ECOLOGY

Is a Warmer Climate Wilting The Forests of the North?

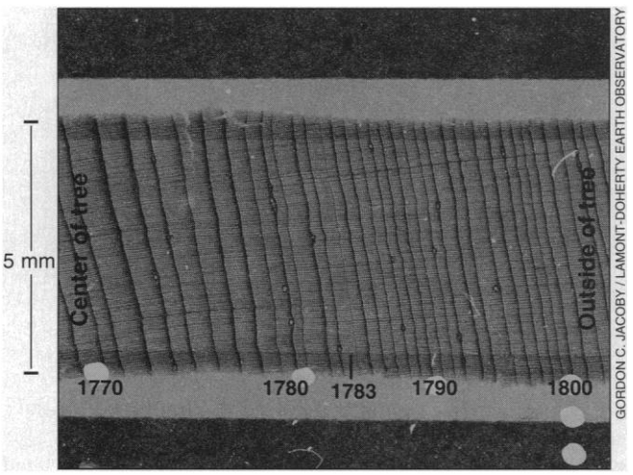
In the great belt of forests that stretches across Canada, Alaska, and Siberia, global warming seems to be well under way. Either because of increasing greenhouse gases or a natural climate fluctuation—researchers can't say which—the far-northern climate has warmed some 2 degrees Celsius since the 1880s, much more than the rest of the world. That makes the boreal forests a natural laboratory for researchers interested in how global warming can affect forests and other ecosystems. Now two of these researchers have returned from the north woods with some disturbing news.

A warmer climate might be expected to speed tree growth and drive the northern edge of the forest farther into the Arctic. But that's not what Gordon Jacoby and Rosanne D'Arrigo of the Lamont-Doherty Earth Observatory saw in a 4-year study of growth rings in trees growing near the timberline in northern and central Alaska. In a paper to be published in the journal *Global Biogeochemical Cycles*, Jacoby and D'Arrigo report that as the high latitudes warmed over the past 100 years, tree growth at first accelerated, as expected. But recently, the growth rate has flattened while the northern climate has continued to warm. As Jacoby explains, "The trees are not responding as they did in, say, the 1930s and 1940s, when it was also very warm."

Jacoby and D'Arrigo say that the most recent decades of warming, instead of encouraging exuberant growth, may be stressing these forests by speeding up moisture loss and perhaps subjecting them to more frequent insect attacks. While some ecologists had speculated about such effects, studies like Jacoby and D'Arrigo's are more convincing than any model, says climate-change researcher Gordon Bonan of the National Center for Atmospheric Research in Boulder, Colorado. "The tree-ring data are the best data out there to tell you whether or not the trees are responding to any temperature change," he says.

To collect those data, Jacoby and D'Arrigo had to charter small planes, put down in remote lakes, and travel by foot or boat to reach trees growing near the limits of their range, where they should be especially sensitive to climate change. The trees—all white spruce—are stunted by harsh conditions. Although some are as old as 500 years, they seldom reach more than 30 feet high or exceed 10 inches in diameter.

Jacoby and D'Arrigo biopsied the trees by drilling out a slender plug of wood, 5 millimeters in diameter, that transects all the annual rings. In the resulting growth record, says Jacoby, "the wider rings correspond to warmer times and the narrower rings correspond to colder, but there's not an exact year-to-year response. These evergreen trees integrate over several years." The density of the wood as revealed by a technique called x-ray densitometry provides a finer level of detail, however: "You get denser wood at the end of a ring in a warmer summer," says Jacoby.



Memories of summer. Dark latewood in a spruce's annual growth rings records summer temperatures in Alaska. A virtual absence of latewood marks the chilly summer of 1783, which followed a volcanic eruption in Iceland.

The tree-ring record confirms the high-latitude warming over the last century seen in weather station records of air temperature and in bore-hole measurements, which detect the traces of past surface temperatures that linger deep underground. Indeed, records from some of the oldest trees indicate that by the middle of this century the boreal regions were warmer than at any other time in the last 300 years. Most of the warming took place in the fall, winter, and spring rather than in the summer. According to Brian Luckman, a climate-change and tree-ring researcher at the University of Western Ontario in Canada, most forest specialists have assumed that such warming, by lengthening the growing season, should boost the growth rates of trees near their northern limits.

That's exactly what happened through the 1930s and '40s for the trees sampled by Jacoby and D'Arrigo: They put on steadily thicker growth rings. But then their growth rates stalled while other records showed that the climate was continuing to warm. The growth might have slowed, says Bonan, because the warmer temperatures allowed the trees to run into another barrier to faster growth: lack of sunlight at these far northern latitudes. "Physiological studies suggest that it's the amount of solar radiation absorbed by the leaves that's limiting growth," he says, "especially in boreal forests, because the climate tends to be very cloudy."

That limit isn't likely to be felt outside the boreal forests, at lower latitudes, but Jacoby raises another possibility that has broader implications: The trees are suffering from what's known as moisture stress. "If there's enough moisture," he says, "the warmer temperatures help these boreal trees to grow better. But if it's too warm, evapotranspiration becomes more of a factor." Evapotranspiration is the arboreal equivalent of perspiration: The trees lose moisture through their needles on warm, sunny days. If there's not enough rain or soil moisture to compensate, photosynthesis and hence tree growth will slow. In a sign that moisture stress may indeed have become a limiting factor for tree growth, Jacoby and D'Arrigo's analysis showed that beginning in about 1970, the trees became markedly more sensitive to rainfall variations.

Perhaps the most worrisome possibility they raise is that climate warming in Alaska may be allowing populations of pests to burgeon. Since the 1970s, some southern Alaskan forests have suffered from what Jacoby calls "severe outbreaks" of bark beetles, which have devastated several million acres of forest. Entomologists have pointed out that warmer temperatures can shorten the reproductive cycle of the bark beetle from 2 years to one. "If you halve the time needed for the reproductive cycle," says Jacoby, "you can have a dramatic population increase." He and D'Arrigo aren't prepared to claim the beetle infestations are a direct effect of global warming, but "certainly the insect survival benefits from warmer temperatures. As far as nailing down cause and effect, people are studying that right now."

Meanwhile, the study has reminded ecologists how hard it is to predict the response of an ecosystem as complex as a forest to a warmer world. Says Bonan, "The results [of the Lamont-Doherty work] are really just showing what the unproven assumptions were in our ecological models to begin with."

–Gary Taubes