UC Irvine researchers shine light on rapid changes in Arctic and boreal ecosystems

The changes point toward increasingly unstable ecosystems at high latitudes
Tuesday, April 16, 2024
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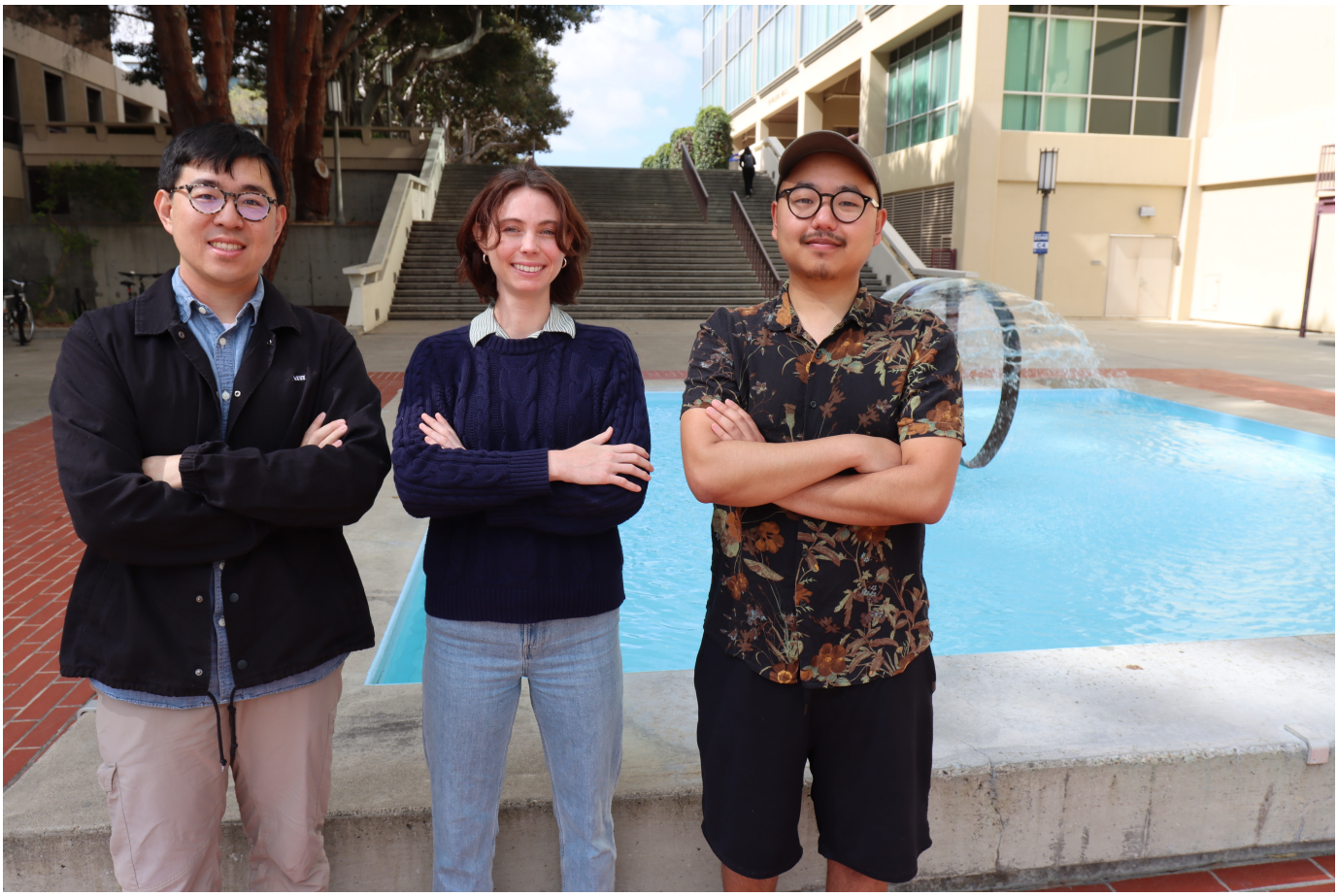
UCI News



The lead authors of the new studies, from left to right: Hui Wang, Allison Welch and Jinhyuk Kim of the UCI Department of Earth System Science.

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Irvine, Calif., April 16, 2024 — Arctic and boreal latitudes are warming faster than any other region on Earth. In three new studies, Earth system scientists at the University of California, Irvine report how the ecosystems in these regions are changing.

In a study published in *Global Change Biology*, a team led by Earth system science Ph.D. candidate Jinhyuk Kim from the lab of James Randerson, professor of Earth system science, reveals how wildfires are increasing rates of photosynthesis in Canada and Alaska.

They find that increasing wildfires are wiping out black spruce forests that grow relatively slowly and which contribute to the organic layer of the underlying soils. In many areas, deciduous shrubs and trees, like willow and aspen, are moving in after a fire. These plants have a much higher metabolism, meaning they can establish themselves faster than spruce.

In 2023, Canada saw its most devastating wildfire season, with over 46 million acres burned. The authors' work suggests that these fires may accelerate changes in northern forests that are already underway due to climate change.

"We're seeing higher levels of photosynthesis that persist for decades after fire," said Kim. "Instead of the evergreen conifer forest coming back right away, in some regions, we see a long-term replacement of these forests with faster-growing species."

The more photosynthesis there is, the more plants can remove carbon dioxide from the atmosphere. One assumption is that this might create a sink for carbon dioxide and help temper global warming.

“But because you’ve combusted the carbon stored in the plants and their organic soils, even the increase in photosynthesis we observe doesn’t necessarily translate into more carbon storage in the long run,” Kim said. “The increasing trends in wildfire have significant implications for forest species composition and ecosystem function but likely negatively affect the land carbon sink. This is why it’s important to study how the changing landscape from wildfire and warming influences different aspects of land carbon cycling.”

To measure the changing rate of photosynthesis in the boreal plants, Kim and his team used data from Orbiting Carbon Observatory 2 satellites that track the fluorescence of plants to use as a proxy for photosynthesis.

“It’s a more recent measurement that we’ve been able to observe globally,” said Kim, who explained that using fluorescence measurements is a novel approach to measuring photosynthesis. “We also have this long land cover time series from Landsat, and we can look at how fires are changing the land plant cover and then tie it to changes in the solar-induced fluorescence signal. We find that wildfires are changing the land cover, which, in turn, can enhance the seasonality of carbon fluxes at large spatial scales.”

Kim added that it’s a sign of unstable ecosystems in which the types of plants in the region are rapidly changing.

In another study from a team led by Earth system science Ph.D. candidate Allison Welch, researchers describe what kind of plants are expanding into the Arctic and alpine tundra.

“With increasing temperatures and wildfire activity, we’re seeing increased growth of bigger, deciduous shrubs,” Welch said, whose team studied five different alpine tundra sites for the research, which appears in *Arctic, Antarctic, and Alpine Research*.

“We found increased shrub growth of a specific species called alder,” said Welch, who works in the lab of Claudia Czimczik, professor of Earth system science. “And just increased vegetation productivity in general at these sites.”

Welch’s team also reported a decrease in the thickness of the organic layer – the uppermost layer of soil characterized by high organic carbon content – at their tundra sites. Shallower organic layers, Welch explained, means there is less insulation for the underlying Arctic permafrost. Permafrost carries vast reserves of frozen organic matter, which, if thawed, may decompose and release planet-warming gases like carbon dioxide into the atmosphere. “If you have a healthy organic layer, you’re likely going to promote permafrost stability,” said Welch.”

In the third study, published in *Geophysical Research Letters*, a team led by Ph.D. candidate Hui Wang, who works in the Department of Earth System Science with Prof. Alex Guenther, obtained field measurements and then ran computer simulations to describe how, as Arctic ecosystems experience a warming climate, emissions of the molecule isoprene are escalating at rates that are far higher than anticipated.

“This change will indirectly change the climate,” said Wang. That’s because isoprene affects the formation of ozone, aerosols and levels of methane in the air. Aerosols affect the formation of clouds, which can, in turn, influence the local climate. And plants, Wang explained, release more isoprene when the weather is warmer.

The changes reported in the studies point toward Arctic-boreal ecosystems that are rapidly changing in response to wildfires and warming.

“These three studies are examples of how the Arctic is changing more rapidly than previously expected,” said Czimczik, a co-author on Welch’s paper as well as the other papers. “Increasing wildfire activity, via its effect on vegetation composition, has the potential to accelerate permafrost thaw beyond the rates we expected from changing climate."

"We can see the environment is unstable, and that there are complex interactions from not only the changing plant communities but the responses of those plants to the rapidly changing climate. These have consequences for the environment and the overall Earth system, so it's something important that we need to understand better," Kim said.

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