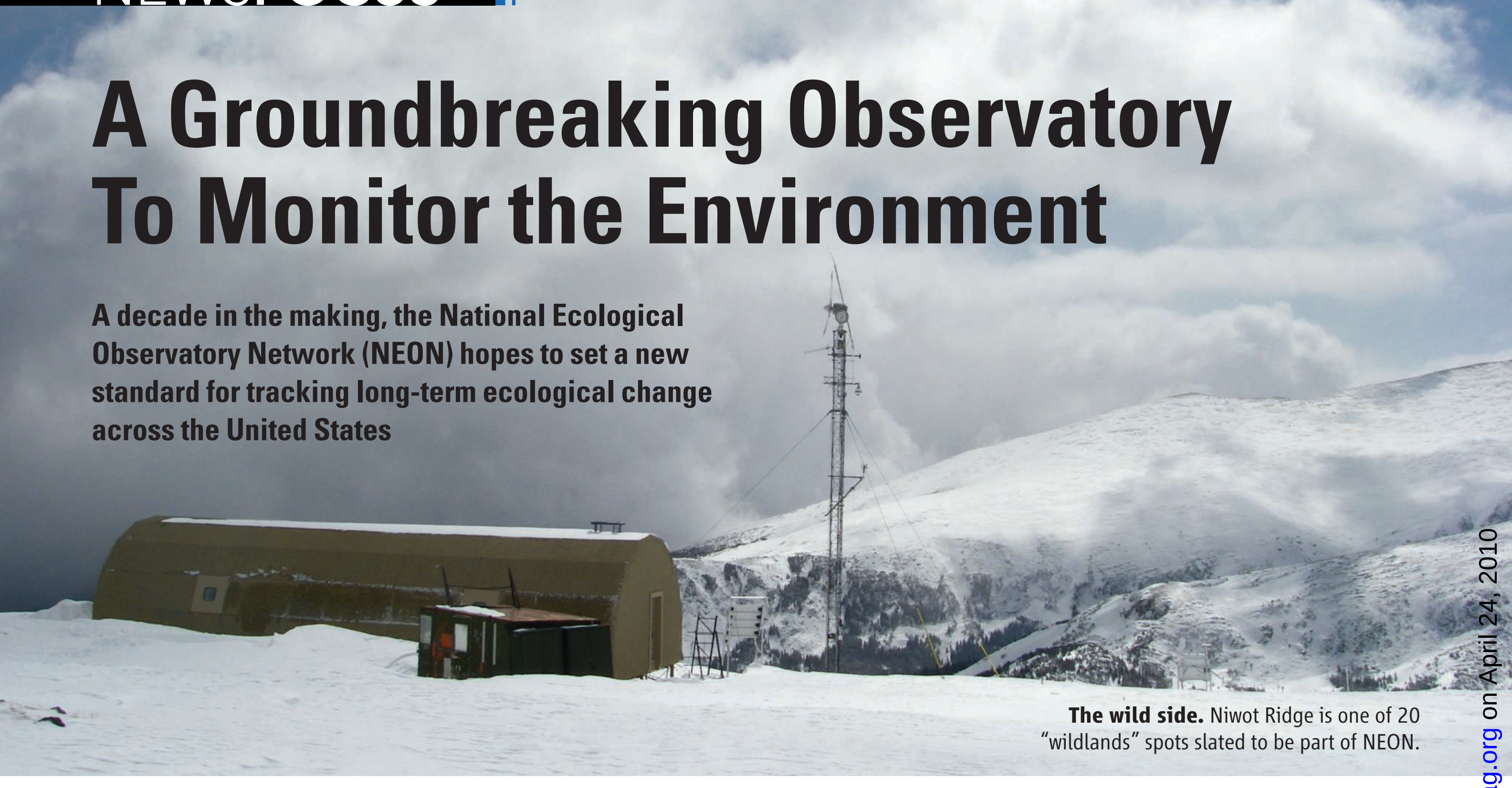
A Groundbreaking Observatory To Monitor the Environment

A decade in the making, the National Ecological Observatory Network (NEON) hopes to set a new standard for tracking long-term ecological change across the United States



The wild side. Niwot Ridge is one of 20 "wildlands" spots slated to be part of NEON.

BOULDER, COLORADO—Plowing a path through 43 centimeters of freshly fallen snow in late March, the snowcat rumbles past the last spruces and climbs up above the tree line of Niwot Ridge, elevation 3300 meters. Its driver, hydrologist Mark Williams of the University of Colorado, Boulder, is accompanying the area's climatologist on his semiweekly trek to check instruments and change out equipment for experiments, some of which have been running for decades.

A field site since 1951 for what is now the university's Institute of Arctic and Alpine Research, Niwot Ridge has provided researchers with a unique opportunity to witness the interaction of climate—snow, rain, wind—with the local soil, flora, and fauna. Among other advances, the work has helped explain the role that snowbound microbes play in the nitrogen cycle. The equipment is not much to look at: a few rows of snow poles, a couple of antennas with instruments mounted on their booms, and an odd-looking, two-bucket setup for collecting rain and snow. And the mode of research is time-tested: Individual researchers design and set up their experiments, often on a shoestring budget, and then visit them periodically to collect data that are shared with the community and that inform the next set of experiments.

But that small-scale, incremental approach to science is about to change. A 20-meter-square patch of land here is slated to be one of 20 sites in a $434 million project funded by the National Science Foundation (NSF) that will usher in a new era of large-scale environmental science. The project, called the National Ecological Observatory Network (NEON), represents the most ambitious U.S. attempt to assess environmental change on a continental scale.

Next month, NSF's oversight body, the National Science Board, is expected to give its final approval to NEON, and NSF has requested $20 million in its 2011 budget to begin construction. Within 5 years, if all goes well, an 8-meter steel tower will dominate this landscape, bearing instruments that will make it possible to compare this environment with 19 other ecosystems across the country. "This is an entirely new resource for ecology," says Michael Keller, chief of science at NEON Inc., the nonprofit consortium that runs NEON. Christopher Field, an ecologist at the Carnegie Institution for Science in Stanford, California, expects NEON "to produce some fundamentally transformational results."

Online
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Podcast interview with author Elizabeth Pennisi.

For NEON to do that, however, ecologists will need to change how they do science. Instead of being free agents deciding what data they will collect, how, and from where, the researchers will need to become part of a collective, tapping into a database whose parameters have already been determined in a top-down approach. They will need to practice "ecoinformatics": the use of computers and software tools to integrate different types of information from many locations. They will need to think about trends across a whole country instead of a single ecosystem. The success of NEON will depend in large part on whether they embrace or reject that new model.

Not everyone is pleased with how the project is set up. Some, like ecologist David Tilman of the University of Minnesota, Twin Cities, lament the excision of an experiment to test the effects of global change. They say such an experiment, deemed too expensive, is essential to obtaining timely answers about climate change. Others complain that NEON won't be investing enough in the field sites that will host its instruments. There's also some concern that ecologists, untrained in the approach NEON is taking, won't use NEON's data. "Everybody still has some questions because it's a new thing," says John Porter, an ecologist at the University of Virginia in Charlottesville who is not part of NEON.

LTER on steroids

Monitoring a patch of land over time isn't a new idea for NSF. In 1980, it set up five U.S. sites, including one at Niwot Ridge, under the Long Term Ecological Research (LTER) Network that has grown to 26 sites, including

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two in Antarctica and one off the Fiji Islands in the South Pacific. The $30-million-a-year program is widely considered a success, with findings on the effect of global warming on plant diversity, how forests could be overloaded by anthropogenic nitrogen, and the greater stability of diverse ecosystems.

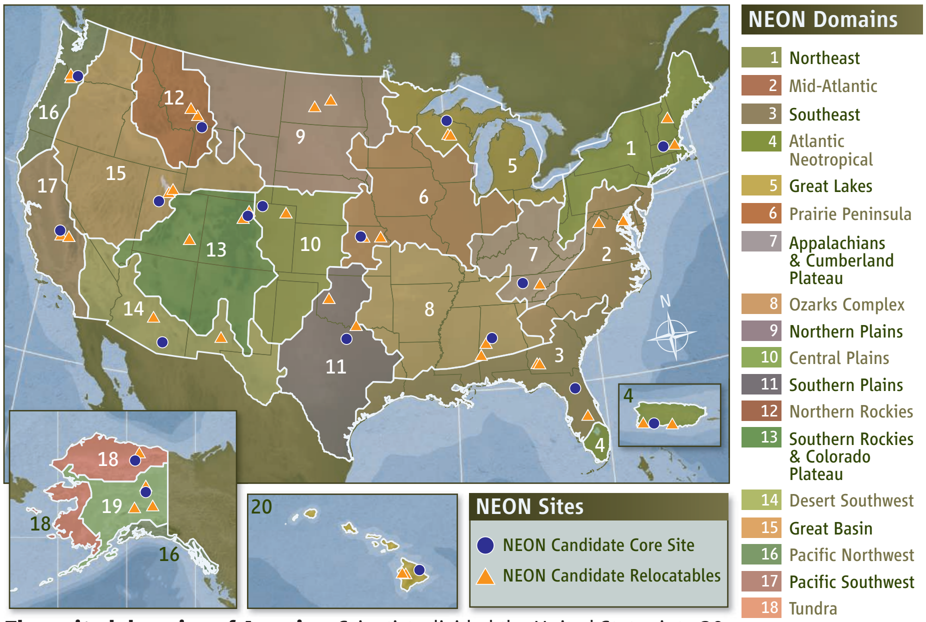
But by the late 1990s, says Williams, "we realized there were limits to the LTER model." Each LTER was designed to answer questions posed by an individual investigator or a small team. Core activities, such as measuring primary productivity, were not a high priority, Williams acknowledges. "It was hard to integrate data [from different sites] and to do synthesis," he adds, because investigators followed different timetables and used different instruments.

At about the same time, Williams says, the community began to ask itself, "How do we grow ecology, and how do we tap additional resources?" For NSF program managers, the goal was to fund construction of a large-scale biology project without devouring their annual budgets, which nurture thousands of individual investigators (*Science*, 20 June 2003, p. 1869). Their models were the astronomy and geosciences communities, which have managed for decades to build costly instruments such as telescopes and ships without bankrupting their bread-and-butter programs. NSF already had a mechanism: Its budget included a special facilities account to finance construction of half a dozen projects at a time, with the understanding that NSF's research directorates would pay for operations and maintenance of those facilities from their annual budgets.

A series of workshops yielded a vision of NEON hailed by then-newly arrived NSF Director Rita Colwell, who inserted the project into NSF's 2001 budget request to Congress. But the larger ecological community had reservations. Congress also balked, wondering what particular scientific question NEON would be addressing.

In response to that resistance, NSF asked the American Institute of Biological Sciences to hold three town meetings in 2002 and 2003. The resulting white paper called for a network of 17 sites in different biomes that, in turn, would be linked to other research sites nearby. Each site was projected to cost $20 million to set up and $3 million a year to operate.

Again, however, the community was divided. Although some people were excited, others wondered if ecologists, known for being independent, would take full advantage of NEON. To many, the program looked like "LTER on steroids," says Williams. "It was not a good-enough plan."



The united domains of America. Scientists divided the United States into 20 ecological domains. Three sites within each domain will be instrumented.

SOURCE: NEON

Next up was an evaluation by the U.S. National Academies. The resulting National Research Council (NRC) report endorsed NEON in principle but urged that the program be reoriented around six specific research questions, including biodiversity and land use. Each question would be the focus of one observatory (*Science*, 26 September 2003, p. 1828). "It forced us to look at large-scale ecological processes and large-scale drivers of change," says NSF's Elizabeth Blood. Nonetheless, Congress chose not to give NSF money in 2004 to begin construction, the third time in 4 years it had passed on funding NEON.

A plan takes shape

For NSF, the flaw in the NRC proposal was that the observatories were too independent to be considered a single entity. That feature would preclude NEON from being funded by the agency's major research equipment account. For NEON's supporters, the solution was obvious. NEON "must be built as one giant Earth-facing telescope," says David Schimel, CEO of NEON Inc. Although there would be multiple sites, together they would cover the entire nation in a statistically valid way. "It really is taking a different approach to doing national-level science," says Porter.

The first step was to refine the six research questions as science goals that could be tackled on a continental scale. Next came deciding what measurements would address these goals. NEON "needed to come up with those things that can be measured in the same way in every place," Porter recalls. Only with uniform, standardized data would researchers be able to "statistically integrate the information to look at processes at a bigger scale," explains Blood.

Coming up with what biology to monitor, for example, was a challenge because each site has a distinct assortment of plants and animals. NEON's designers settled on a few key groups. Bypassing ants and frogs, they chose beetles, mosquitoes, birds, deer mice, and microbes. The last will be characterized by DNA sequencing. The team also had to develop a plant-sampling procedure that could work in grasslands as well as in a forest.

Every site will have a tower that reaches about 10 meters above the existing vegetation. Each tower will host instruments for measuring climate variables such as temperature and wind speed as well as the exchange of carbon dioxide between the atmosphere and the land and vegetation in the immediate vicinity. NEON also plans to measure soil carbon dioxide and other soil characteristics, and will use fiber optic video cameras, called minirhizotrons, to monitor root growth. "What is unique and revolutionary is the fact that [these instruments] are being deployed all over the country," says Field.

Three airplanes will be equipped with a spectrometer that detects "greenness" of the vegetation by picking up the chemical fingerprints of the area they fly over. Those data can be matched with satellite observations to look for changes in vegetation and land use. The

Test bed. All NEON sites will have a tower like this prototype, which is used for evaluating sensors, communications, and data-collection devices.

planes will also carry cameras and lidar to measure forest canopy heights and biomass.

Initial plans for a giant climate change experiment that would manipulate carbon dioxide and temperature locally were dropped after the approach proved to be too expensive and unwieldy. However, a smaller manipulation survived as part of an effort to build predictive models of how streams adapt to stress. The Stream Observatory Network Experiment will boost nitrogen and phosphorus levels in 10 streams and monitor the impact for at least a decade. Upstream traps will also remove fish and other organisms at the top of the food chain, mimicking one of the big threats to aquatic ecosystems worldwide.

All together, NEON's instruments and people will monitor 550 variables, and the data will be released to the public after being checked for quality. In many cases, NEON will also provide analyses that incorporate spatial and temporal information, and use models that predict parameters, such as net productivity, that couldn't be measured directly.

While some scientists were debating what to monitor, others began figuring out how to divide up the country. "We wanted to maximize the amount of environmental variety in North America," says Schimel. William Hargrove, now with the U.S. Forest Service in Asheville, North Carolina, created a matrix for each square kilometer of the United States with data on nine variables, such as days below freezing, amount of precipitation in the growing season, and vegetation growth. Using a supercomputer, he grouped like squares to come up with specific regions, called domains, characterized by particular ecological characteristics: tundra, prairie, alpine, and southeastern forest domains, for example. After settling on 20 domains, Hargrove and his colleagues then determined which locations in each domain best represented the range of environmental conditions of that domain.

Each domain will have one permanent "wildlands" site and two temporary sites that will host instruments for 3 to 5 years. Some 800 permanent sites were proposed; under the rules, a potential site needed to be available for 30 years, offer year-round access, and permit flyovers by remote-sensing aircraft. To reduce the cost of visits, the sites within a domain also needed to be as close together as possible.

Full speed ahead?

The site selection was completed in 2007, and in November 2009, NSF signed off on NEON's final design. If approved by the science board, NEON expects to start work this summer at an agricultural field in eastern Colorado, followed in summer 2011 by the core site of that region in the Central Plains Experimental Range, 241 kilometers away. It hopes to build sites at two domains in the first and final years of construction, and four a year over the middle 4 years. NSF is asking Congress for $20 million in FY 2011 in a budget that ramps up to about $100 million annually in 2013 and 2014; work on all 20 domains should be completed in 6 years. Niwot Ridge will be one of the last sites built. NEON's annual operating budget is expected to be $80 million.

But will this be money well spent? Not everyone thinks so. "I don't believe we will move environmental science along at the maximum speed with NEON," says William Schlesinger, a biogeochemist at the Cary Institute of Ecosystem Studies in Millbrook, New York. "I think if you took the same amount of money and used it to enhance the competitive grants for young people, we'd get [better] science for the money."

Tilman, the chair of the NRC committee that reviewed NEON in 2003, also has some reservations. "The current NEON in my mind takes too literally the word 'observatory,' " he says. He disagrees with NEON's decision to drop the climate change experiment his panel recommended. "You need observations of natural systems and observations of experimentally manipulated systems" to begin to determine cause and effects and then to check those findings against what is happening in nature, he says. Those experiments would also motivate young researchers to invest their careers in NEON, he adds.

Indeed, there's an undercurrent of nervousness about whether the community will use the information that NEON generates. "People are a little wary about what we'll get out of it," says Eugene Kelly, a soil scientist at Colorado State University, Fort Collins. He thinks his generation of senior researchers might not benefit much from NEON because it has a different mindset, and many may not want to wait a decade or longer for the trends from the data being collected to become evident.

In addition, he and Williams are upset because NEON's investment in infrastructure at its sites, including places like Niwot Ridge, won't enhance existing facilities. "The sites get nothing" to augment their budgets, says Williams. "It's a major bone of contention." Williams worries that NEON will not be well integrated with the operations of his LTER once construction begins and that the two teams won't work together in a scientifically productive way.

But Schimel says NEON will pay its way at these sites and will work with local managers. And NSF is hoping to attract researchers with a new $20 million grant program announced this month. Macrosystems Biology: Research on Biological Systems at Regional to Continental Scales will fund proposals from scientists seeking to use data from NEON. Williams is already planning to apply for funds to incorporate early Niwot Ridge data into the NEON data stream.

"When they did the first [telescope] observatory, I bet it wasn't the very best there is," Porter explains. "But you will never get to that second observatory until you've had the first. We'll learn a lot from NEON."

–ELIZABETH PENNISI

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