The reduction of polluting emissions often improves air quality – but sometimes all efforts seem useless. Why? A group of atmospheric scientists has revealed the ultimate cause of the contradiction

In the loop of the atmosphere

"WE have reduced emissions quite a lot in this city – why do people still need face masks?" This kind of question could be posed by a disappointed municipal official after smog remains following the implementation of new clean technology or restrictions in traffic. "Were all the efforts useless?" Not according to Tuukka Petäjä, professor of experimental atmospheric sciences at the University of Helsinki, Finland. "Despite the possible backlashes," he says, "it is crucially important to reduce the emissions. But it is true that sometimes the air quality does not seem to get any better. The situation may, unintuitively, turn even worse."

This, however, is not the whole story.

Petäjä and his colleagues have recently found the ultimate cause of persisting smog episodes in large cities. The reason for the perseverance of pollutant haze is hidden behind the complex microphysics and chemistry of the atmosphere. More accurately, there is a feedback loop which may strengthen itself with time – seemingly endlessly.

Petäjä puts it more concretely by drawing a circle like the one shown in Fig. 1.

"Imagine there is an emission of, say, black carbon. It is easy to understand that it increases the pollutant concentration of the air. The increased pollutant concentration weakens one special property of the

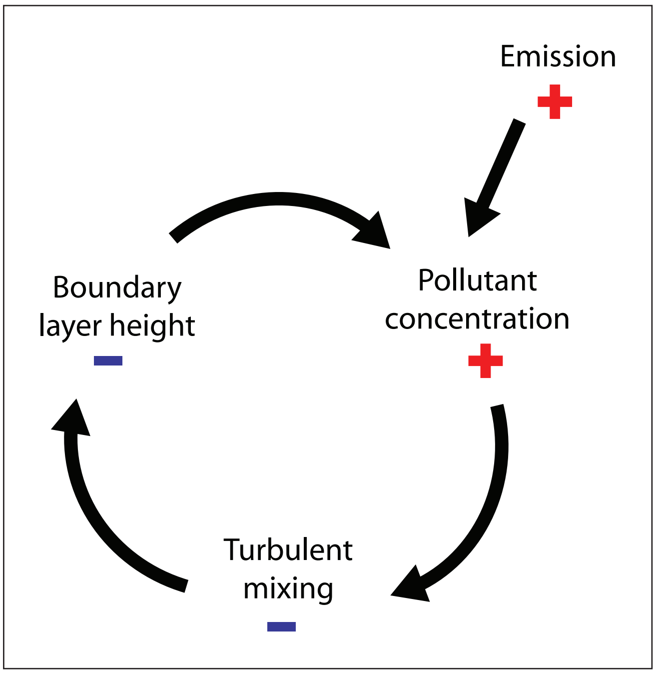


Fig. 1

The atmosphere is stratified. The layer which is affected by the surface of the Earth is called the boundary layer. During daytime it is turbulent, which means that the movement of the tiny aerosol particles and the ambient gas can be characterised as chaotic.

atmosphere called turbulent mixing. To simplify, the air cannot dilute to a larger volume. Less mixing, in turn, makes the boundary layer of the atmosphere even thinner. Now we come to the point: the thinner the boundary layer, the higher the pollutant concentration, although the original emission source remains constant."

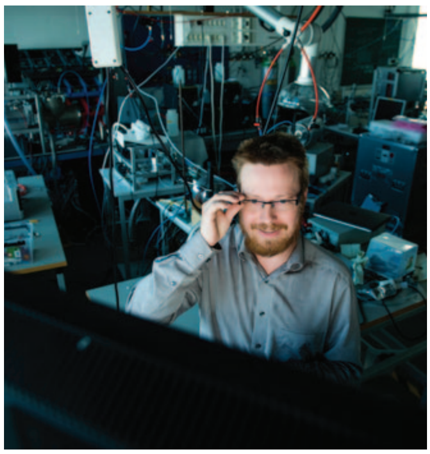
Is there anything we can do? Possibly a lot, says Petäjä. But to tackle the loops or to escape the vicious circle we need more basic knowledge of the interlinks between the Earth's surface and the atmosphere.

This is exactly what Petäjä does at the moment. The focus of his research group is centred on the different feedback loops prevailing everywhere in the atmosphere-biosphere interface.

In particular, Petäjä emphasises the importance of quantification: the loops should be quantified, revealing exactly, in the form of numbers, how one phenomenon or reaction affects another.

"Without this kind of quantitative knowledge we are not able to develop, say, reliable early

Professor and physicist Tuukka Petäjä explores the feedback loops of the atmosphere



The loops explored by Petäjä might be the ultimate cause of persistent smog episodes like the one shown here

warning systems in the cities," says Petäjä. "Knowledge offered by results of basic research also makes emission reductions more cost-effective. Because of the feedback loops, removing a certain pollutant from the air may even slow down the cleaning process of the air. The order of actions might under certain conditions make the difference.

"It should be noted that some feedback loops may turn out to have positive effects, for example by cooling the atmosphere. Nature has, thus, its own cleansing capacity, which we should support to make our own efforts easier and less expensive."

Hanna Lappalainen is the secretary general of the Pan Eurasian Experiment programme

Quite a few atmospheric scientists put it like this: mapping the unknown loops is the first and most important step to optimising the pathway to clean air and to tackling climate change.

PEEX opens boreal puzzles

Where, then, are the most important and currently unidentified feedback loops between the atmosphere and the biosphere? Probably in the northern forest and Arctic area, including Scandinavia, Russia, Siberia and China. This is why leading atmospheric scientists – including Petäjä and his colleagues – initiated the Pan Eurasian Experiment (PEEX) programme in 2012.

At the moment, there are already hundreds of physicists, chemists, forest scientists and other experts from all over the world contributing to PEEX. They have, for example, published their scientific results in the PEEX special issue of *Atmospheric Chemistry and Physics.*

One of the many aims of PEEX is to establish a network of technically special observation stations over an area spanning from Hyytiälä, Finland, to Nanjing, China. The effort is huge, covering some 25,000km^2. One single observation station is like a fully equipped laboratory located on site and run by specialised staff. The instruments therein are integrated to measure the material and energy flows between the Earth's surface

Many famous Russian science institutions are active participants of the Pan Eurasian Experiment programme. Besides, some atmospheric measurement instruments of Mukhtrino station in Siberia

and the atmosphere, and the measurement data is used to test various atmospheric theories and climatic models.

Petäjä and his senior colleagues already have experience in constructing, equipping and running observation stations. This is because Petäjä works for the Finnish Centre of Excellence in Atmospheric Sciences. The researchers of the centre have altogether established six technically special observational stations in Finland, Estonia and China. The stations are known under the abbreviation 'SMEAR': the Station for Measuring Earth Surface Atmosphere Relations. The oldest SMEAR station is located in Värriö, northern Finland, and has been producing data of various biospheric interlinks since 1991.

"True, we have a lot of knowledge concerning the observational stations," states Hanna Lappalainen, the secretary general of the PEEX programme. "However, to implement a plan of 30 new stations may take years, perhaps even decades. Thus we proceed by taking small steps. We have to think how the existing stations and measurement capacity could be linked to the PEEX programme.

There are many different flows between the Earth's surface and atmosphere. The organic vapours emitted from vegetation as a by-product of photosynthesis serve as an example of material flow. Radiation is an example of an energy flow.

"At the moment, we negotiate with political decision makers and business people both in Russia and in China. If everything goes well, we could possibly locate our first Siberian station in the city of Nadym, Russia."

Lappalainen emphasises that the main focus of the PEEX programme is not in observational stations. "One of our most important targets is to deliver a science-based message and recommendations to policy makers and institutions like the Arctic Council."

Hopefully, this aim will take a step forward in 2017 as Finland takes the chairmanship of the Arctic Council.

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