Methods for Fog Abatement

Visibility – Reduction of Light from Object

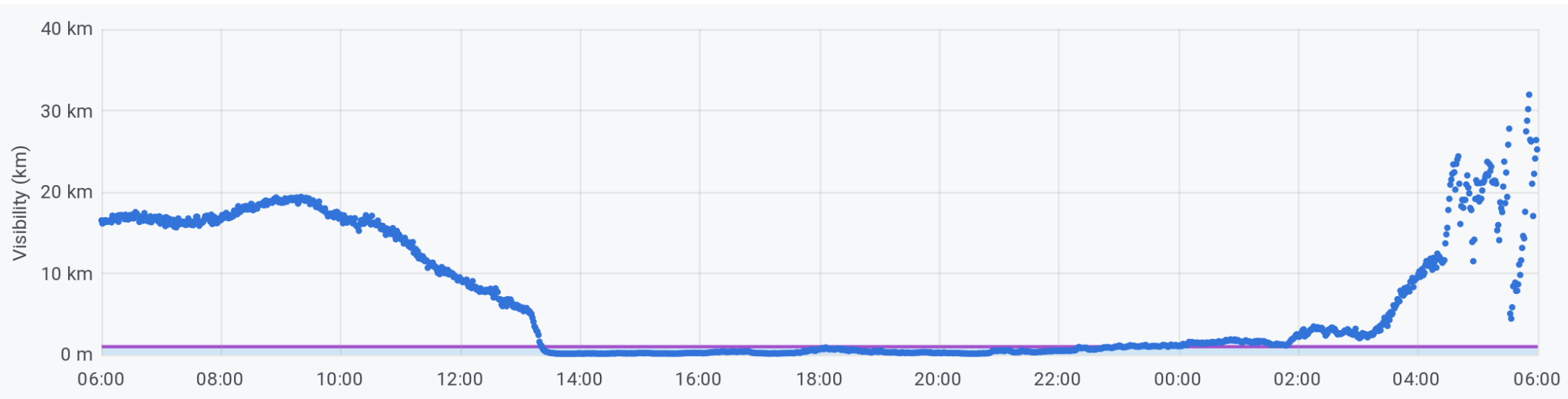
- We are able to see and discern objects when there is light coming from the object to our eyes.
- Visibility is reduced by particles in the atmosphere that scatter light, thus changing the path of the light coming from an object.
- The amount of scattering is proportional to the number and size of the particles.
- If there is enough scattering taking place, we are no longer able to discern the object.

Visibility – Equation and Measurement

Visibility (VIS) is typically related to extinction (Ext) as:

$$VIS = 3 / Ext$$

- Extinction can be derived from the particle size distribution and is the summation of scattering and absorption of light.



Time (UTC) series of 1-min visibility during a fog event at the Fargo International Airport (FAR) on December 15-16, 2021 obtained with a Campbell Scientfic Model CS125 Present Weather Sensor. The violent horizontal line denotes 1 km visibility.

Fog – What is it?

- Basically, a stratus cloud very near the ground.
- Visibility is reduced in proportion to the sum of the optical scattering cross-sections of the fog particles.
- Therefore, many small droplets reduce the visibility much more than a few large droplets.

Fog Abatement - Objective

- The objective of fog abatement programs is to reduce the numbers of fog particles by either:
  - removing the water from the air completely, or
  - converting the many small particles into a few larger particles.

Fog Abatement - Methods

- The most proven of weather modification methods/types.
- Generally employed at airports, where the cost of closing an airport for any length of time can be considerable.

Types of Fog

- Supercooled
- Warm
- Ice

Dissipation of Supercooled Fog

- The easiest type of fog to clear, assuming that the temperature is colder than about -2 °C.
- Most common approach is seeding with glaciogenic seeding agent.
- The objective is to form ice crystals that grow rapidly while the water droplets evaporate.

Glaciogenic Agents for Supercooled Fog

- A cooling substance such as dry ice or liquid propane is often used since the supercooled fogs are often at temperatures of -4°C or warmer, where most ice nuclei are relatively ineffective.

Seeding Techniques for Supercooled Fogs

- Seeding can be done from the air, but it may be difficult to get the seeding aircraft off the ground if the airport is closed due to the fog.
  - Unmanned Aircraft Systems?
- It is becoming more common to have ground systems in place around the airport for release of liquid propane.

Seeding Methods for Supercooled Fogs

- Generally, it requires about 30 minutes for a supercooled fog to be cleared by seeding.
- Therefore, the seeding is not usually done right over the runway, but about 30-45 minutes upwind of the runway.
- Winds are normally light during times of fog formation; hence, distance from runway is usually within 1-2 miles of the runway.

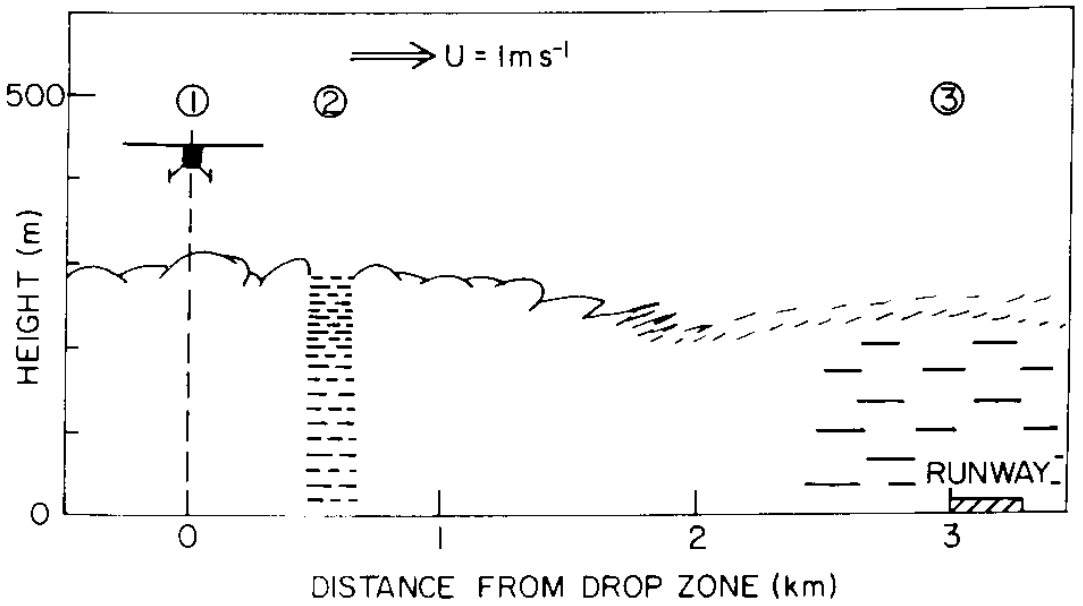


Fig. 7.1. Clearing of supercooled fog by dry ice seeding. (1) $t = 0$. Aircraft drops dry ice at 1 kg km^{-1}; ice crystal curtain forms with 5×10^8 crystals per square meter. (2) $t = 500$ s. Curtain drifts downwind while spreading due to turbulence. Ice crystal concentration has decreased to a few thousand per liter due to turbulent spreading. (3) $t = 3000$ s. Runway visibility improves as area of partially cleared cloud, now over 1 km wide, drifts across runway. Ice crystal concentration is down to about 100 liter^{-1} due to turbulent spreading, aggregation, and fallout. Very light snow near runway or upwind. (4) Cleared area fills in due to turbulent mixing with untreated air some 50–100 min after dry ice drop.

Supercooled Fog Seeding

- Videos - https://www.voanews.com/a/fog-busters-airports/3765780.html

Cloud Seeding Supercooled Fogs

- Seeding closer to the runway will not produce complete clearing, but may improve visibility enough to land aircraft.
- Fogs forming under relatively high wind conditions (advection fogs) tend to be much more difficult to clear, especially with aircraft.
- Radiation fogs tend to form under light winds and is easier to clear.

Cloud Seeding Warm Fogs

- Harder to clear than supercooled fogs.
- Two approaches are common:
  - Seeding with Giant Hygroscopic Nuclei
  - Heating the Air

Cloud Seeding Warm Fogs Issues

- Unlike seeding a convective cloud, where there is substantial depth and time due to the presence of updrafts involved, the particles used to seed the fog are only going to be available for several minutes and will fall to the ground.

Seeding Agents for Warm Fogs

- Problems with most hygroscopic substances (like NaCl) is that they are not environmentally acceptable in the quantities that must be used.
- One of the more acceptable hygroscopic substances is urea.
  - Not quite as effective as NaCl, but much better to the environment.

Cloud Seeding Warm Fog Experiments

- Most experimentation with seeding warm fogs has been done with numerical models.
- A few field experiments have been conducted with limited success.
- Generally, the cloud seeding approach is not used operationally.

Heating for Warm Fog Clearing

- The importance of clearing fogs at airports along with the fact that a relatively small volume of the fog has to be cleared make a “brute force” technique attractive.
- Clearing by heating was used in England with FIDO (Fog Improvement and Dispersal Operation) during WWII.

Operations for Heating Warm Fog

- An operational system (called Turboclair) was installed at Orly Airport in 1970.
  - Consists of a series of jet engines run in underground chambers just upwind of the runway.
  - Expensive to install and to run, but cheaper than closing the airport.
  - Similar systems have been installed in several other airports.

Turboclair

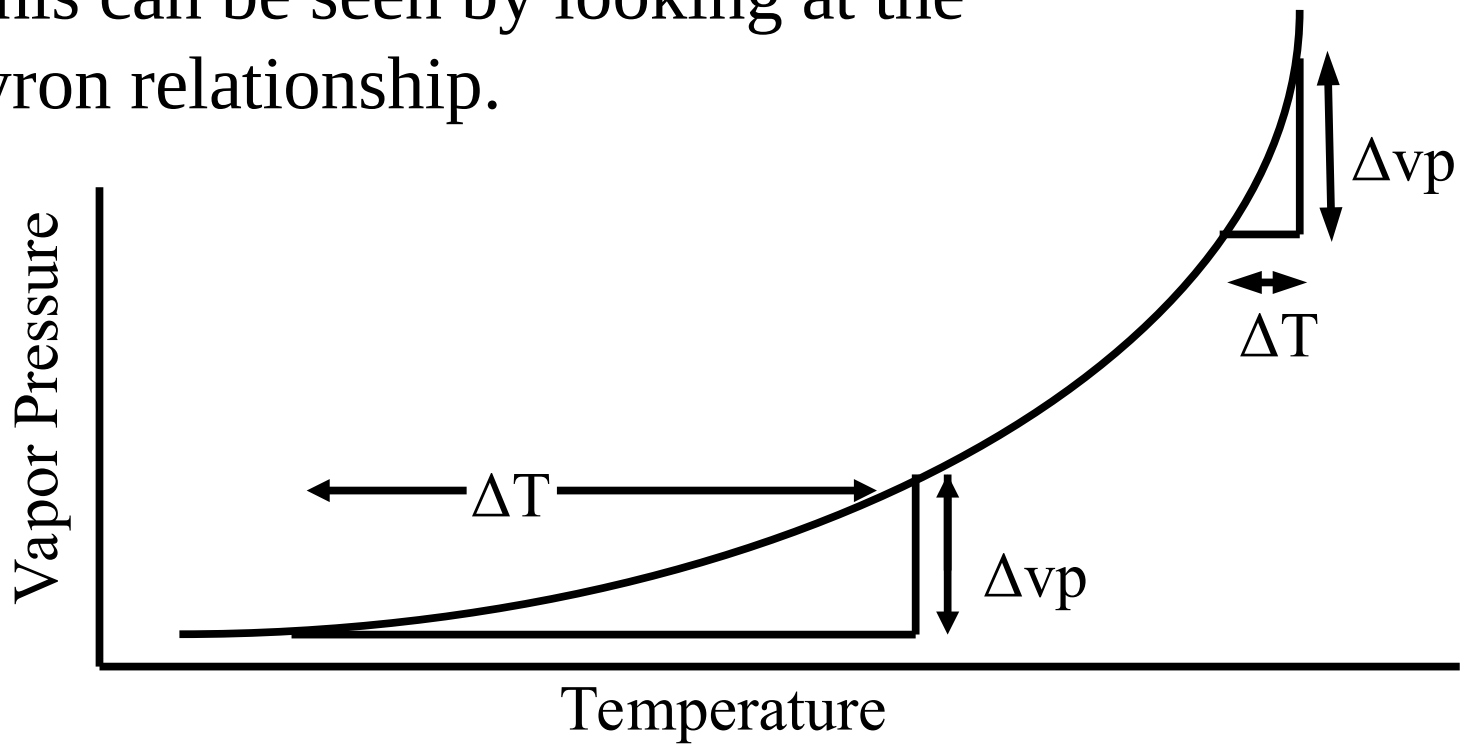
- Works best where the winds are light (radiation fogs)
- Where wind speeds exceed a couple meters/second (advection fog), it is not very effective.
- LAX was investigating a Turboclair installation, but the winds are often too high.

Ice Fog Removal

- This tends to be the most difficult of the three fog forms to clear.
- Glaciogenic seeding obviously will do no good, since the fog particles are already in the ice phase.
- Hygroscopic seeding will not do much good since the vapor pressure in the cloud is close to saturation with respect to ice instead of liquid, retarding the growth of water drops.

Ice Fog Removal

- Heating can be done in an ice fog, but it is not nearly as effective as in a warm fog.
  - The reason for this can be seen by looking at the Clausius-Clapeyron relationship.

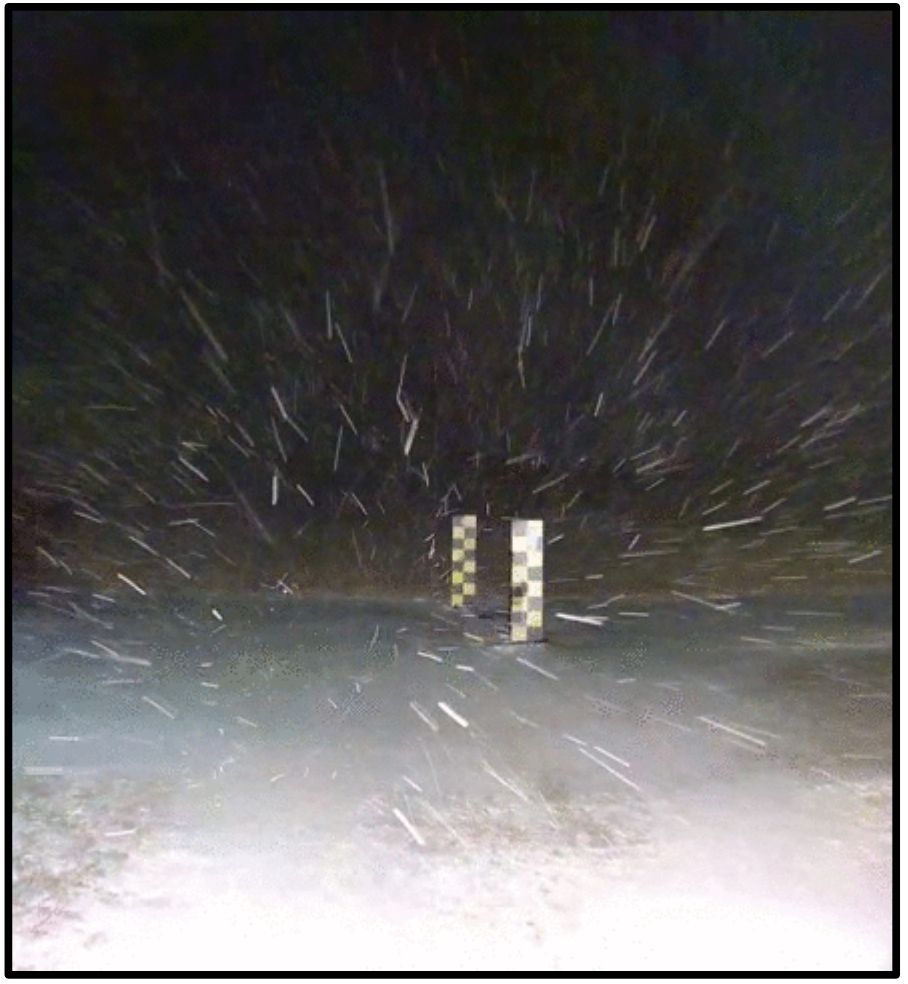


Ice Fog Heating Methods

- In the heating methods, one of the biggest problems is keeping the air close to the surface.
- When the warm air is introduced at the surface, it tends to rise and the space vacated is filled in with foggy air.
- The more heating, the worse this problem becomes.

Ice Fog Locations

- Fortunately, ice fogs are relatively rare where there are large airports.
- The only work that has been done on curing an ice fog problem has been to try to eliminate the source of the problem.



Other Approaches to Clearing Fog

- Helicopter downwash. This has met with some success, but tends to be very short-lived.
- Various droplet collection schemes.
  - “Fog Broom”
  - Planting of Evergreens