Mountains west of Boulder continue to lose ice as climate warms

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CU-Boulder researchers are seeing a loss of ice in the high mountains west of Boulder as the climate warms. Credit: University of Colorado

New research led by the University of Colorado Boulder indicates an ongoing loss of ice on Niwot Ridge and the adjacent Green Lakes Valley

in the high mountains west of Boulder is likely to progress as the climate continues to warm.

The study area encompasses the Niwot Ridge Long-Term Ecological Research (LTER) site, thousands of acres of alpine tundra, subalpine forest, talus slopes, glacial lakes and wetlands stretching to the top of the Continental Divide in the Rocky Mountains. The Niwot Ridge LTER site, which includes Green Lakes Valley and CU-Boulder's Mountain Research Station (MRS), is one of 26 North American LTER sites created and funded by the National Science Foundation (NSF) and one of the initial five LTER sites designated by the federal agency in 1980.

The decline of ice at the Niwot Ridge LTER site appears to be associated with rising temperatures each summer and autumn in recent years, said CU-Boulder Professor Mark Williams of the Institute of Arctic and Alpine Research, lead study author. The decline is especially evident on the Arikaree glacier—the only glacier on Niwot Ridge—which has been thinning by about 1 meter per year for the last 15 years.

"Things don't look good up there," said Williams. "While there was no significant change in the volume of the Arikaree glacier from 1955 to 2000, severe drought years in Colorado in 2000 to 2002 caused it to thin considerably. Even after heavy snow years in 2011 and again in 2014, we believe the glacier is on course to disappear in about 20 years given the current climate trend."

Niwot Ridge Long Term Ecological Research program site. In the background, from left to right, are Arikaree Peak and the Arikaree Glacier, Navajo Peak and Apache Peak, all on the Continental Divide. Credit: Bill Bowman, University of Colorado.

The new study looked at changes in the cryosphere—places that are frozen for at least one month of the year— at the Niwot Ridge LTER site going back to the 1960s. In addition to the changes occurring on the Arikaree glacier, the researchers also have seen decreases in ice associated with three rock glaciers (large mounds of ice, dirt and rock) as well as subsurface areas of permafrost - frozen soil containing ice crystals.

The team used several methods to measure surface and subsurface ice on Niwot Ridge: ground-penetrating radar, which measures ice and snow thickness; resistivity, which measures the conductivity of electrical signals through ice; and seismometers to measure signals bounced through subsurface ice. "We found that a combination of all three methods provided the best picture of changing snow and ice conditions on Niwot Ridge," said Williams.

The researchers also discovered an increased discharge of water from the Green Lakes Valley in late summer and fall after the annual snowpack had melted, a counterintuitive trend that began in the early 1980s, said Williams. The increased discharge appears to be due to higher summer temperatures melting "fossil" ice present for centuries or millennia in glaciers, rock glaciers, permafrost and other subsurface ice.

"We are taking the capital out of our hydrological bank account and melting that stored ice," he said. "While some may think this late summer water discharge is the new normal, it is really a limited resource that will eventually disappear."

Scientists have been gathering information on the snow, ice and plant and animal abundance and diversity on Niwot Ridge going back to the 1940s, when CU-Boulder Professor John Marr and colleagues began studies. The two highest climate stations on Niwot Ridge, one at 10,025 feet and the other 12,300 feet, have been monitoring data continuously since 1952.

"This study demonstrates declines in ice—glaciers, permafrost, subsurface ice and lake ice in the Niwot Ridge area over the past 30 years," said Saran Twombly, LTER program director in NSF's Division of Environmental Biology, which funded the research. "Long-term research at Niwot Ridge offers a rare opportunity to document the continuous, progressive effects of climate change on high alpine

ecosystems, from ice and nutrients to plant and animal communities."

A special issue of the journal *Plant Ecology and Diversity* that includes several research papers involving CU-Boulder faculty and students is being published this month. Study co-authors on the Niwot Ridge snow and ice paper, part of the special issue, include emeritus Professor Nel Caine of CU-Boulder, Professor Matthew Leopold of the University of West Australia and professors Gabriel Lewis and David Dethier of Williams College in Williamstown, Massachusetts.

From an ecological standpoint, Niwot Ridge has seen a significant increase in alpine shrubs above treeline in recent decades, said Williams. At one research site known as "The Saddle" at about at 11,600 feet in elevation and 3.5 miles from the Continental Divide, the ecosystem has gone from all tundra grasses and no shrubbery in the early 1990s to about 40 percent shrubs today.

"Places that once harbored magnificent wildflowers in this area are being replaced by shrubs, particularly willows," he said. "The areas dominated by shrubs are increasing because of a positive feedback - patches of these shrubs act as snow fences, causing the accumulation of more water and nutrients and the growth of more shrubs."

One nutrient, nitrogen—produced primarily by vehicle emissions and agricultural and industrial operations on the Front Range and elsewhere in the West—is being swept into the atmosphere and deposited on the tundra in increasing amounts, said Williams. Nitrogen deposition also is an issue in nearby Rocky Mountain National Park.

Niwot Ridge is part of the Roosevelt National Forest and has been designated a United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve. The Green Lakes Valley is part of the City of Boulder Watershed and CU-Boulder's MRS is

devoted to the advancement of mountain ecosystems, providing research and educational opportunities for scientists, students and the general public.

Provided by University of Colorado at Boulder