Cloud birth

And for my next trick… **Roy Harrison** (right) explains how particles appear out of thin air.

Living as most of us do in cities or other polluted regions, airborne particles are all around us. We only notice them when we see visible black smoke from a poorly tuned diesel engine or the emissions from a power station chimney, but they are there nonetheless.

Not all airborne particles are man-made: sea spray, desert sand, pollen and wildfires all count. Particles are essential ingredients for cloud formation. In some places, off the west coast of Ireland for example, particles are rare but clouds are not. Where are the particles coming from? Recently, our team and colleagues in Helsinki have developed the technology to pinpoint the moment when particles appear, almost out of thin air.

We are very close to observing the birth of new particles.

Airborne particles are microscopic fragments of solid and liquid matter floating in the atmosphere, some staying airborne for periods of days or even weeks. They are currently a very topical source of scientific interest for two reasons. Firstly, particles from pollution sources have a serious adverse effect on human health. Medical experts estimate that everyone in the UK is losing on average about eight months of life expectancy due to exposure to airborne particles. In some parts of Europe, the figures are much worse.

The other major role of airborne particles is in influencing the climate. The particles do this in two ways. Firstly, light-coloured particles can reflect sunshine back into space and this offsets some of the effects of greenhouse warming. On the other hand, black particles that come from burning coal or diesel absorb incoming sunshine and cause local warming.

Secondly, perhaps the most important effect particles have is on cloud initiation. Clouds develop when the atmosphere cools creating a supersaturation of water vapour. In other words, the air becomes more and more humid until the water vapour is forced out, condensing to cloud droplets. However, water molecules cannot just stick together to form cloud droplets. They need a surface (the particles) on which to condense.

Above oceans there may be few particles available, and of the total number present, only a small percentage have the right properties to act as what are known as cloud condensation nuclei on which cloud droplets form. Sea spray can provide a few nuclei, but it is not by itself sufficient to account for all of the cloud condensation nuclei present. There has to be another source of particles. That source comes from a process known as homogeneous nucleation, which is a term describing how molecules that struggle to become vapours draw together to form new particles: the birth of airborne particles. These newly born particles can grow to a size where they act as cloud condensation nuclei. This is crucial because clouds that form in an atmosphere with plentiful nuclei contain more and smaller water droplets than when nuclei are scarce. Clouds with a larger number of smaller water droplets are more efficient at reflecting sunshine back into space and thereby cooling the Earth's surface.

Researchers have been very interested in the chemical and physical processes involved in homogeneous nucleation as a source of new particles. It looks like one of the key processes is when sulfur dioxide reacts to form the much less volatile sulfuric acid. Sulfur dioxide has natural sources in the marine atmosphere, such as from the gas dimethylsulfide released from phytoplankton – tiny floating marine plants. If water and ammonia are present, sulfuric acid can form new particles. These new particles are of the order of one or two

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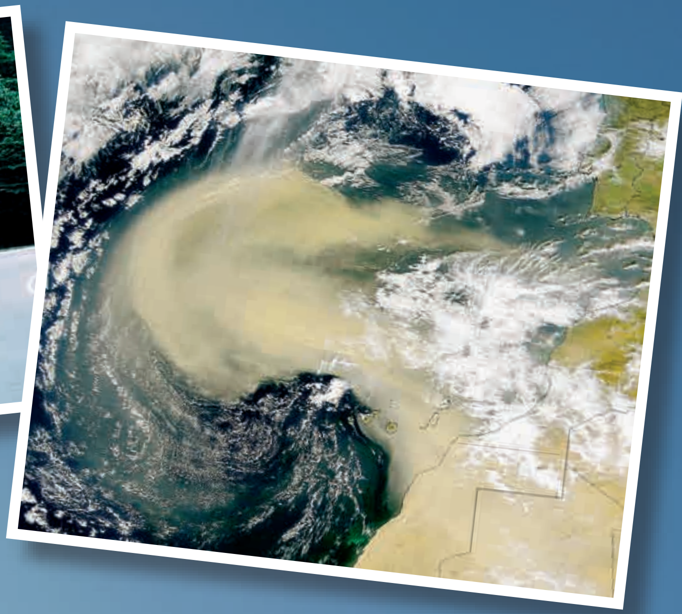


nanometres (or billionths of a metre) in size and contain just tens of molecules, or thereabouts.

Until recently, there were no instruments available with the resolution to allow us to observe the nucleation processes. In October 2007, we published a paper in the journal *Science*, a

Particles are essential ingredients for cloud formation.

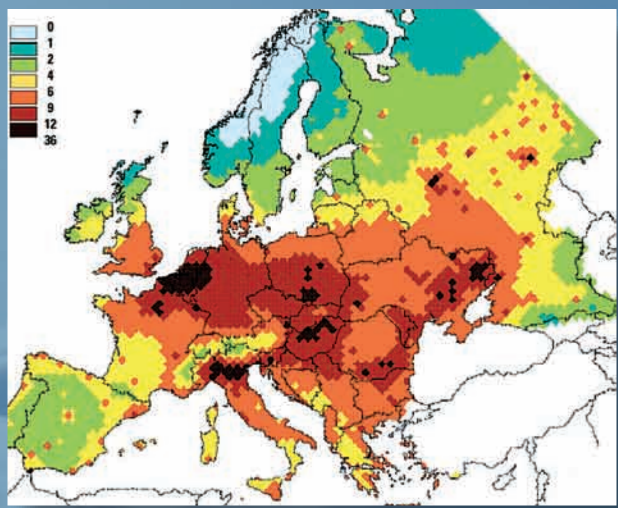
collaboration between the University of Birmingham and Markku Kulmala and colleagues at the University of Helsinki. The paper discusses new instruments developed by us which can measure particles below two nanometres in size and so come very close to observing the birth of new particles. Markku had already published a theory suggesting that the atmosphere typically contains a reservoir of short-lived clusters of involatile molecules which under the right conditions go on to grow into fully fledged particles. The new work provides dramatic confirmation of those concepts. We have already observed particle growth in a number of locations as diverse as the west coast of Ireland, where particles form from gases released by seaweed which contain bromine, and central Birmingham where particles have grown when organic molecules from road traffic and other sources such as paints and solvents are oxidised to less volatile molecules.

We now want to make more observations in the atmosphere and in laboratory chambers, which simulate the atmosphere under controlled conditions, to find out exactly which molecules club together to form new particles, and the environmental controls, for example, temperature or humidity, on these processes. ✿

Typical numbers of particles in a cubic centimetre of air

Marylebone Road, London	80,000
Russell Square, Bloomsbury	25,000
Rural Oxfordshire	8,000
Marine air	200

Loss in life expectancy attributable to exposure to fine particles from human atmospheric emissions in 2000. Source: IIASA



Roy Harrison is professor of environmental health at the University of Birmingham and NERC's environment, pollution and human health theme leader. Tel: 0121 41 43494, email: r.m.harrison@bham.ac.uk

More information

'Towards Direct Measurement of Atmospheric Nucleation', M. Kulmala, I. Riipinen, M. Sipilä, H.E. Manninen, T. Petäjä, H. Junninen, M. Dal Maso, G. Mordas, A. Mirme, M. Vana, A. Hirsikko, L. Laakso, R.M. Harrison, I. Hanson, C. Leung, K.E.J. Lehtinen and V.-M. Kerminen, *Science*, 318, 89-92 (2007). DOI: 10.1126/science.1144124