Sylvia Knight

Cloud control

How to make a cloud

Clouds come and go, rain comes and goes. There is nothing we can do about it – or is there? And what are the implications if we do? ***Sylvia Knight*** *explains.*

Key words
clouds
evaporation
condensation
climate control

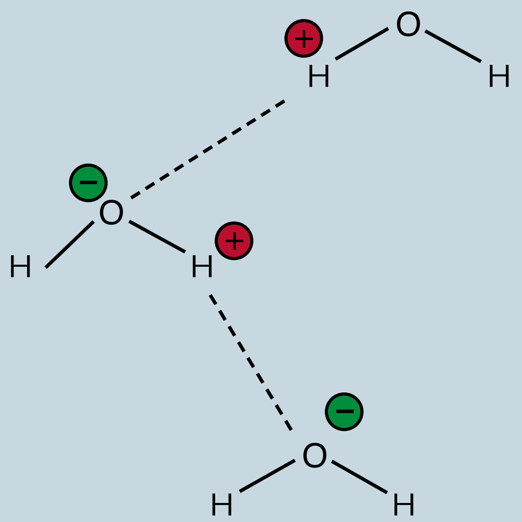
1 μm = 0.001 mm

What is a cloud?

Clouds are made up of hundreds of thousands of tiny droplets of water – about 10 000 000 000 per m^3! They form from water vapour in the air, whenever the rate of condensation is greater than the rate of evaporation – usually this means when the air is cold enough. It is similar to what happens when warm moist air from your shower hits a cold mirror. In the atmosphere the same process is at work: when relatively warm moist air cools, the air becomes saturated, the rate of condensation becomes greater than the rate of evaporation and a cloud forms. The temperature at which this happens is known as the *dew-point temperature*.

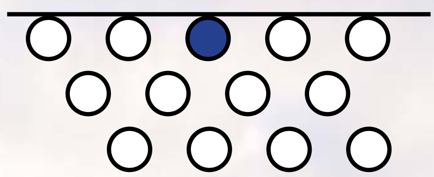
However, sometimes the air can be much colder than the dew-point temperature and still cloud droplets do not form. When relatively few water molecules form a tiny droplet, there are fewer neighbours attracting a molecule at the surface of the droplet holding it in place than there would be for a bigger droplet or a flat surface and the water molecule can evaporate more easily. In fact, the rate of evaporation from a droplet of radius 0.001 μm is more than three times as fast as from a droplet of radius 0.1 μm. It is therefore very difficult for cloud droplets consisting of just water molecules to form and grow.

The attraction between water molecules

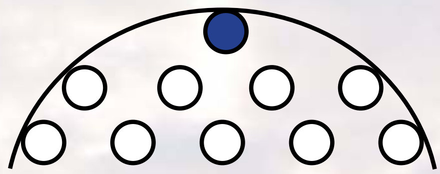


The dotted line represents the forces holding neighbouring molecules together

Water molecules have tiny negative charges on the oxygen atoms and tiny positive charges on the hydrogen atoms. These charges are much smaller than those on ions, but are strong enough to hold the molecules together more strongly than other molecules of similar size. These are the forces which hold water molecules together in droplets in clouds.



In a very large droplet or flat surface, there are many molecules binding a molecule near the surface, making it relatively hard for it to evaporate and leave the droplet.



In a small droplet, there are fewer molecules binding a surface molecule in place, so evaporation is easier.

How clouds form

Most cloud droplets get a 'head start' by forming on a particle in the atmosphere. This might be dust, soot, sea-salt or even phytoplankton. The particles are typically 0.1 µm or more in diameter. In this way, pollutants in the atmosphere are incorporated into clouds and can later be rained out of the atmosphere. The particles are called Cloud Condensation Nuclei (CCN). Cloud droplets grow – either as more water condenses onto each droplet, or by several droplets coming together and coalescing, until they are up to 9 mm in diameter. They then fall as rain, snow or hail.

Cloud seeding

The idea of cloud seeding is that by changing the number of CCN in the atmosphere, you can control how many cloud droplets there are. If the atmosphere is very clean, then adding CCN could cause a cloud to form. On the other hand, a cloud consisting of many small droplets is less likely to produce rain than a cloud with fewer, larger droplets.

Actually, most cloud-seeding techniques try to produce ice crystals rather than water droplets in the clouds. Once ice crystals have formed, they grow rapidly by taking water from any nearby water droplets because the intermolecular bonding is stronger in ice than it is in water. If the conditions are right, the latent heat released as the crystals form and grow can add energy to the cloud, increasing the convection going on and making the cloud grow much more rapidly than it would have done otherwise.

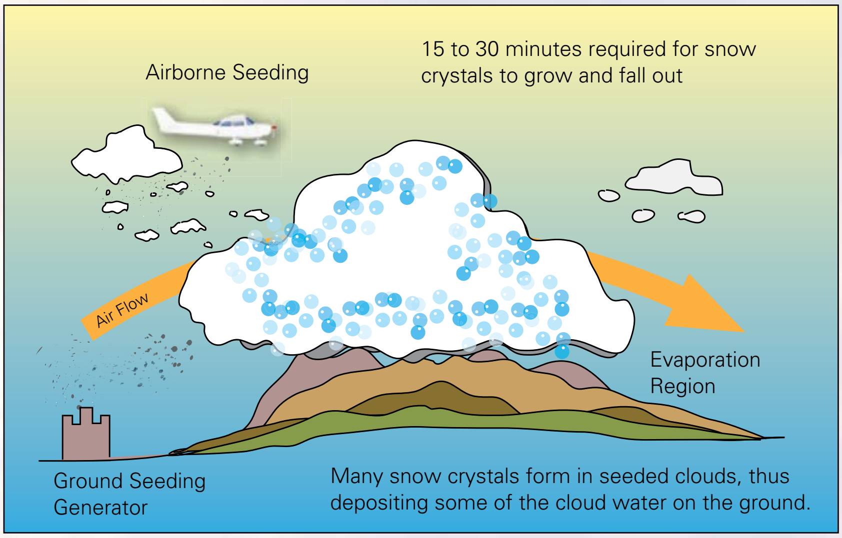
Typical substances used in cloud seeding include silver iodide, frozen carbon dioxide (dry ice) and salt. These are dispersed from aircraft, or fired into the atmosphere by ground based artillery.

A cloud-seeding aircraft is equipped with sprays along both wings.

Experiments

Cloud seeding experiments started in the mid 20th century. They continue today but there has been a lot of debate about how successful they are. There is a general consensus that winter cloud seeding over mountains can produce extra snow, and some studies suggest that cloud seeding in general can produce up to 30% more precipitation – rain or snow.

Dry ice crystals were dropped from a plane on this cloud in New York State in an early crop-seeding experiment, 1947.



Clouds often form over mountains, where rising air expands and cools. By adding silver iodide to the air, scientists hope to encourage ice crystals to form, so that they grow rapidly and produce more snow or rainfall than the cloud might have done otherwise. Some winter cloud-seeding projects over mountains in the USA have been running continuously since the 1950s, with the aim of supplementing water resources.

Ethical issues

Cloud seeding has led people to ask: who owns the weather? Does one government or authority have the right to cause it to rain more or less elsewhere?

Several governments have experimented with the cloud seeding. Between 1967 and 1972 the United States tried to 'make mud, not war' in Vietnam by intensifying the monsoon rainfall; an international treaty has since banned such actions. More recently, the USA has experimented with trying to affect the development of hurricanes by changing the cloud structure. This has similarly led to controversy. What happens if, by changing the intensity or path of a hurricane, a different set of people suffer adverse consequences?

Sometimes, clouds can be seeded inadvertently by aircraft. The exhaust from jet engines – mainly water vapour – cools rapidly. We sometimes see this as condensation trails (contrails) if conditions are right for clouds to form. However, if the aircraft flies through a cloud and conditions are just right, as the air expands and cools over the aircraft propeller or wing, ice crystals can be seeded. If these grow large enough and fall to the ground – probably melting into rain as they fall – they can leave clear skies behind, or a clear 'hole punch' in the cloud.

Contrails left by jet-engined aircraft flying through cold air.

This 'hole punch' cloud was formed by an aircraft flying through a cloud.

Cloud seeding at the Beijing Olympics

The organisers of the Beijing Olympics in 2008 used cloud seeding techniques to try to prevent it raining during the opening and closing ceremonies by forcing rain to fall before the events, clearing the skies, or away from the Bird's Nest Olympic stadium. Before and during the opening ceremony, 1 100 rockets containing silver iodide were fired into the sky. The ceremony was dry – but who knows whether that was because of the cloud seeding attempts. The organisers also had plans to induce rain to clear smog and other pollution during the games, if needed. Some reports suggest that China employs 40 000 scientists looking at weather modification and spent several million pounds on trying to manipulate the weather during the games.

Clouds over Beijing's Bird's Nest stadium, main arena of the 2008 Olympic Games

Cloud seeding and climate change

One suggested way of tackling (or at least masking) climate change involves spraying salty sea water into the air to encourage low clouds containing many, small cloud droplets to form. Clouds can have two impacts on climate. High level clouds act a bit like a greenhouse gas, absorbing heat from the Earth, whereas low clouds tend mostly to reflect the Sun's incoming visible radiation.

A cloud with many, smaller droplets is more reflective than a cloud with fewer, larger droplets (it looks whiter when viewed from space). So, if we can encourage low, reflective clouds to form, they will let less solar radiation into the atmosphere and it might not heat up as much as it would have done given only the increase in greenhouse gases. However, in 2010 the United Nations banned 'climate engineering' projects such as this one until they can be proven to have no unforeseen consequences, such as causing drought in some countries.

Stephen Salter of Edinburgh University designed wind powered ships like these which would spray salt water into the sky, seeding low level, very reflective clouds. These clouds could reflect incoming solar radiation, and cool the Earth, giving us time to reduce greenhouse gas concentrations in the atmosphere.

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