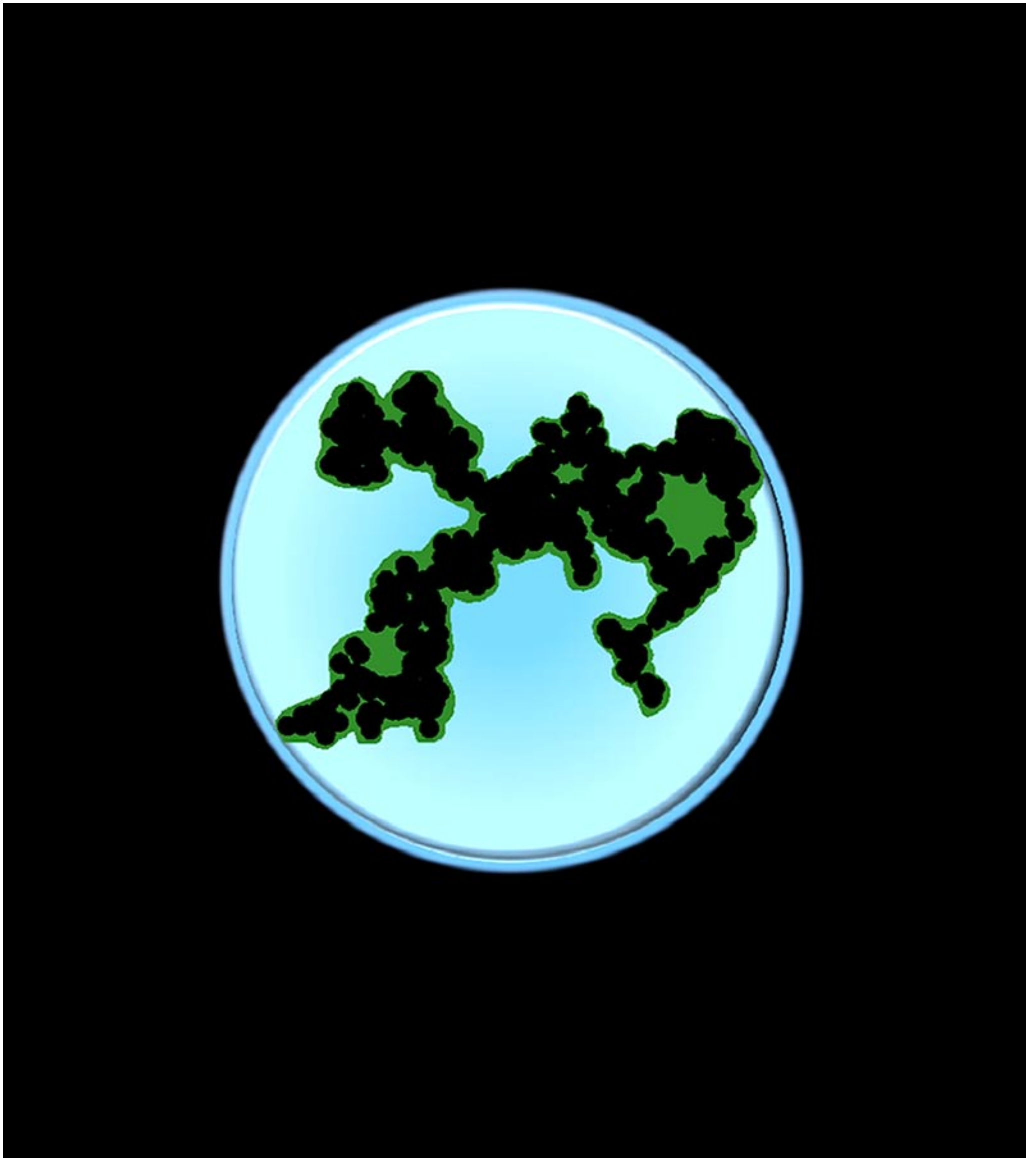
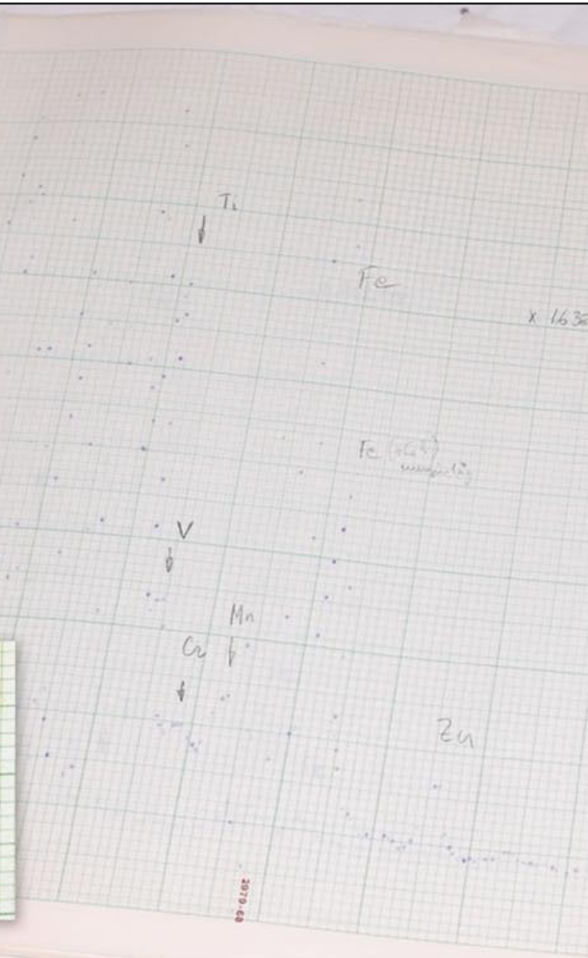


Atmospheric aerosols

Particles and gases in the atmosphere
form aerosols that can affect
the climate and our health.

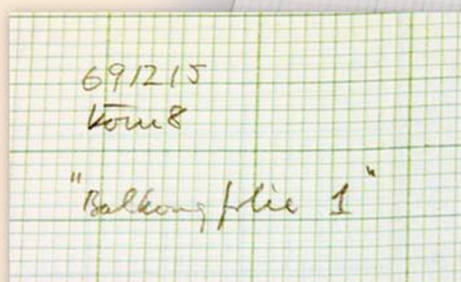
The advent of PIXE and its application to aerosols

One of the main advantages of PIXE (particle-induced X-ray analysis) is that it can be used to analyse several elements at once, in a very short time, in small samples. This makes the method suitable for the analysis of aerosol samples. An aerosol lab was established at the Division of Nuclear Physics at the end of the 1960s for just this purpose. In 1973, researchers at the division began collaborating with a research group at Florida State University in Tallahassee, USA. This contributed to the rapid development of sample collection techniques, and the use of PIXE to study atmospheric pollution in both Sweden and the USA.



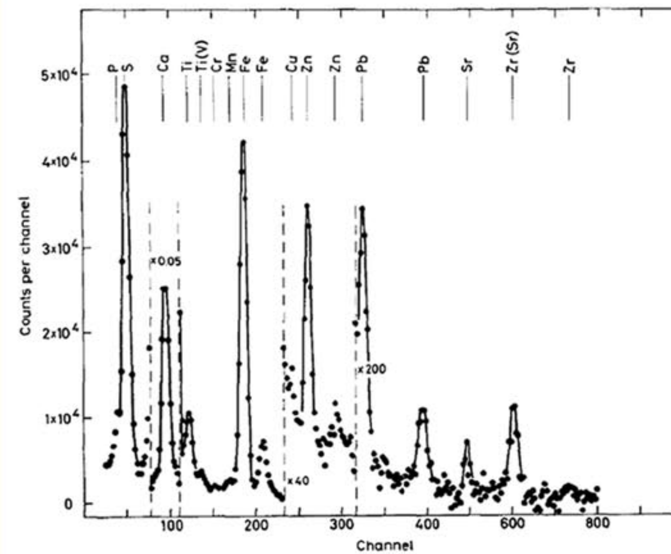
The term *Aerosol* is derived from the Greek *aer* meaning air, and the Latin *solutio*, meaning solution. An aerosol consists of small particles dispersed in a gas. These particles can be solid or liquid, and the term aerosol includes both the particles and the gas.

Typical examples of aerosols are smoke, fog, and atmospheric pollution.



The first measurement

When the environmentally committed innovators of PIXE, Professor Sven Johansson and his PhD students Roland Akselsson and Thomas B Johansson, looked for suitable applications of PIXE in the early 1970s, they identified particulate air pollution, and this became the area that developed most rapidly.



The original output from the first series of PIXE analyses of aerosol samples, carried out on 15th December 1969. The first scientific paper on PIXE was published in 1970.

Aerosol studies at the Division of Nuclear Physics

Hans-Christen Hansson, Professor at Stockholm University since 1994.

Bengt Martinsson

Erik Swietlicki

Birgitta Svenningsson

Bengt Martinsson, Erik Swietlicki, and Birgitta Svenningsson remained in Lund, and are involved in research on the effects of atmospheric aerosols on climate and health. Aerosols in the indoor environment are now being studied at the Division of Ergonomics and Aerosol Technology in Lund, but there are still strong ties between the two groups.

From the early work, a research group was formed to study atmospheric aerosols, including Hans-Christen Hansson, Bengt Martinsson, Erik Swietlicki and Birgitta Svenningsson. Initially, they studied the long-range transport of aerosols across national borders, and source–receiver studies related to the acidification of soils. Later, the relation between aerosols and climate became of interest, especially the interaction between clouds and particles.

Source–receiver modelling

One way of using PIXE to trace the source of particles in outdoor air is to look for characteristic *fingerprints*, which are related to the composition of the particles collected. It is then assumed that the particles emitted from different sources differ in terms of their elemental composition. Hans Lannefors and Hans-Christen Hansson performed the first studies as early as 1978, in Landskrona, to determine which sources influenced the air in the city, and several follow-up studies have been carried out there over the years.

Master's student, Hanna-Maria Frankman checks the sampling equipment in the harbour in Landskrona (2008). Boliden Bergsöe AB, a company that recovers lead from spent batteries, can be seen in the background.

Icebreaker expeditions in the Arctic

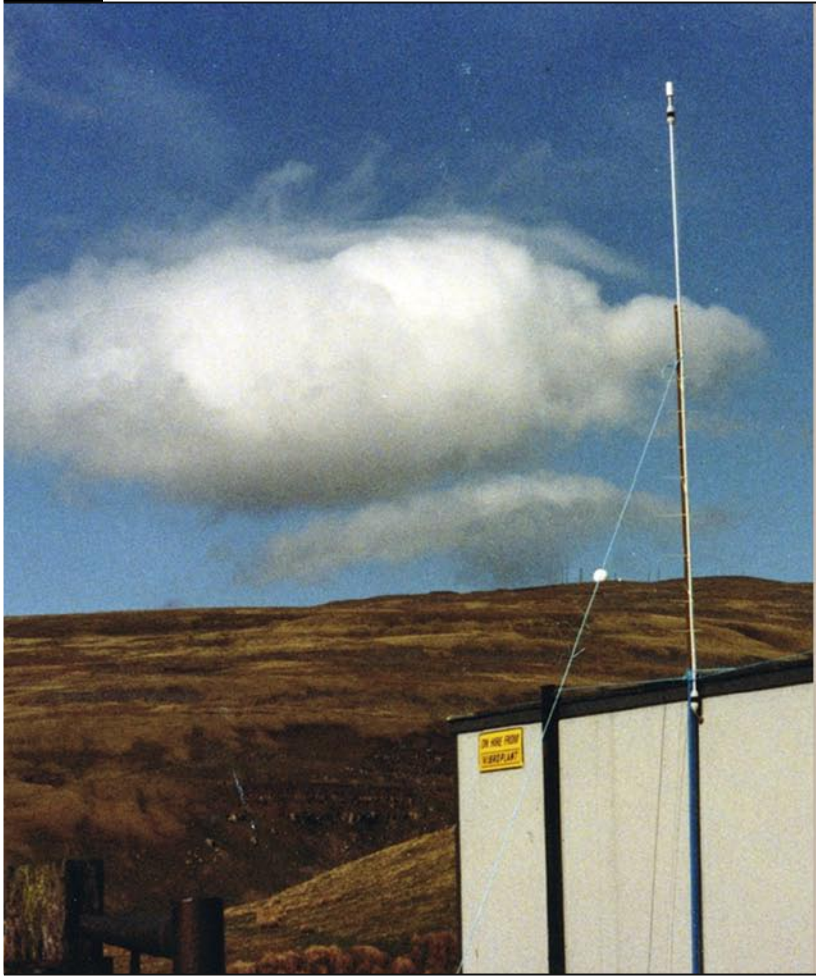
The Aerosol Group has participated in expeditions to the Arctic with the icebreaker *Ymer* in 1980, and with *Oden* in 1991, 1996, 2001 and 2008. The purpose of these expeditions was to study how particles are formed and how they affect the pure Arctic air found over the pack ice in the summer. These particles, in turn, affect the clouds and thus the radiation balance and ice-melting. Measuring the number of particles, and their physical and chemical properties in exceptionally clean air that is almost free of particles poses a considerable challenge.

The icebreaker Oden during the expedition to the High Arctic in the summer of 2001.

Cloud droplets

Cloud droplets form by the condensation of water vapour on aerosol particles, and particulate air pollution affects light scattering in clouds, causing considerable uncertainty in climate models. The Aerosol Group has participated in several international cloud experiments, and in this way contributed through unique custom-built instruments invented and developed by Bengt Martinsson, and further developed by Göran Frank. It was found that polluted clouds can contain considerably more drops than previously demonstrated, and that clouds with weak dynamics may have low visibility without the formation of thermodynamically activated cloud droplets.

Cloud studies using the droplet aerosol analyser (DAA) on Mt Brocken in Germany, 2010. The DAA set up for field measurements.



Aerosol researchers from Lund were also pioneers in the measurement of particle water uptake through their development of Europe’s first H-TDMA (hygroscopicity tandem differential mobility analyser) under the leadership of Hans-Christen Hansson. Within the framework of several international projects, Birgitta Svenningsson and Erik Swietlicki investigated the water uptake of particles during conditions of undersaturation with respect to water vapour (relative humidity of 85 % or 90 %) and showed, among other things, that this particle property, together with particle size, is important in describing which, and how many, particles act as condensation nuclei for cloud droplets.

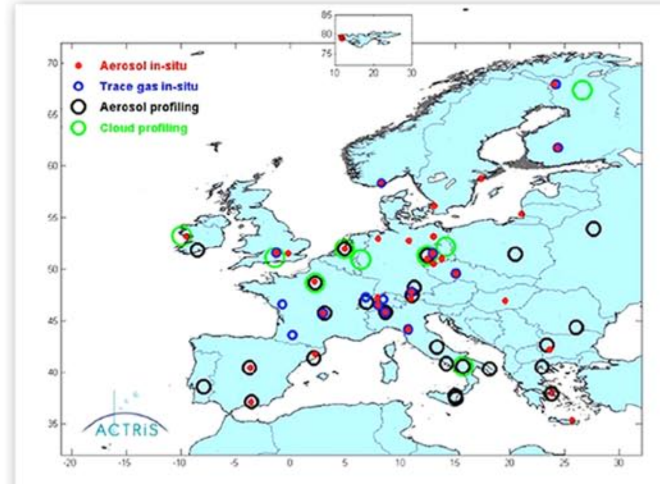
During measurements at Great Dun Fell, somewhat below the peak of the mountain ridge, which is visible in the background. In this way, it was possible to characterize the aerosols from which clouds were formed. The photograph shows clouds with bases higher than the peak, but when the peak is swathed in clouds the instruments provide information on cloud properties (see, for example, the DAA in the previous section).

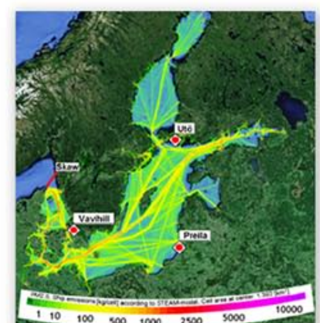
The field station at Vavihill

Already in the 1990s, Erik Swietlicki and his colleagues from the Division of Nuclear Physics realized that there was a need for stations in Sweden to determine the extent to which cross-border particulate compounds affect our health and the climate. Work was begun on a field station at Vavihill on Söderåsen. This station was made permanent in 1999, and is part of a larger European network of monitoring stations (ACTRIS). It has proven to be very important to many researchers across Europe and in global climate studies.

Doubling of particles

An example of the research being carried out at Vavihill is the study by Adam Kristensson, showing that emissions from ships in the Baltic Sea cause a doubling of the number concentration of particles as the air travels over the sea.





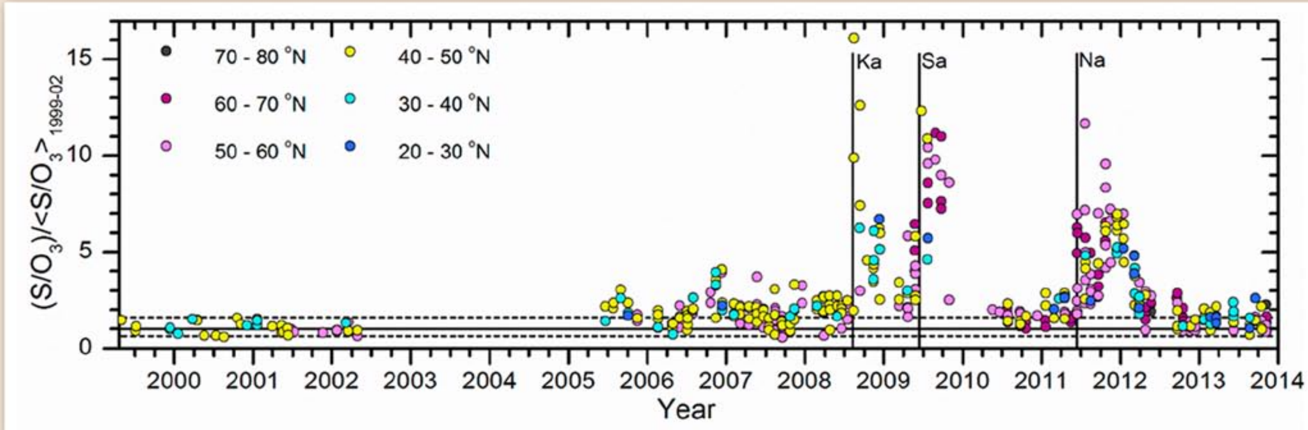
This picture shows the emissions of particulate matter smaller than 2.5 μm in diameter along the busiest shipping lanes in the Baltic Sea.

Airborne measurements

Detail from the wing of a Lufthansa Airbus 340-600 used in the IAGOS-CARIBIC project, showing the inlet for air and aerosol particles for atmospheric aerosol sampling.

The Division of Nuclear Physics has been part of the European consortium CARIBIC (now IAGOS-CARIBIC), under the leadership of Bengt Martinsson, since the 1990s. The upper troposphere and lower stratosphere are regularly investigated to map aerosols and trace gases using instruments on board intercontinental passenger aircraft.

Volcanic activity



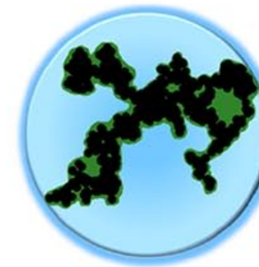
Time series of sulphur (S) concentrations in stratospheric aerosol particles. Volcanism leads to an increase in the ratio of sulphur to ozone (S/O_3) due to an increase in the sulphur concentration. The different colours indicate the latitude range for the measurements. Vertical lines indicate powerful volcanic eruptions: Kasatochi (Ka), Sarychev (Sa) and Nabro (Na).

The Aerosol Group collects samples that are analysed using the accelerator-based methods PIXE and PESA. Their work has resulted in a unique time series of elemental concentrations in aerosols. The results have been used in combination with measurements from the satellites CALIPSO and MODIS to better describe the natural variation in climate associated with volcanic activity.

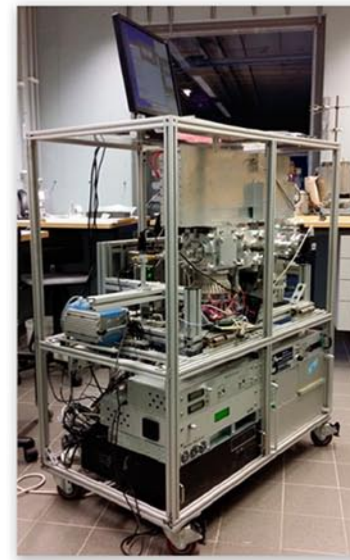
Particle studies in the Aerosol Lab

In recent years, several studies on soot, cloud droplet formation and simulated atmospheric aging have been carried out at the Aerosol Lab in Lund, which has a very high international standard, and is a joint resource for CAST (Consortium for Aerosol Technology at Lund University). Thanks to the availability of direct-reading instruments, it is possible to carry out detailed studies on, for example, the transformation of soot particles to cloud droplets and particle formation of volatile hydrocarbons from vegetation and human activities.

Conceptual image of a condensation nucleus consisting of an agglomerated soot particle with condensed organic material which has started to take up water to form a cloud droplet. This image forms the basis of the theoretical model developed to describe the experimental results.



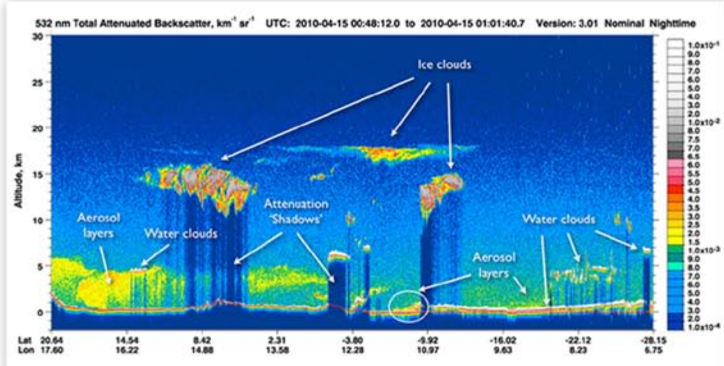
The aerosol mass spectrometer used to determine the chemical composition of aerosol particles.



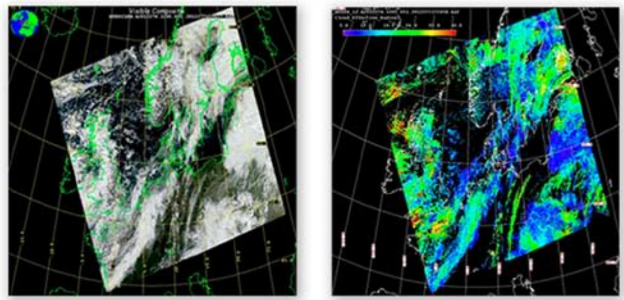
The potential aerosol mass (PAM) reactor used to speed up the aging of gases and particles that takes place naturally through oxidation.

Satellites as tools in aerosol research

Satellite measurements can be used to obtain a global picture of how aerosols affect clouds and the climate. The Aerosol Group's direct measurements on the ground or using aircraft can be compared with satellite remote sensing data. For example, studies have been performed to investigate how the number of particles in the air entering a cloud affects cloud droplet size and the ability of clouds to reflect sunlight back into space. In this way, it is possible to investigate whether air pollution in the form of small aerosol particles actually helps to cool the earth down, and if so, to what extent. Volcanic aerosol particles in the stratosphere can also affect high cirrus clouds and the climate.



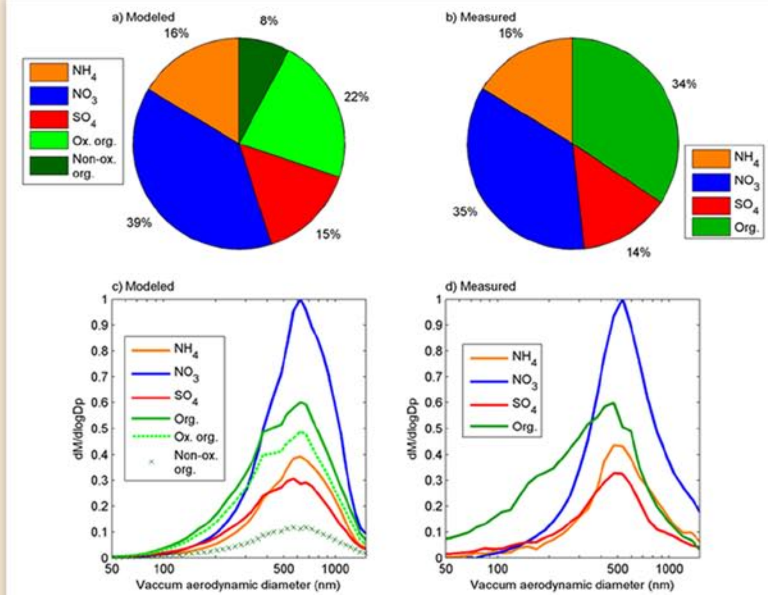
Vertical profile of the atmosphere obtained using lidar (laser radar) on the satellite CALIPSO. Both hot (water) and cold (ice) clouds are formed on the aerosol particles.



Examples of images of clouds from the satellite-borne instrument MODIS.

Aerosol dynamics modelling

The development of two aerosol dynamics models (ADCHEM and ADCHAM) was started by Pontus Roldin in 2008. ADCHEM is used to model the composition of atmospheric aerosols. It has been used to study, amongst other things, the dispersion of air pollutants from cities such as Copenhagen and Malmö. ADCHAM is used in the design and analysis of aerosol experiments in smog chambers. An important application is the study of secondary organic aerosol formation. Both models contribute to the work within MERGE, a strategic research area on climate modelling.



Comparison between the measured (with an aerosol mass spectrometer) and modelled aerosol particle composition at the measuring station Vavihill on Söderåsen, 50 km downwind of Malmö. The modelled organic aerosol composition has been divided into substances that are oxidized in the atmosphere and have then condensed on the existing aerosol particles (denoted Ox. org.), and non-oxidized organic substances emitted as primary particles or that have condensed directly without being oxidized in the atmosphere (Non-ox. org.).