Vincent Gauci explains how wetlands, acid rain and volcanoes interact to affect our climate.

Pollution is a 'bad thing' right? If only things were that simple! New research suggests acid rain falling on wetlands could be helping to keep greenhouse gases in check. Earth's wetlands store vast amounts of carbon. Water-loving plants like sphagnum mosses photosynthesise, turning carbon dioxide into plant material that builds up soggy, carbon-rich soils over thousands of years. In peatlands—just one form of wetland—there's as much carbon locked away in the soil as is contained in the atmosphere. Carbon dioxide isn't the only gas that moves between wetlands and the atmosphere. These ecosystems emit vast quantities of methane, a greenhouse gas that, molecule for molecule, is about 20 times more powerful than carbon dioxide. Microbes called methanogens, which thrive in waterlogged and oxygen-free conditions, produce methane. Wetlands are the largest global source of the gas.

There are wetlands in Europe and the United States, but most are found in remote areas of the world such as Siberia and northern Canada, and in the tropics, for example Indonesia and the Pantanal in South America. At the Open University, we realised that although most wetlands are far from big industrial centres, some of these important ecosystems could still be susceptible to atmospheric pollution. Could pollution affect the amount of methane wetlands emit?

We decided to investigate the sulphur pollution that is found in acid rain. Many countries, particularly in Western Europe and North America, have taken great strides to reduce this problem since the 1980s. But globally, the problem continues to grow, roughly keeping pace with the economic growth of Asia. Volcanoes are also important sources of sulphur, and over the Earth's history they have been the main 'polluters'. For example, the Icelandic Laki eruption of 1783-84 emitted as much sulphur as Western Europe's industry would over ten years.

In Moidach More, a peat bog in north-east Scotland, my colleagues (Nancy Dise, now at Manchester Metropolitan University, and David Fowler of the Centre for Ecology & Hydrology, Edinburgh) and I simulated the sulphate deposition that acid rain still brings to polluted parts of the world. The experiment also simulated the amount and timing of acid rain that would have come from the Laki eruption. Our monitoring showed that the pollution actually reduced methane emissions by 30-40%. The reason for this is that the sulphate component of acid rain pollution sparks a battle between different microbial populations that live in the peat. Most peatland organisms get their nutrients from elements dissolved in rain and snow – and normally there's very little sulphate. Under these conditions, methane production is the last step as plant matter decomposes. But even the very small amounts of sulphate in acid rain can shift the balance of microbial power. A different set of microbes, called sulphate-reducing bacteria, now succeeds in the battle for limited food sources within the peat. They out-compete the methanogens, leaving them without much food, so less methane is produced.

It's one thing to find out that simulated acid rain can reduce emissions from a single peat bog experiment, but quite another to find out whether or not the interaction is important globally. So with colleagues at the NASA Goddard Institute for Space Studies (GISS), we drew together the results of similar experiments in Sweden and North America. With the help of a global wetland methane emission model, and estimates of sulphur deposition from our colleagues' model of the world's atmosphere, we were able to make an estimate at the global scale.

The results surprised us. Without the effect of sulphur from industrial sources, wetlands would become an increasingly large source of methane as climate warms. This is because more methane is produced as temperatures rise. But when we included acid rain in our model, we found that sulphate pollution offsets the effect of warmer temperatures, bringing global methane emissions from wetlands down to pre-industrial levels.

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Intriguing questions arose from this work: What would happen if you solved the acid rain problem in Asia? Would methanogens in wetlands, suddenly relieved of sulphate input from acid rain, immediately fight back against the competitive sulphate-reducing bacteria? How would wetland ecosystems respond to a single large pulse of acid rain like the fallout from the Laki eruption?

To try to answer these questions, we went back to Moidach More in 2000 and 2003 with Open University volcanologist Steve Blake. We found that wetlands are slow to return to business-as-usual methane emission rates (and the modelling work had also suggested the acid rain effect should continue well into the middle of the 21st century). Sulphur fallout from a Laki-like eruption should suppress methane emissions for five to ten years after the end of the eruption—much longer than the two or so years during which volcanic aerosols might affect the atmosphere.

Many wetlands are near active volcanoes, or in the path of volcanic fallout (like wetland-rich Siberia in the path of Icelandic eruption fallout). So over geological time scales volcanoes may play a crucial role in controlling how much methane wetlands release. Deeper in geological time, around 50 million years ago during the early Eocene, wetland methane emissions may even have been the main driver behind the warm climate of the day. Large, Laki-like eruptions during that time could, by stimulating battles between bugs in bogs, have resulted in significant changes to Earth's climate.

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