Is global warming creeping into Southwest forests?

Evidence building that warming is already affecting the region

by Melanie Lenart

How do we recognize global warming when we come face to face with it? And if we see it—perhaps in the form of millions of acres of beetle-ravaged forests, or when half the remaining red squirrel habitat goes up in flames—how do we convey that message to the public?

These questions peppered the talks at a Sedona workshop in mid-February that drew forest managers and scientists together for an exchange of views on climate variability and change. The workshop was sponsored by the University of Arizona Cooperative Extension Service, and organizers also included the UA's Climate Assessment for the Southwest and Northern Arizona University.

Climate change, a.k.a. global warming, may be stoking the flames of southwestern wildfires, and promoting "woody encroachment" of grasslands, issues that concern land managers.

Has the warming already started?
Mean annual temperature in the Southwest could rise by as much as a toasty 10 to 14 degrees Fahrenheit or more by the end of the century, pointed out Jonathan Overpeck, director of the UA's Institute for the Study of Planet Earth, citing results of a January 27 *Nature* article.

The Intergovernmental Panel on Climate Change (IPCC) has long predicted global warming would result from the input of greenhouse gases from cars and electrical production. A growing body of evidence suggests the warming already kicked in during the previous century, especially the last quarter (Figure 1).

Mean annual temperature climbed by about one degree Fahrenheit per decade in Arizona between 1970 and 2004, according to an online analysis at the National Climate Data Center website. So a warming of 10 degrees by the end of this century would be merely following the existing trend since 1970. In New Mexico, the ascent was less steep, at about 0.6 degrees per decade for the same time frame. Both rates are higher than the 0.5 degrees per decade for the United States overall for that time period.

In past reports, the IPCC predicted the warming would be greater during cool seasons. In both Arizona and New Mexico, the warming since 1970 is greatest in spring. This mirrors the national trend toward an earlier spring, which in effect means a shorter winter.

The IPCC also predicted that the poles would warm more rapidly than the planet as a whole. In fact, the warming around the North Pole is happening even faster than scientists expected, and many consider the melting ice a harbinger of things to come.

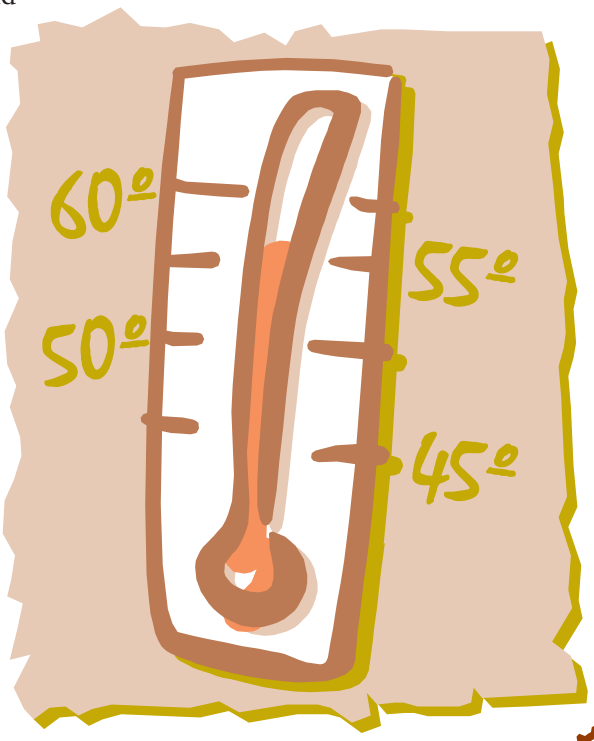
"The signal-to-noise problem that might exist in other parts of the world doesn't exist there," Overpeck told the roughly 100 workshop participants. He recalled a recent trip to the Arctic where he was awakened in his tent by the sounds of running water and chirping birds during the normally frozen spring. Sea ice has thinned by a quarter to half its original depth depending on location since submarines began measurements in the 1950s, he noted.

Such compelling evidence for global warming helped convince most of the world to support the Kyoto treaty, which went into effect last week with the support of 141 nations. The United States and Australia are the only industrialized countries that have not signed on to the pact to help slow the rate of global warming by reducing emissions of greenhouse gases like carbon dioxide.

It's somewhat more difficult to separate a long-term climate warming "signal" from the garden variety ups and downs ("noise") of natural climate variability in the mountainous western United States than in the Arctic. Temperatures drop at an average rate of about 3 degrees Fahrenheit for every 1,000-foot increase in altitude, making it more challenging to calculate averages. Too, the Southwest's semi-arid nature makes it a land of extremes, in rainfall as well as temperature.

Impacts of higher temperatures
Even so, the warming trend of recent decades appears to have spurred insect outbreaks in high-elevation southwestern forests, reported Thomas Swetnam, director of the UA Laboratory of Tree-Ring Research.

continued on page 3



Warming, continued

The variety of insects feasting on the spruce-fir forests atop Arizona's Mount Graham near Tucson included exotic maritime species that hadn't been seen in this region before, he noted. The dead trees then contributed volatile pitch and fuel to a fire last summer that burned to varying degrees about half of the spruce-fir forests there—the world's only habitat for the endangered Mount Graham red squirrel.

"The combined warmth and drought may be the real kicker here," Swetnam told the group. After also discussing recent increases in the scale of southwestern wildfires, he said, "Maybe we're at that point where we can say climate change is affecting the Southwest."

Unfortunately, high-elevation forests rarely host weather stations. One that does—the McNary station at 7,340 feet in elevation—shows a decrease since 1940 in the number of days without significant frost events, based on an analysis by U.S. Forest Service researcher Ann Lynch (Figure 2). Lynch, Swetnam and others consider these higher temperatures related to the severity of insect invasions of recent years.

Bark beetles damaged roughly four times as many acres of Arizona forests during peak outbreak years of the current drought compared to the 1950s drought. Airplane assessments tallied 1.9 million acres damaged in 2003, compared to 490,000 acres in 1957, according to data collected by U.S. Forest Service entomologist Roberta Fitzgibbons. (Another 860,000 acres were damaged in New Mexico in 2003.) The good news is the attacks on Arizona forests appear to have waned, she indicated, with a drop to 135,000 acres damaged statewide in 2004.

Meanwhile, about 18 million acres of Canadian forests were being ravaged, Swetnam noted. In addition, Canadian researchers have linked regional temperature increases to acres-burned in recent wildfires, he said, citing research reported in the September 2004 issue of *Geophysical Research Letters.*

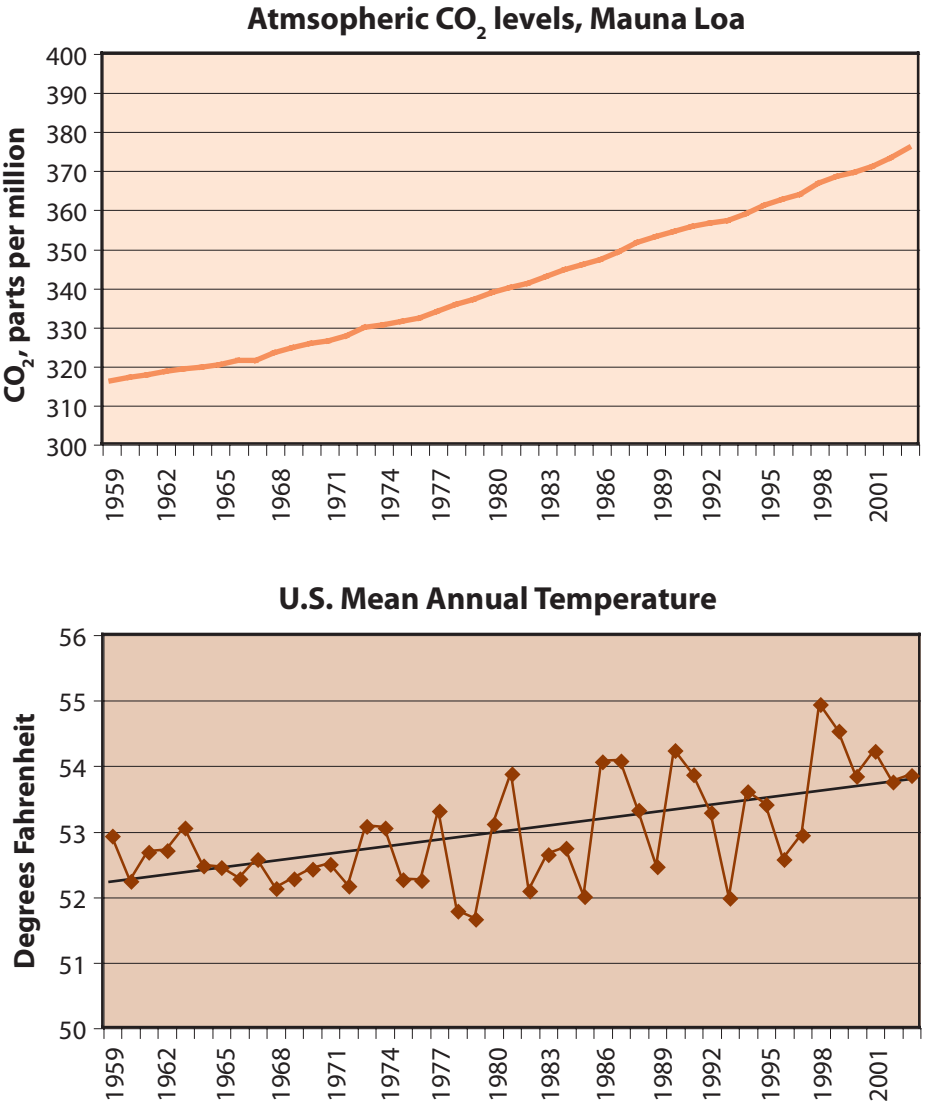


Figure 1. Carbon dioxide levels (top figure) as measured on the Hawaian island of Mauna Loa depict the ongoing rise of this greenhouse gas in the atmosphere. C.D. Keeling and his colleagues began collecting these measurements in 1958. Data for average annual temperature in the United States are also plotted for this same time period (bottom figure), with means estimated by the National Climatic Data Center based on available weather stations. As predicted, rising carbon dioxide rates are associated with rising temperatures, although other factors also are involved in the annual ups and downs. Source for carbon dioxide measurements: Keeling and Whorf data sets available at http://cdiac.esd.ornl.gov/ftp/trends/co2/maunaloa.co2. Source for U.S. temperature data set: http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html.

Western U.S. wildfires have also been on the rise as temperature climbs, although other factors come into play. For instance, the suppression of surface fires in Ponderosa pine forests promoted proliferation of seedlings and saplings, as did the harvesting of large trees. A wet period centered on the 1980s encouraged seedling and tree growth beyond what drought can support. On top of this, the carbon dioxide that enhances the Earth's natural greenhouse effect also serves as a fertilizer for trees and other plants.

As a result, many interior southwestern forests contain roughly twice the amount of biomass—i.e., the com-

continued on page 4

Warming, continued

bined dry weight of the living and dead vegetation—than would be expected given a natural fire regime, explained Ron Neilson, a U.S. Forest Service researcher based in Oregon who heads the Mapped Atmosphere-Plant-Soil System (MAPSS) project. Models he constructed with his colleagues suggest that only about one-eighth of the U.S. acreage that would naturally burn each year does so. Fire suppression thus encourages an unnatural build-up of biomass.

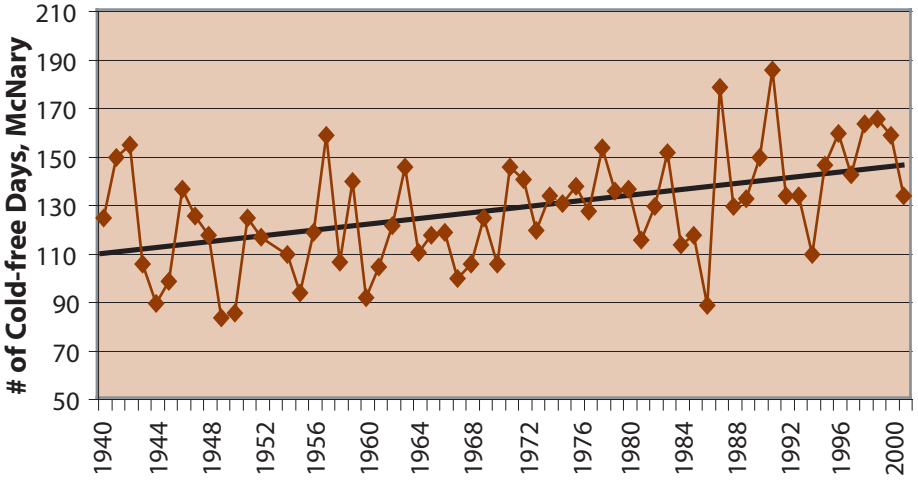


Figure 2. The length of time between frost events lasting more than a few hours in McNary, Arizona, has grown on average by roughly half a day each year, based on an analysis of daily temperatures by researcher Ann Lynch. This analysis excluded "isolated frost days," i.e., those with 10 frost-free days on either side. Source: Ann M. Lynch, research entomologist with the U.S. Department of Agriculture Forest Service Rocky Mountain Research Station in Flagstaff.

Managing dense forests

This "woodification" of forests, as some speakers called it, fuels the large-scale wildfires that have plagued the Southwest during dry years. For instance, the 2000 Cerro Grande fire around Los Alamos was the largest wildfire in New Mexico's history with about 47,000 acres burned. Two years later, the 2002 Rodeo-Chediski fire in northern Arizona's White Mountains burned about 460,000 acres, making it an order of magnitude larger than any other fire in Arizona's documented history.

Some forest managers, such as those in Arizona's White Mountains, are responding to the risk by thinning some of the smaller trees in the forests near residential communities.

"Going out there and thinning the wood is a good idea, but you're bucking the tide," Neilson told the group.

In addition to being a huge undertaking, thinning treatments are an expensive task. Few sawmills remain in the Southwest, except on tribal lands. This poses a dilemma for national and state forest managers trying to clear the smaller trees that increase fire risk yet yield little to no profit to loggers after transportation costs. As a result, the standard thinning rate for small-tree thinning treatments is $400 to $1,000 an acre.

Prescribed burning is also used by some forest managers, particularly on tribal lands, such as northern Arizona's Apache reservations, and in New Mexico's Gila National Forest. Although this technique can be more efficient than thinning when it works, air-quality restrictions and the high fuel build-ups can make this approach challenging to adopt and safely carry out in overgrown forests. The Cerro Grande fire started from a prescribed burn, for instance.

In addition to struggling to reduce fire risk near communities, land managers at the workshop worried about how global warming might impact ecological niches for various species. For example, some wonder whether the 1.9 million acres of southwestern pinyon pine devoured by beetles in 2003 will rebound into comparable pinyon-juniper stands, or be replaced by something else.

Invasive species and other colonizers

"A rapidly changing climate favors those species that can make rapid transitions," warned Kathryn Thomas of the U.S. Geological Survey's Southwest Biological Science Center. Following this logic, global warming might favor invasive species.

Thomas is just starting a five-year research project to document what's happening with invasives regionally. A survey of land managers found about half of them unsure whether "weeds" were increasing or decreasing, with the other half roughly split between the two options. More than 115 different alien invasive plants have been reported in the Southwest, and 88 of these thrive in woodlands, she said.

Ecologists and bioclimatologists agree that global warming would be expected to shuffle species around as their various habitats move north or south, or up or down a mountain. Neilson's modeling work, for example, points to large-scale expansion of woodlands at the expense of grasslands. For instance, live shrub oak and a variety of other species currently limited by frost could find their habitat had expanded up and over the Mogollon Rim.

Land managers are already reporting an ongoing "woody encroachment" of southwestern grasslands by mesquite trees and other woody plants. While woodlands expand into grasslands, grasslands could replace some southwestern deserts, according to Neilson's modeling results.

Land managers will face tough decisions about whether a plant is an invasive or

continued on page 5

Warming, continued

the rightful inhabitant of a new niche as the climate warms, Thomas and Neilson agreed.

"Do you protect the species that would be outcompeted in the Great Basin and hold that tide back? Or do you foster diversity—isn't diversity good?" Neilson asked.

Carbon dioxide fertilization

The influence of carbon dioxide on the plants themselves adds to the uncertainty about what the change will bring. The main greenhouse gas behind global warming, carbon dioxide (CO_2), is also an essential building block of plant tissue.

"There's no controversy over the fact that CO_2 levels are rising," noted Bruce Kimball, research leader at the U.S. Department of Agriculture's Maricopa facility between Phoenix and Tucson. "There would be some changes going on out there in natural ecosystems whether or not global warming was going on."

For decades, Kimball has been involved in testing how various plants respond to the increased rates of carbon dioxide in the atmosphere using an elaborate system of pipes and computers. The system maintains carbon dioxide levels in an open field at about 1½ times background levels. He and his colleagues have consistently found an increase in photosynthesis that translates into higher plant biomass.

Biomass typically increased by about 25 to 30 percent under the elevated carbon dioxide in woody species like cotton and grape, he noted, and by about 75 percent in sour orange trees.

In general, trees seem to respond better than grasses to elevated carbon dioxide rates, especially if precipitation rates increase, according to a 2004 *New Phytologist* paper Kimball recommended by Robert Novak and colleagues. This difference could be encouraging woody encroachment, although, again, other factors are involved.

Along with improving growth, elevated carbon dioxide levels improve a plant's water use efficiency. This factor could make a big difference in how the Southwest fares under climate change.

Output from Neilson's vegetation models considering potential niches for about 45 types of vegetation showed that the improvements in the water use efficiency rate as expected under rising carbon dioxide levels could dictate whether the U.S. West greens up or becomes more barren with global warming. The extent of the warming and potential changes in precipitation also would make a difference.

Immediacy in the message

Given the enormous risks at hand, one might ask why Americans, who as a nation produce a quarter of worldwide carbon dioxide emissions, won't sign on to an international effort to slow down the rate of global warming.

UA Environmental Psychology Professor Terry Daniel has a few hypotheses about why many people remain unconcerned. For instance, research indicates that in the human mind, "global" translates into "that's happening somewhere else." Meanwhile "Everybody is exposed," translates into "Nobody is exposed."

Also, scientists and society need to convey a specific course of action to take, not just report gloom and doom. It's difficult to be afraid of something abstract, and even more difficult to think about it if there's no solution in sight, he suggested.

When people understand global warming is happening in their own back yard, or affecting their favorite plant or animal or community, that's when they'll move to act, Daniel theorized. In short, if scientists want people to become concerned, they need to convince them that global warming is not a century away—it's here and now.

Melanie Lenart is a postdoctoral researcher with the Climate Assessment for the Southwest.

Resources on the Web

- The IPCC provides its reports and other background information at: http://www.ipcc.ch/index.html
- The National Climatic Data Center provides instrumental data at a variety of scales at: http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html
- To see how the current warming compares to 1,000-year temperature records reconstructed from tree rings and other archives, go to page 4 at the following link: http://www.ltrr.arizona.edu/trt/20040302.pdf
- Monthly data on atmospheric carbon dioxide measurements collected by Charles Keeling and colleagues since 1958 are available at: http://cdiac.esd.ornl.gov/ftp/trends/co2/maunaloa.co2
- For more on the Mapped Atmosphere-Plant-Soil System (MAPSS) project, see: http://www.fs.fed.us/pnw/corvallis/mdr/mapss/
- Also, a 12-page background document providing some MAPSS results is available at: http://www.fs.fed.us/pnw/pubs/science-update-6.pdf
- For more on Kathryn Thomas' invasive plant project, see the Southwest Exotic Plant Information Clearinghouse at the following website: http://www.usgs.nau.edu/SWEPIC/index.html