Fog studies

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Large fog collector at the Atacama Desert Center research site in northern Chile (Photo: FogQuest/Robert Schemenauer)

BLIND VISION

The impact of fog on ecosystems and society

Fog can be a positive contributor for water distribution and ecosystems but a hazard for transport, health and economies

Fog is defined by aviation experts as visibility less than 1km when no precipitation exists; it is basically a cloud in contact with the ground – a definition accepted by the meteorological community. Education about fog is important for pilots, as it can be a major aviation hazard. However, the impact of fog goes well beyond aviation, and has both positive and negative impacts on the environment and society.

When the general public thinks of fog, they usually think of it as a hazard. To a certain extent this is true, but its impact on the environment is huge, and sadly it is neglected in climate change assessments and sometimes in aviation mission planning. Transportation, communications and health are also affected adversely by fog.

Fog is also beneficial in many ways for the components of the hydrological cycle. It is a major reason for the sustainability of coastal forests in California and Australia, indicating that it is a source of long-term water supply. The fog water collected by high-elevation forests can sustain vegetation at lower elevations by contributing water to underground aquifers that can be used to raise crops. Fog water can also be collected effectively by man-made collectors to provide a managed source of clean water.

Fog observations and prediction

Fog formation, development and dissipation are strong functions of meteorological parameters that include temperature, relative humidity, radiation, wind, nucleation processes and surface conditions. It can be especially dangerous if it occurs at temperatures below 0°C – known as supercooled fog.

Fog observations are made using various spectral sensors such as the DMT FMD (Droplet Measurement Technologies Fog Measuring Device). Its spectral range is usually between 1µm and 50µm.

Using FMD measurements, the Fog Remote Sensing and Modeling (FRAM) field project in 2009 helped develop a visibility parameterization as a function of both liquid water content (LWC) and number size distribution (Nd), rather than only LWC, and this parameterization is used commonly for fog modeling approximations.

The most important issue in fog prediction is related to the prediction of Nd, which is either fixed or estimated as a function of aerosol number concentration in double moment microphysical algorithms. However, because of uncertainty in nucleation processes related to Nd, prediction of visibility includes large uncertainties. Comparisons of visibility obtained from various sensors also suggest that visibility bias can be up to 50%.

Fog as a benefit

To better understand how fog can be used as a managed water resource and how it is used by forests, we must understand something about its microphysics. Fog is composed of microscopic liquid droplets that usually have diameters between 1µm and 50µm. More typically, the droplet diameters are less than 25µm in size. Because the droplets are so small, their settling velocities are negligible compared with horizontal winds. This means that they move with the winds. This also means that a fog collector should be a vertical surface in order to intercept the droplets that are moving horizontally.

TRAFFIC HAZARD

Massive highway accidents occur in the presence of dense fog by reducing visibility down to a few meters. According to the Federal Highway Administration of the USA, fog is a contributor to 3% of weather-related accidents, 3% of weather-related injuries, and 9% of weather-related deaths.

There are efforts to improve road safety and these efforts include the fog chamber studies such as work done in the Regional Laboratory of Bridges & Roads in Clermont-Ferrand, France.

There are also innovative fog collection systems in place to remove fog that would otherwise occur across highways.

capable of being constructed in the country of use from largely locally available materials.

Cloud forests, defined as forests fed by cloud or fog LWC, are actually fog forests, since the clouds are touching the ground. The collection of fog droplets by the foliage results in the coalescence of the droplets into larger drops that then drip onto the ground (throughfall) or run down the stem (stemflow). This supports the individual tree water need, but also contributes water to the aquifers.

On a larger scale, the fog cycle is an important hydrological process, but it is rarely used in hydrologic studies. The need for fog water has perhaps been looked at most carefully in the case of the Californian redwood trees, but it is also an important

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There are also other considerations that result from a study of fluid flow around obstacles, such as the optimum size of the collection fiber and the need for an open structure that the wind can pass through. It is the wind that will carry the microscopic droplets to the collection surface. For this reason, solid structures, no matter what their surface characteristics are, will always be very poor choices as fog collectors.

The liquid water content in fog typically ranges from 0.005 g/m^3 to 0.5 g/m^3; however, the LWC range for suitable fog collection is approximately from 0.05 g/m^3 to 0.5 g/m^3.

It is necessary for large volumes of air to pass through a fog collector to generate useful amounts of water. This, in turn, means that fog collectors have very large surface areas. It also means that the sites for fog collectors must be very carefully selected and this is usually done with a standard fog collector that can be inexpensively deployed. The amounts of fog water collected at operational fog collection sites range from 2-30 l/m^2 per day, with annual averages of around 5 l/m^2 per day, being considered a productive site. In scientific investigations of fog, more complex instrumentation can be used to measure the actual fog liquid water contents and the meteorological conditions.

Materials used

There are practical considerations in choosing materials to optimize the water collection by the large fog collectors. To be useful in remote parts of developing countries, materials must be inexpensive, durable, made of non-toxic materials, and

A 1m² standard fog collector, such as this example in the Atacama fog oases in northern Chile, is used to measure fog fluxes (Photo: Nicolas Zanetta/Atacama Desert Center)

water input to ecosystems in many temperate and tropical locations. Fog has other impacts on forest health through increasing humidity, reducing solar radiation, and influencing the presence of plant diseases and insects.

Fog as a hazard

Fog is not only a source of water for ecosystems, but also a hazard for aviation and both marine and land transportation. For example, in 1977, at Los Rodeos Airport (now called Tenerife North Airport) on the Island of Tenerife in the Canaries, the deadliest airplane crash in history occurred when two Boeing 747s collided in the fog and 583 people were killed. Although pilot error was the main factor, the dense fog was a contributing cause.

Fog dissipation is an important process that has been used for 60 years or more and needs to be studied further. It may be used for mitigating the hazards of airport fog when fog occurs at a temperature below 0°C. One technique for dissipating cold fog is to use a land-based vented liquid propane system. The vaporizing propane reaches very cold temperatures resulting in the freezing of liquid water droplets along with the formation of additional ice crystals. The ice crystals then grow at the expense of the water droplets because of their low pressure at the surface. The fall of ice crystals clears the air when no additional moisture moves in and improves visibility.

This technique has been used successfully for many years at Fairchild Air Force Base, Washington, USA. Cold fog can also be dissipated by the airborne dispensing of crushed dry ice, but this technique can be dangerous as any improvement in the visibility may be short-lived once the seeding has terminated, creating landing issues for pilots.

The Great Smog of 1952

Another adverse effect of fog occurred in London, in December 1952. The Great Smog occurred and lasted for five days. Thick with soot and with high concentrations of sulfur dioxide from the burning of soft coal, the fog was thought to be responsible for 12,000 excess deaths (deaths in excess of what would normally be expected) during the fog and for weeks afterward. The elderly and those with respiratory conditions were especially vulnerable.

Similar to the London Fog, in the town of Donora, Pennsylvania, USA, during October 1948, a zinc smelting plant and steel mill's emissions contributed to the toxicity of the fog resulting in severe respiratory issues. During the fog, high levels of sulfur dioxide and fluorides were observed. According to the Pennsylvania historical and museum commission, this fog contributed to the deaths of 19 people. Events like the Great Smog and the Donora fog were the impetus for clean air legislation passed in the UK and the USA during the 1950s and 1960s.

Fog can be a positive contributor for water distribution and ecosystems or a hazard for the economy and human activities. It can be used to provide drinking water over mountainous and coastal regions. Fog also provides a great opportunity to study and understand cloud formation, to document changes in climate, and to test instruments and operational procedures under challenging weather conditions. Overall, its observations and modeling aspects need to be improved. ▮

It takes 10 million fog droplets to make a drop the size of a match head on the end of the Ponderosa pine needle, but this process is widespread in both temperate and tropical ecosystems (Photo: FogQuest/Robert Schemenauer)

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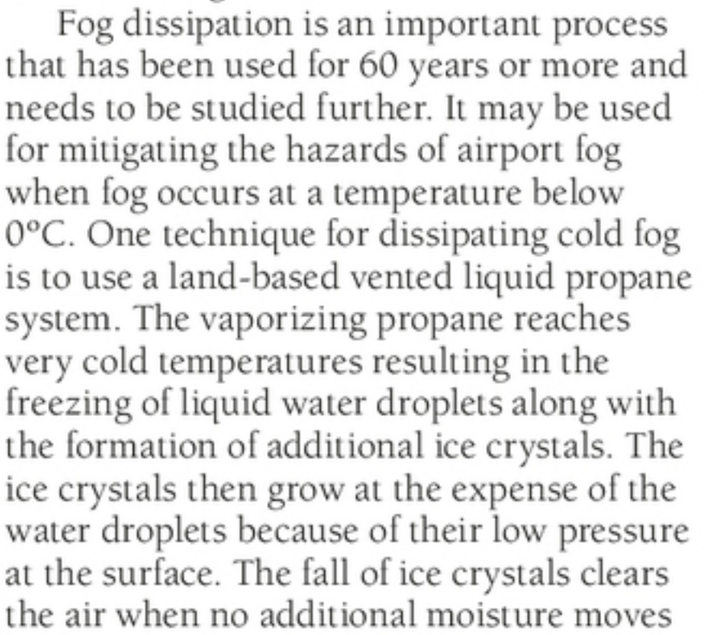

At temperatures below 0°C, liquid fog droplets freeze on impact with structures to form rime ice – this is a wintertime fog deposition process (Photo: FogQuest/Robert Schemenauer)

Fog water in remote locations meets drinking water standards and can be used for a wide range of domestic and agricultural uses. This photo is from a project in the Western Highlands of Guatemala (Photo: FogQuest/Melissa Rosato)