Increasing Mediterranean salinity (and therefore increasing density) produces marked cooling in the north Atlantic and over Canada, Greenland and Europe. Dense, deep water normally flowing south from the far northern Atlantic is essentially replaced by Mediterranean outflow water so that the northern latitudes remain cooler.

Conversely, a freshening Mediterranean becomes less dense than the Atlantic, meaning that water flows into the ocean at the surface rather than at depth. The entire Atlantic water column freshens, with extreme and widespread consequences. The thermohaline circulation breaks down completely in the Atlantic, so warm, tropical water no longer reaches higher latitudes. Cool, fresh water even spreads into the Pacific through the Central American Seaway. As a result, the entire northern hemisphere cools by as much as 8 °C. On the other hand, parts of the southern hemisphere experience some warming because cold, north Atlantic water is no longer transported south.

The Earth was a very different place during the MSC than it is now, so naturally the results Ivanovic and her colleagues obtained differ from studies looking at present-day climate. Then as now, however, it is clear that R. G. Johnson was not exaggerating when he claimed that the Mediterranean could wreak havoc with global climate. It remains to be hoped that potential far-reaching impacts are considered when planning future mega-projects like the Aswan Dam.

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Local flaring, global impacts: modelling Arctic black carbon

Although most of the Earth's population isn't aware of it, the Arctic is burning. The flames are being fed by natural gas produced as a by-product of crude oil extraction, which is then flared away at the surface. Although practiced worldwide, high-latitude gas flaring has the greatest impact on the fragile Arctic environment. Since the black carbon emissions resulting from flaring know no national boundaries, only a global solution will bring about results to improve conditions in the Arctic.

The flaring of natural gas impacts the Arctic (Credit: Fabien Darrouzet, distributed via imaggeo.egu.eu)

Modelling black carbon

Black carbon (soot) and other combustion emissions from flared natural gas are released into the Earth's atmosphere where they move in patterns that atmospheric scientists try to model. However, standard models have trouble predicting the patterns of black carbon transport into the Arctic. This has been confirmed by Andreas Stohl of the Norwegian Institute for Air Research and his collaborators. According to their research, published in Atmospheric Chemistry and Physics, the atmospheric concentration of black carbon found in the Arctic is underestimated by all existing models.

What makes the Arctic atmosphere so difficult to model? It is a combination of factors, including the complex seasonal changes that occur in higher latitudes (above 40 degrees). The relative inefficiency of aerosol removal in late winter and spring, known as the Arctic Haze phenomenon, also complicates the modelling process.

"It is the removal of black carbon from the atmosphere that is so difficult to model. Black carbon is mainly scavenged by precipitation, which is relatively inefficient in the period between January and March, but the deposition is not very well modelled and the existing models do not show enough black carbon being transported into the Arctic in relation to ground measurements," said Stohl.

The politics of flaring

It is not always clear how much associated natural gas will be produced from an oil well, and it may change in amount, quality and chemical composition over the life of a field. Producers often find

Flaring gases from an oil platform in the North Sea. (Credit: Wikimedia Commons user Varodrig)

that the easiest way to deal with the less economical, and sometimes contaminated, gas is to burn it on site by means of flaring. There are several alternatives, but no cookie cutter solution to the problem, as each area has unique issues in terms of geography, geology and infrastructure.

Russia and Nigeria lead the list of countries with the most flaring activity, with 66 billion cubic metres, or 24% of the overall associated Russian production, flared in 2010. But flaring occurs all over the world. The World Bank estimates that 140 billion cubic metres of associated gas is burned or wasted annually. This is equivalent to about a third of EU gas use and, in terms of CO_2 emissions, it equates to taking 70 million cars off the roads.

The issue is most serious in places where infrastructure development and investment is difficult, especially on brownfield sites and remote locations. It is especially bad for the Arctic, where the combusted black carbon particles settle on the snow and increase the snow-albedo effect, which causes further melting of Arctic ice. Atmospheric warming is also increased by black carbon over the highly reflective surface of the Arctic.

Tracking flaring activities

Historically, it was only possible to track flaring activities through the limited data gathered from companies and governments reporting on local hydrocarbon industries. But this information tends to be incomplete for political reasons. It is now possible to follow black carbon emissions through observation of the black carbon/carbon monoxide emissions ratio, which is specific to certain sources such as diesel vehicles, biomass burning or flaring. Carbon monoxide is another combustion by-product. It remains in the atmosphere over several weeks to months, sometimes longer, and is often used to trace polluted air masses.

It is also possible to track flaring via satellite. A Japanese satellite named IBUKI is able to collect infrared information and detect CO_2 and methane emissions. The collected data can be cross-referenced with additional data points. This is one step closer to a complete picture, but it is not perfect: no completely reliable information on flaring as it occurs is yet available.

"New satellites can detect temperature signals and have the capacity to not only exactly pinpoint where flaring is happening but to also quantify the gas volumes burned by each flare, which is really needed to estimate the flaring emissions. This technology is also capable of distinguishing between flaring and other sources like forest fires, based on temperature measurements, as flares are extremely hot. Thus, we expect that estimates of flaring emissions will become much more reliable in the near future," Stohl said.

Sources of black carbon

Where is the black carbon most likely coming from? This depends on specific latitude, location and season. Some models show that flaring emissions are dominating at latitudes above 66 degrees (up to 80%) in winter. It can be assumed that flaring is the main producer of black carbon during this time, as biomass burning, one of the other big black carbon contributors, is less frequent in the winter. Residential, transport and industry are the major polluters in the middle latitudes, with aircraft and international shipping contributing to a much lesser extent.

Although flaring occurs globally, the impacts from Russia have a proportionally large impact on the Arctic compared to flaring from lower latitudes. When flaring occurs along the main low-level pathway of air masses directly entering the Arctic from Siberia, black carbon emissions are measured at their highest levels. According to the models, this makes Russia responsible for a large fraction of black carbon loading in the Arctic lower troposphere. Russia also has strong flaring at very high latitudes and Northern Russia has the highest measurements of black carbon concentrations in snow.

Flaring in the Siberian oil fields has been occurring for decades and can generally be attributed to coordination problems and conflicting interests. The Russian presidency has raised this as an issue and has suggested that companies that flare pay large fines, and new laws require companies to use a high percentage of associated gas. The government has also allowed preferred access to the electricity grid for power generated from flare projects and has encouraged use of gas for local power generation, which is often needed in remote regions to supply power to processing plants.

What can be done to reduce flaring?

The problem will only get worse as more and more Arctic areas are opened up for drilling activities and will take on a more international aspect as other areas of the Arctic are exploited.

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There are a number of ways to combat natural gas flaring, but since there is no one-size-fits-all solution, a number of organisations need to come together to ensure a balance amongst government, business and private interests. Assumptions that associated gas is not worth gathering need to be challenged. So far, the best efforts to eliminate flaring look at the entire gas value chain and involve a combination of penalties, incentives, investment and inventive uses for the available gas.

For the Arctic, the role of both the scientific and international communities is of vital importance. As the Arctic has no single authority, international institutions and Arctic groups will be vital in supporting commitments to mitigate flaring activities. And as technology advances, there is also the hope that new methods and processes to deal with flared gas will become available. Since there are a number of ways to reduce flaring, this is a realistic and achievable step towards decreasing the presence of black carbon in the Arctic, most possibly in the next ten years. It is another step towards changing local behaviours that have tremendous global impacts.

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Molecules and meteorites: big impacts for life on Earth

You'd be forgiven for thinking that meteorite impacts only spell disaster for life on Earth, and there is plenty of evidence to suggest that an impact was bad news for the dinosaurs. However, a growing body of research suggests that asteroid and comet impacts early in our planet's history may actually hold the key to the origins of life on Earth. In terms of the global impact of a local event, they surely don't come much bigger than this.

As a geophysicist, I'm well aware of the problems that researchers in my field face in delving back in time to establish the geology of the early Earth. The challenge of doing a similar thing with organic molecules, which I guessed would be rather more ephemeral than the Earth's tectonic plates, seems a daunting prospect! Nonetheless, there are plenty of active researchers in this field, including at NASA and the European Space Agency (ESA). One academic collaborating with these organisations is Zita Martins at the Department of Earth Science and Engineering of Imperial College London. Ahead of her attendance to a symposium on the origins of life, I met with her to get some perspective on the extra-terrestrial influences on the beginnings of life on Earth.

The question of our 'alien origins' is usually taken with a good pinch of salt, as Martins explains. "It's important to appreciate that we're not talking about life being formed somewhere else in space and then being brought to Earth." However, it is entirely possible that the carbon-rich organic molecules contained within asteroids and comets, and delivered to Earth at the point of impact, do have a role to play in the initiation of life on our planet – and unpicking this biological history is a fascinating and multi-disciplinary science. Martins describes herself as an astrobiologist, but she has a background in chemistry and an understanding of physics and geology. "The beauty of astrobiology is that it draws together scientists from different fields, all trying to answer two big questions: how did life originate here on Earth, and is there life in other parts of our solar system?"

Zita Martins and a sample of space – in the lab at Imperial College London

So, what are the origins of life on Earth? There are a few theories which sit alongside a meteorite impact, including chemical reactions taking place around sea-floor hydrothermal vents. While Martins is happy to accept that there's room for contributions from many processes, she is drawn to a cosmogenic explanation in part because of a set of observations in our geological record. "We know that between 4.6 and 3.8 billion years ago the Earth suffered a heavy bombardment of comets and asteroids." Indeed, our whole neighbourhood was a risky place to be at this time, as there is evidence in craters on its surface that the Moon suffered the same astrophysical assault. "Geological records then show that life originated on Earth around 3.5 billion years ago," give-or-take the uncertainty in the geological dating method. So – cause and effect, or cosmic coincidence? Martins smiles: "As a scientist, I can't believe in coincidences!"