Tracking the scent of warming tundra

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Mini-ecosystems were collected from the tundra in Abisko, Subarctic Sweden. Credit: Riikka Rinnan

Climate change is causing subarctic tundra to warm twice as fast as the global average, and this warming is speeding up the activity of the plant life. Researchers from the University of Copenhagen, Denmark, and the Helmholtz Zentrum München, Germany, have now elucidated how this warming affects the tundra ecosystem and the origin of an increased amount of volatile compounds released from the tundra.

The results are published in the renowned scientific journal *Global Change Biology*.

The creeping bushes and lush mosses of the tundra emit a scent that consists of a complex mixture of volatile organic compounds (VOCs). VOCs are gases that include thousands of natural chemicals, including the fragrances in essential oils. The VOCs protect plant cells from environmental stresses, but they are also chemical messengers and function as a "language" between plants and animals. By releasing VOCs, plants can directly repel and attract insects, or warn neighboring plants of impending dangers such as insect infestation.

Field studies led by the Copenhagen team have shown that a temperature rise of just a few degrees doubles or triples the amount of VOCs released from tundra vegetation. Until now, it was not known whether this "gas bomb" is merely a consequence of the temperature-related release of vaporized essential oils stored in plant tissue or whether the enzymatic synthesis of VOCs is stimulated in plants.

"Our new results show that the share of the VOC release from direct biosynthesis increases significantly with global warming. This leads to a shift in the composition and amount of VOCs released towards more reactive hydrocarbons," says Professor Riikka Rinnan from the University of Copenhagen.

Rinnan's team collected a large number of mini-ecosystems—blocks of tundra including naturally growing plants and the soil below them to the depth of 10 cm—and brought them to the unique phytotron facility at the Helmholtz Zentrum München, Germany. The facility has some of the best climate chambers for mimicking a natural environment, which can be used for experimentation with different climate scenarios. The mini-tundra ecosystems were then cultivated under the current or simulated future arctic climate, while monitoring the released volatiles. To study the processes taking place in the plants and the ecosystem, the mini-ecosystems were exposed to manipulated air, in which the CO_2 absorbed by plants during photosynthesis was marked with isotopes so that it could be traced.

"13C is a naturally occurring stable isotope of carbon. By feeding the plants with enriched levels of 13C-labelled CO_2, we can follow the fate of atmospheric carbon dioxide. We simulated the future climate and traced CO_2 from the atmosphere into the subarctic ecosystem," says the first author of the study, Dr. Andrea Ghirardo, from the phytotron facility in Munich.

Under these conditions the researchers could follow the carbon. They tracked where the labeled carbon ended up in the different plant tissues, in soil, microorganisms, and the released VOCs. When the plants use CO_2 to synthesize certain VOCs, they observed 13C appearing in the released VOCs. They hereby could distinguish the newly synthesized VOCs from those VOCs that simply evaporated from storage structures in the plants, or were formed in the soil.

The incorporation of carbon isotopes in tissues and soil helps the researchers understanding where the ecosystem allocates the recently-fixed carbon and allows the quantification of carbon sequestered from the atmosphere. When this is done in the climate chambers under controlled environmental conditions, this provides pieces to the puzzle of what will happen in arctic ecosystems in the future.

More information: Andrea Ghirardo et al, Origin of volatile organic compound emissions from subarctic tundra under global warming, *Global Change Biology* (2020). DOI: 10.1111/gcb.14935

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