Science FINDINGS

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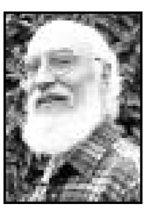

RONALD P. NEILSON is a bioclimatologist and team leader of the Mapped Atmosphere Plant Soil System (MAPSS) vegetation modeling team in the Managing Disturbance Regimes Program of the PNW Research Station, USDAForest Service. He received his B.S., M.S., and Ph.D. degrees in biology with increasing emphasis on plant ecology and biogeography. His published dissertation work resulted in the 1987 W.S. Cooper Award from the Ecological Society of America for excellence in physiographic ecology. In 1999, he received the Forest Service Chief's Honor Award for Superior Science for his contributions to climate change science and assessments. For the past 25 years his research has focused on understanding and simulating the mechanisms of vegetation distribution and function.

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Science
F I N D I N G S

INSIDE

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"Science affects the way we think together."
Lewis Thomas

IS CARBON STORAGE ENOUGH? CAN PLANTS ADAPT? NEW QUESTIONS IN CLIMATE CHANGE RESEARCH

Rhone glacier in the Bernese Oberland, Switzerland. The 1859 etching shows the glacier's ice filling the valley right to the tiny crossroads of Gletch.

Photo: Gary Braasch ©

In 2001 the glacier was nearly out of sight.

"Are human activities leading to a world with impoverished natural endowments, even deeper inequities among peoples, and the ultimate collapse of civil society? Or is that too easy a conclusion?"

Gunderson and Holling, "Panarchy," 2002

In the highly modeled world of global climate change, probably the most recurring adjective is complicated. An understatement, surely, when you're talking about capturing change for endless interacting variables across the entire planet.

Most people are past the point of arguing about whether human activities are speeding up global warming: a dozen varieties of colored graphs in dozens of different publications can show the dramatic upward swing of average temperatures, starting not too long after the Industrial Revolution. Overlay it with carbon dioxide concentrations. Overlay that with carbon emissions. Same story: big jump.

We're doing it; we're speeding up global warming. But what do we do about it?

One approach recognized internationally is the estimating of carbon budgets, along with evaluation of their changing status through time. Carbon is stored in the biosphere chiefly as live and dead vegetation. Land management activities such as clearing and burning forest and replacing it with an annual crop, release carbon stored in the vegetation and soil. This carbon proceeds into the atmosphere in the form of carbon dioxide, a known contributor to global climate change. The challenge for sustainable land management is to balance this off-take from the surface with replenishment of the soil's carbon.

IN SUMMARY

As it becomes increasingly apparent that human activities are partly responsible for global warming, the focus of climate change research is shifting from the churning out of assessments to the pursuit of science that can test the robustness of existing models. The questions now being addressed are becoming more challenging: Can water-use efficiency of plants keep up with rising temperatures? Will we see a greening period for some decades, even a century, before facing a rapid browndown as threshold temperatures are reached? Or could the thresholds be reached much sooner because of interactions of biophysical processes? Is the carbon storage issue missing the point?

The ongoing development of climate change models includes delving into the dynamic processes that interact to affect world climate, vegetation, and ocean conditions. As the computing power to reflect the complexity of these interactions increases, is it possible to improve our ability to look wisely to future scenarios, and manage our resources flexibly in response?

Well, that's complicated. The challenge is that the more we know, the more we see we need to know. But the questions are getting much better, the places we need to focus are becoming clearer, the bigger issues are sorting themselves out.

"Where are the threshold temperatures for carbon buildup or blowoff? How do we properly allow for the effects of such huge variables as the Pacific decadal oscillation (PDO) on temperatures? Will water-use efficiency of plants improve under gradual stress? How do physiological processes and their interactions affect our scenarios? That's where it gets really complicated," says Ron Neilson. He addresses these kinds of questions on a daily basis, and pushes hard on the ability of climate and vegetation change models to come up with reasonably viable answers.

Neilson, a bioclimatologist with the Pacific Northwest Research Station in Corvallis, Oregon, has long been buffeted by the political maelstrom that climate change research creates in its wake. He helped create the dynamic vegetation change models—which rely on dynamic climate models that incorporate such processes as ocean circulation. The simulated time-dependent changes in vegetation at first showed some pictures that were significantly less alarming than pictures from the older, more static equilibrium models.

"The dynamic models set a cat among the pigeons at first: were we saying the earth was going to green up after all, and was that going to be grabbed as a reason to say we have nothing to worry about?" he recalls. "But ultimately the clamor led me to consider whether all the different models we were looking at from labs around the world did not in themselves constitute a grand experiment. And if so, what were the trends and patterns that might be sending us a signal?"

KEY FINDINGS

- Model results across seven scenarios suggest that for each Centigrade degree of future warming, 11 percent of the United States could become drought stressed; each degree of warming places 17 percent of forestland under drought stress.
- With 3 to 4 degrees Centigrade of warming, about half of U.S. forests could be in some level of drought stress and losing carbon to the atmosphere. This appears to be the threshold temperature below which the biosphere could be a sink for carbon and help slow warming, but above which it could become a source of atmospheric CO_2 and help accelerate warming.
- Under the warmer scenarios examined, the southeast U.S. forests become increasingly dry, and very large fires could occur. Pacific Northwest forests could follow a similar trajectory, but may not be as sensitive to warming partly because of increased precipitation as well as a possible increase in water-use efficiency owing to elevated CO_2 levels.
- Early storage of carbon could lead to management complacency about carbon budgets, but with increased warming, forests could undergo a rapid turnaround from carbon storage to drought-induced carbon releases, particularly by fire.

THE GREEN UP-BROWN DOWN HYPOTHESIS

Up until 1998, he recalls, all the modeled scenarios were coming up with outcomes that were fairly stark, based on the nondynamic models in use at the time. When dynamic models suggested literally greener responses, Neilson's greatest fear was that politicians would either say we know nothing after all, or that all's well.

"I did everything possible in communicating my findings to keep the uncertainties open. I said 'don't throw away what we thought previously, don't stick with one or two good or bad scenarios, just keep investigating.'"

What Neilson and his team came up with as a result of that investigation—reviewing seven different climate change scenarios from two different models—was an idea right out of the good news-bad news book. Generally, for a while things could look fairly good, and the trend would be toward greening of much of the planet. The explanation for this is quite simple, Neilson says: a moderate warming trend would accelerate the hydrologic cycle. In other words, lots of places would get more rain, and things would grow faster and better with the combination of more rain and warmer weather, plus some direct benefit from elevated carbon dioxide (CO_2) concentration.

"But at a certain threshold, and it looks to be about 3 to 4 degrees Centigrade, global warming will likely accelerate, and the initial benefits could be wiped out by drought-induced stress," he says. At this threshold point, about half of U.S. forests could be in some level of stress and losing carbon to the atmosphere, but the remaining forests could still be growing better and storing carbon.

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To provide scientific information to people who make and influence decisions about managing land.

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fires potentially causing rapid vegetation conversions from forest to savanna.

In the Pacific Northwest, forests are quite sensitive to climate variations because warm dry summers already stress them directly, limiting seedling establishment and summer photosynthesis, and create conditions favorable to pests and fire. No clear picture exists of the most likely future of our forests, but Neilson believes they are very likely to depend on complicated interactions between the timing and amount of precipitation, the seasonal water-storage capacity of forest soils, and changes in trees' water-use efficiency under elevated CO_2.

"It looks like these factors will jointly determine the consequences of the likely increase in summer moisture stress, which will also depend on interactions with forest management practices, land use conversions, and other pressures from development," Neilson says.

Complicated.

PLANNING ON UNCERTAINTY

So back to the question of what we do about climate change.

Given the uncertainty surrounding future scenarios—so amply demonstrated by the range of results from different temperature levels and models—Neilson thinks managers would be well advised to develop contingency plans for alternative futures, plans that are built on flexibility rather than adherence to single outcomes. These plans must incorporate increased vegetation growth, or increased vegetation stress, with specific regional patterns and timing or both. Monitoring could be configured to identify these alternative conditions as they occur: a compelling argument for adaptive management.

Neilson sees that the last decade or so has been dedicated to doing assessments, masses of them, tomes full of them, and the time has come for scientists to hunker down and do more of the research that fine tunes and brings the models incrementally closer to reliably complex projections. Models already on the workbench will be capable of tracking such factors as the change in dominant species over time and their movement across landscapes. Inevitably, new models will more closely be coupled to processes such as disturbance and their ongoing interactions.

"A better understanding of interactions among fire, windstorms, and biological disturbances such as insect and disease would improve our long-range predictions about forest succession and ecosystem dynamics, and would lead to better prediction of the conditions under which one event would predict the response to a subsequent one," he says. Research also needs to be focused on interactions between known oscillations in weather patterns and other ocean-atmosphere general circulation patterns.

The Kyoto Protocol, as it stands, is unlikely to take care of the problems generated by rising CO_2 emissions, Neilson says. What it can do is bring people to the table to look more realistically at the possible futures we face. The decisions we make on global warming policy in the next decade, he and many of his colleagues believe, may be the most crucial to the future of the planet.

"And then of course there's the elephant in the room that no one wants to talk about," he adds. "No one will lay the population graph over the top of the CO_2 emissions graph, or the temperature rise graph, to see the absolute and direct relationship."

Complicated, indeed.

FOR FURTHER READING

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STATION LAUNCHES NEW PUBLICATION

Science Update, a 12-page color publication, offers scientific knowledge for pressing decisions about controversial natural resource and environmental issues. The first issue, published in May 2002, can be found online at the PNW Research Station Website at **www.fs.fed.us/pnw**.

Under a moderate warming scenario, the temperature threshold is not reached until after the 21st century, and most U.S. ecosystems see increased growth and carbon storage. However, a warmer scenario shows temperatures exceeding the threshold level much sooner, and about 80 percent of current forest area goes into drought stress and sheds carbon, producing a net carbon loss from ecosystems within the United States.

The hypothesis seems to be holding up, and its implications are appearing in various modeled scenarios from labs around the world and in the literature, Neilson says. But it's not the final answer. Nothing is.

"Whether or not the world's vegetation experiences large drought-induced declines or if large vegetation expansion in early stages could be determined by the degree to which elevated CO_2 will actually benefit vegetation, are issues still under debate," Neilson explains. Some lab-based studies suggest that increased levels of CO_2 in the atmosphere will force plants to become more efficient in their water use, thereby somewhat offsetting early effects of drought stress. Larger-scale studies have so far produced less certain results.

LAND MANAGEMENT IMPLICATIONS

- It may be difficult to separate carbon storage owing to management from storage owing to climate change.
- With biomass and fuels expected to increase in the West, managers will be challenged to balance carbon storage options with fuels reduction needs.
- Finding trees genetically matched for optimal growth in their environments could be challenging: growing well in today's climate may not equate to growing well in warmer future climates.
- Increased risk of wildfire could further strain the fire fighting and response infrastructure of management agencies. Smoke pollution problems will likely increase dramatically. It may be necessary to develop maximally flexible management approaches that can adjust as monitoring tracks changes.

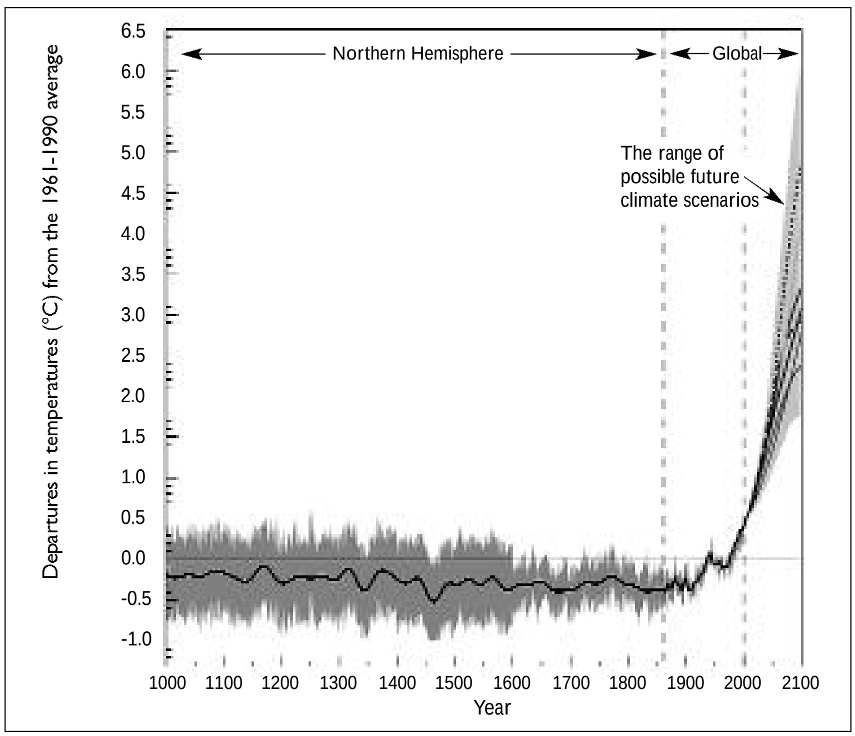
DEALING WITH OSCILLATIONS

To add to the complications, Neilson says, there may occur oscillations, perhaps on long timescales, between greener and drier phases, owing to different responses among the ocean, atmosphere, and biosphere. Such oscillations would no doubt impart further reverberations to the Earth system he and his colleagues are trying to understand.

We're starting to hear more about the Pacific decadal oscillation or PDO, for example. What the heck is that?

"It's what throws a monkey wrench in all the findings," says Neilson.

The PDO is a recently-discovered pattern of climate variation that changes phase every few decades and particularly affects weather patterns in the Pacific Northwest, Alaska, and Pacific Islands. In the first half of the 20th century, a warming trend moved across the northern hemisphere in particular, but from 1940 through the early 1970s there was a marked cooling trend. Then the switch back: since the early 1970s, temperatures have been steadily increasing again, in what Neilson describes as a planetary signal.



The range of possible future increases in temperature over the next 100 years (climate models) is shown in contrast to the range of temperature variations in the Northern Hemisphere over the past 1,000 years (direct observations and tree rings).

WRITER'S PROFILE

Sally Duncan is a science communications planner and writer specializing in forest resource issues. She lives in Corvallis, Oregon.

Along with the El Niño and southern oscillation, the PDO shows clear correlations with regional climate variations.

Specifically, warm years tend to be relatively dry with low streamflow and light snowpack, whereas cool years tend to be relatively wet with high streamflow and heavy snowpack. "The differences in temperature and precipitation are small, yet they have clearly discernible effects on important regional resources, such as water, salmon, and forests under threat of fire," Neilson explains. "The observed effects of these patterns provide powerful illustrations of regional sensitivities to climate, but how they might interact with future climate change is not yet understood."

In other words, how will the PDO behave under warming scenarios? Will it turn out to be a stronger global force, and override the temperature increases, thus damping down potential effects of global warming? Or will other interactions tend to negate the effects of the PDO, or send it onto a different trajectory?

Complicated. About as complicated as the whole carbon story.

CARBON: TO SEQUESTER OR TO LOSE?

"The Kyoto Protocol [treaty that requires nations to reduce the greenhouse-gas emissions believed to be responsible for global warming] has focused the attention of the public and policymakers on the Earth's carbon budget," Neilson notes. "It has fostered a continuing search for more accurate measurement of global sources and sinks of carbon, which could be used to mitigate effects of climate change."

The reason the issue is so dominant at present, he believes, is because various proposed global agreements could allow some level of carbon sequestration, or storage in the earth's soil and ecosystems, to offset CO_2 emissions, which are largely created by burning fossil fuels.

The problem is, it is not a simple matter of addition and subtraction. First issue: natural variations can produce measurable gains and losses in the carbon budget in some parts of the world. Should those gains be counted?

Second issue: the climate can influence the carbon budget not only directly by affecting the rates at which carbon is stored or used, but also indirectly by affecting both the disturbance regime and the vegetation type.

"Even when the national average indicates an overall carbon gain under conservative climate change scenarios, regional droughts and fires can still cause significant distress to local ecological and economic systems," Neilson says. "The location and extent of these regional stress areas is important for land managers interested in sustainability issues."

He also points out that the results suggesting early storage of carbon could lead to management complacency about carbon budgets. However, with increased warming, forests could undergo a very rapid turnaround from carbon storage to drought-induced carbon releases.

To put the carbon budget-disturbance regime relation in a more sinister way: the results of simulations so far suggest that the Western United States could store a great deal of carbon in growing trees if the combination of warmer temperatures and more rain produces the anticipated green-up period. Sounds good for the carbon budget, but what happens if drought stress enters the picture, and forests begin to lose live trees?

A further increase in fuel loads, and a dramatic increase in the already high likelihood of catastrophic fires. This supports current national fire policy, which centers on fuels reduction.

STRESS AREAS AND THE DISTURBANCE REGIME

Across the seven climate change scenarios for the United States that Neilson simulated to investigate patterns among them, there is a significant relation between the projected increase in temperature and the so-called stress areas. Stress area refers to land that undergoes a decline in vegetation density. The cause of stress, in most cases, is drought that follows either lower rainfall or higher temperatures or both.

Because trees can survive from decades to centuries, and take years to become established, climate-change impacts are expressed in forests, in part, through alterations in disturbance regimes. In other words, local, regional, and global changes in temperature and precipitation can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides.

Under the seven scenarios in the United States, the stress area increases by 11 percent per year for each degree Centigrade of temperature increase. Considering only U.S. forest lands, the stress area increases at the rate of 17 percent per degree of temperature increase. This change, so far, appears to bear a direct relation to temperature.

"The warmer models show a range of about 55 to 80 percent of current forest area losing carbon under drought stress by the end of this century," Neilson says. "The implications for fire management are enormous."

Even though the models recently used in a United States national assessment do not simulate fire suppression or land use change such as forest harvest, both future scenarios examined do show increasing fire over the United States, primarily in the interior West. This appears to result from the initial increases in precipitation which encourages forest growth, followed by drying cycles that produce catastrophic fires. The Mapped Atmosphere Plant Soil System (MAPSS) team's current dynamic model did accurately simulate the large fire year of 1910, as well as the Yellowstone fires of 1988.

In the Western states, particularly southern California, precipitation and thus vegetation density increases and forests expand under all but the hottest scenarios. In the Eastern United States, particularly the Southeast, forests expand under the more moderate scenarios but decline under more severe climate scenarios with catastrophic