth rates later flatten out or decline. Recent work on crop plants has even shown that high $CO_2$ makes some crops less nutritious.

Obtaining solid answers to questions like these often takes years or decades, and FACE experiments are designed to monitor plots for the long term as the plants mature. Some FACE sites have been operating for 20 years and are beginning to produce data that could not be gathered in any other way.

Thus, researchers were shocked in 2008 when the U.S. Department of Energy (DOE), which funds Aspen and other major sites, announced it would cease funding. The DOE advised scientists to cut the trees down and dig up the soil to analyze carbon content. This would provide urgently needed data on carbon sequestration, the DOE said, and then millions of dollars could be shifted toward a new and improved generation of FACE experiments.

Many researchers were aghast, however, and argued that the precious and unique long-term sites still had much to teach us. How else can we know how forests and climate will interact after 25 years, or 50, they asked? Except, of course, to wait and let Earth show us—by which time it may be too late to do anything about it.