The butterfly effect of shale gas

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From an observation station located in Switzerland, researchers from the InfraRed Group of Atmospheric and Solar Physics of the University of Liege have identified a potentially worrying phenomenon that could lead to air quality degradation: since 2009, the level of ethane in the atmosphere has increased by 5% per year while previously, it was decreasing by 1%. The explanation for this increase can be found several thousand kilometers away in the United States where the massive exploitation of shale gas contained underground is certainly not without consequences.

How can drilling in the middle of an American plain have effects that can be observed at an altitude of 3,580 meters in Switzerland? This is quite some butterfly effect which needs to be explained. Since the end of the 2000s, the Americans have been exploiting shale gas. In order to do this it was necessary to drill vertical wells in the hope of accessing the geological layers containing methane. This chemical compound which is highly flammable is not always easy to collect. In order to remove it from usual depths of 1,500 to 3,000 meters where it is well-contained in shale, it is necessary to use the horizontal method of drilling known as fracking or "hydraulic fracturing" which involves the injection of a complex mixture of water, sand, lubricants, biocides and detergents which allow the gas to be collected on the surface.

However, at some point during this process, part of the methane gas (CH$_4$) escapes. Not only methane but also ethane (C$_2$H$_6$), which is closely associated with it, also partly evaporates.
At the summit of Jungfraujoch

Amazingly, this leaking of ethane was not identified in the US but from the snow-capped summits of the Jungfraujoch station, in the middle of the Swiss Alps. The station is an international scientific observatory which is also home to the Laboratory of Atmospheric and Solar Physics of ULg among others. It is here that measurements of infrared radiation were carried out at high altitude in order to avoid interference from water which is abundant in the lower layers of the atmosphere and which could interfere with the results.

Two young researchers from Liege, Whitney Bader and Bruno Franco carried out an analysis of this solar infrared light. During the course of 2014, the two researchers developed a method for more accurately analyzing information linked to ethane in infrared observations thanks to new spectroscopic parameters. This improved technique made it possible to study certain data sets including those related to the presence of ethane in the atmosphere.

"While inspecting this series again, we detected a reversal of the trend as it was happening", explains Emmanuel Mahieu, a researcher at the FNRS and head of GIRPAS (the InfraRed Group of Atmospheric and Solar Physics). "Since the middle of the 1990s, the presence of ethane was dropping each year by around 1%. Then, after around 2009, we notice an increase of 5% per year". In other words, the efforts that had been made to reduce these emissions for more than a decade were rendered useless.

Already in the 1980s, this atmospheric pollution due to ethane had been noticed, it was the result of uncontrolled "fugitive" emissions linked to the exploration of oilfields. Public authorities reacted by imposing restrictions on oil companies which brought about a progressive improvement of the situation.

Watch out for bad ozone

Ethane should not be taken lightly! While this gas is not polluting in itself, its degradation makes it dangerous. It ends up by forming ozone in the troposphere. This is "bad" ozone which is found nearer to ground level and reaching a height of ten kilometers. It is a major pollutant for human beings and the biosphere which is the exact opposite of "good" ozone present at higher altitudes and protecting us from the sun's ultraviolet rays. "It is due to this bad ozone that there are sometimes pollution-alert days in summer when people are advised not to practise sport or to go outside if they are suffering from asthma… It is also an oxidant which is dangerous for vegetation and construction materials (roofs, chassis etc.)", Explains Emmanuel Mahieu. More seriously still, ethane is emitted at the same time as methane, a more efficient greenhouse gas than CO₂.

Why did the level of ethane in the atmosphere rise suddenly from 2010 onwards? At first, the researchers from Liege only had a theory. They noticed that the period coincided with the beginning of large-scale exploitation of shale gas in the US. Because the prevailing winds go from the American continent to Europe and the time it takes to transport this gas is lower than its life-cycle it was plausible that traces of it could be found in the Swiss Alps.

The team needed more than mere presumptions and required proof. They contacted colleagues from New-Zealand in order to determine whether they too noticed the same phenomenon. The Southern Hemisphere remains well-preserved for the moment. This led the researchers to believe that the origin of the pollution was in the Northern Hemisphere and that ethane does not survive long enough in the atmosphere to drift below the Equator in significant quantities.
In orbit

The researchers then turned to the sky and the Canadian ACE instrument which has been in orbit since 2004. Their objective was to establish whether the measurements taken from the ground were similar to those detected in space. The results concurred. Above the American continent, the satellite even noticed increases of up to 10% per year!

In order to confirm its theory again, ULg turned to the NDACC (Network for the Detection of Atmospheric Composition Change), which combines several different sites that are similar to Jungfraujoch, particularly in the US, Canada and the Great North... "Our colleagues carried out the same analysis and confirmed the same trend that we had identified", explains Emmanuel Mahieu.

There was hardly any room left for doubt. How was it possible that the American stations did not notice these massive releases of ethane under their very noses until the specialists from Liege armed with the data taken in Switzerland alerted them to the problem? "Our techniques enable us to analyse some twenty constituents, we cannot, however, analyse everything at the same time. It all depends on the priorities of each laboratory", replies the head of GIRPAS. "There were actually some studies being done on methane but the problem is that there are many sources of this gas. It is therefore more difficult to identify the place where the problem originates. This is why we focus on ethane even if we are studying both gases".

Who leaked?

The next stage of the research will be to quantify and identify the source of the emissions. What is the real extent of these leaks? Where precisely are they coming from? In order to establish this, the researchers will resort to what is called "reverse modeling". The measurements taken by satellite will be used to deduce the location of the source and intensity of the emissions. This method is suitable for methane but because it is emitted simultaneously with ethane it should be possible to draw useful conclusions.

"The objective is to determine whether our model is capable of reproducing the trends detected. If we can't not do this, it signifies that there are other elements in different places which have been under-estimated", explains Emmanuel Mahieu. "Otherwise we will carry out sensitivity tests: by how much should we increase the emissions to achieve the atmospheric levels recorded"?

The last phase will consist of evaluating the real impact on the quality of the air. "We still have a lot to do"! Our conclusions could be released in 18 to 24 months' time if the necessary funding is provided for the research. A scientific article focussing on improved analysis of spectroscopic parameters revealing the recent increase of ethane detected at Jungfraujoch has already been published (1) in March in JQSRT (Journal of Quantitative Spectroscopy and Radiative Transfer). Another article is being prepared focussing this time on the comparison of ethane leaks detected by the different measurement sites.

Priority to methane

The objective of the researchers is not to lead a crusade against shale gas. Quite the contrary. According to Emmanuel Mahieu, it is better to exploit methane for electricity than to use coal. "I will be considered mad because this is a greenhouse gas", he smiles.
"It is true that it is a greenhouse gas but if it comes to a choice between the two methane is the better option. Coal contains sulphur, emits more microparticles into the atmosphere and is less efficient with regard to conversion into electricity". In any event, if the leaks are seen to be greater than 3%, the opposite is true. The first becomes less interesting than the second".

This is why it is necessary to optimize the process of extraction and continue to closely monitor the situation. Finally, it remains to be seen whether the massive drilling in the US and the use of pumps, machines and trucks (machines which use diesel) cause an increase in the release of other constituents such as benzene and its derivatives which are known to be carcinogenic.