The Bureau of Meteorology

Aviation services

Fog

Hazardous phenomena

Fog is a major cause of low visibility at airports. As such, it is both a hazard and an inconvenience to aviation traffic.

Credit: Ashwin Naidu

Introduction

The low visibility associated with fog at an airport causes a major problem with taxi, takeoff and landing, resulting in significant delays and diversions. Widespread fog obscuring ground features may also impact the enroute visual navigation.

Fog is defined as a concentrated suspension of very small water droplets causing horizontal visibility to be less than 1,000 metres. If the fog layer is less than 2 metres deep, it is termed shallow fog.

Fog requires the relative humidity near the surface to be near or at 100%, as well as sufficient condensation nuclei for water droplets to form.

Fog formation involves either a decrease in the air temperature or an increase in moisture, or both.

Types of fog

Radiation fog

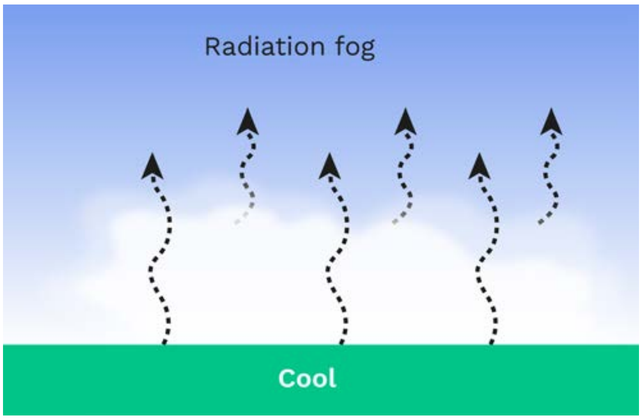
The ideal conditions for the development of radiation fog are:

- high relative humidity at low levels so that overnight cooling will be sufficient for the air temperature to fall to or below its dew-point temperature, causing water vapour to condense into liquid droplets.
- cloudless or near cloudless skies, to allow a large heat loss at the ground, subsequent cooling of the air where the surface temperature becomes close to or equal to the dew point, and condensation.
- light winds (generally 5 knots or less) to promote mixing of this cooled air through a few hundred feet above the surface. Note that a calm wind tends to produce dew or very shallow fog.

Radiation fogs occur primarily overnight or in the early morning. In mid-latitudes, anticyclones (high pressure systems) provide a favourable situation for radiation fog, particularly if the preceding weather system has brought a moist air mass to the area. In the tropics, fog is more likely to occur during the dry season when pressure gradients are weak.

The balance of ingredients is often critical. Small particulate matter assists the process by providing condensation nuclei, so a fog that would not form in open countryside may form under the same circumstances near a city where small pollution particles provide the necessary nuclei. If the wind is calm, the cooling may take place through a depth of just a few centimetres and heavy dew is the only result. The small amount of turbulence (and subsequent mixing of the cooled air) caused by the sun's first warming rays may tip the balance and change clear conditions into an all-enveloping shroud.

Ground moisture can also contribute, so a clear, calm night after a period of rain is also favourable. Since cold air sinks into valleys, these are preferred areas for radiation fogs, especially if a stream or river adds

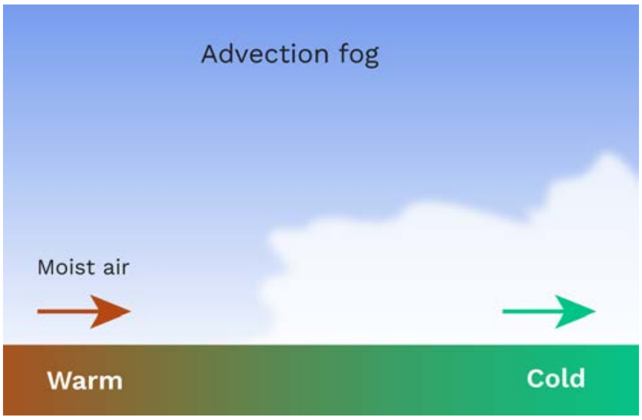


moisture to the air. From the air, fog can be seen like a smooth carpet snaking through the valleys while surrounding hill tops are clear.

Radiation fog usually disperses a few hours after sunrise as the ground warms the air above and moisture evaporates once again. An exception is when the fog is very thick or when middle-level cloud has moved over the fog and slows the heating effect of the sun.

Advection fog

Advection fog develops when warm moist air moves (advects) over a cooler surface resulting in the cooling of the air to below its dew-point temperature, and subsequent saturation and condensation. Radiation processes frequently assist in the formation and maintenance of this type of fog, but it is still usually called an advection fog. A certain amount of turbulence is needed for proper development of advection fog, with wind between 6 to 18 knots required to facilitate a deeper fog. Unlike radiation fogs, advection fogs are often thick and persistent.

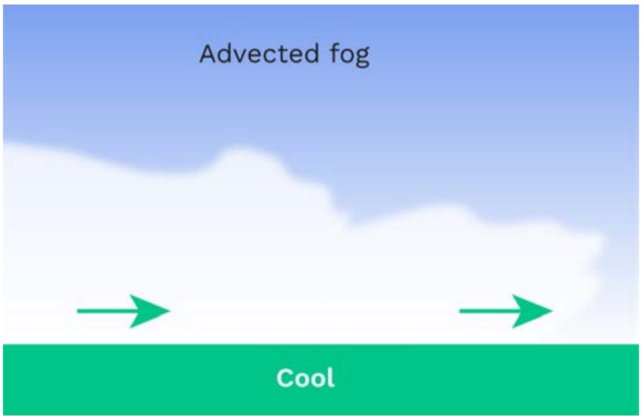


Sea fog

Sea fogs are usually advection fogs. They develop when moist air that has been lying over a warm water surface moves over a colder water surface, resulting in the cooling of this air to below its dew-point temperature. When sea fog forms, it is often widespread and persistent even in moderate strength winds, sometimes lasting for several days around the Australian coastline. They can occur at any time of the year. The main dangers to aviation presented by sea fog are when it drifts inland over coastal aerodromes during the daytime, usually with a sea breeze, or when it obscures the sea surface for seaplane operations.

Advected fog

Advected fog is any fog that forms remotely and is transported (advected) by light winds into an area previously clear of fog. Advected fogs are common in Australia, with Sydney, Adelaide and Hobart being particularly susceptible to this type of fog in the cooler months.



Steam fog

Steam fog is caused by evaporation from water into overlying colder air, causing the air to become saturated and condensation to occur. The convection currents above the water give rise to the steaming appearance. The fog may remain in situ but any light wind may advect it many kilometres. This is a common occurrence in inland Australia where large, shallow and warm waterways and dams exist. In coastal areas, where cool land breezes have the opportunity to flow across warm seas, steam fog can be extensive and lift into low stratus.

Freezing fog

Freezing fog is made up of supercooled liquid water droplets that freeze onto parked aircraft as rime ice. This will increase aircraft drag, which can inhibit takeoff.

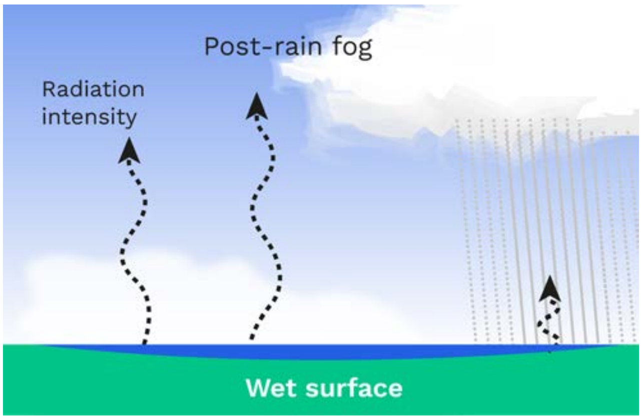
In Australia, freezing fog is an uncommon event but does occur in the middle of winter at airports such as Canberra, Cooma and Launceston. Freezing fog is a common occurrence at aerodromes in Antarctica and can greatly impact Antarctic flying operations.

Frontal fog

Frontal fog occurs at the boundary of 2 air masses rather than within a single air mass. It mainly develops due to precipitation falling from relatively warm air above a frontal surface, evaporating into drier and cooler air below, causing this air to saturate and condense. Such fogs usually form rapidly and are very extensive. The danger of such fogs to aviation is that, unlike radiation fog where the visibility above the fog is good, a frontal fog will be associated with generally poor weather aloft, such as dense cloud and precipitation. Fortunately, such fogs are not common in Australia.

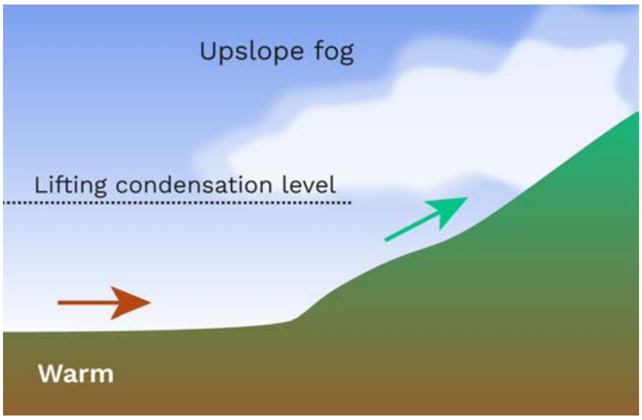
Post-rain fog

Post-rain fog more commonly occurs during the evening or overnight when radiative cooling increases. After rain events, and with the wind nearly calm, the air in contact with a wet surface can be readily saturated without depleting the overlying air of moisture. Thus, the atmosphere is primed for the rapid development of fog.



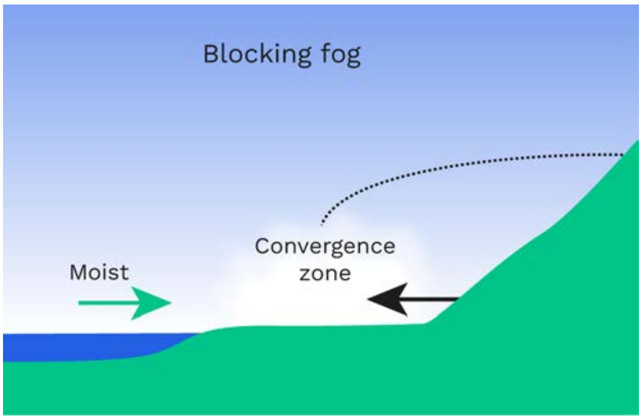
Upslope fog

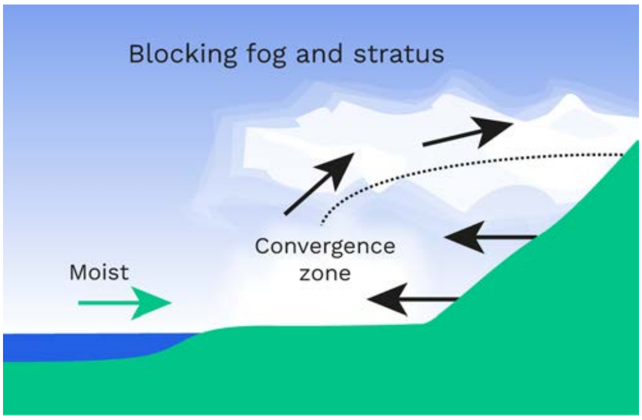
Upslope fog is formed when moist air is forced up a terrain slope and cools to saturation. It is important to note, however, that a hill or mountain is not a necessity; a gentle slope will do. For example, upslope lifting in a southerly airstream is the principal reason for the formation of low stratus at Broken Hill Airport. Upslope fogs can be long-lived when the airstream is very moist.



Blocking fog

Blocking occurs as airflow interacts with barriers. Fog formation within the blocked region is complex and may occur when an upstream atmosphere is highly stably stratified (each layer is less dense than the one below it) and/or the flow toward a barrier is relatively weak, or both. Air can stagnate ahead of a barrier or migrate toward a gap, flowing parallel to the terrain. Pre-existing radiation fog and stratus clouds may mix together and combine to form a deep layer of long-lasting fog. The entire fog bank may then move towards any gaps in the barriers.





Valley fog

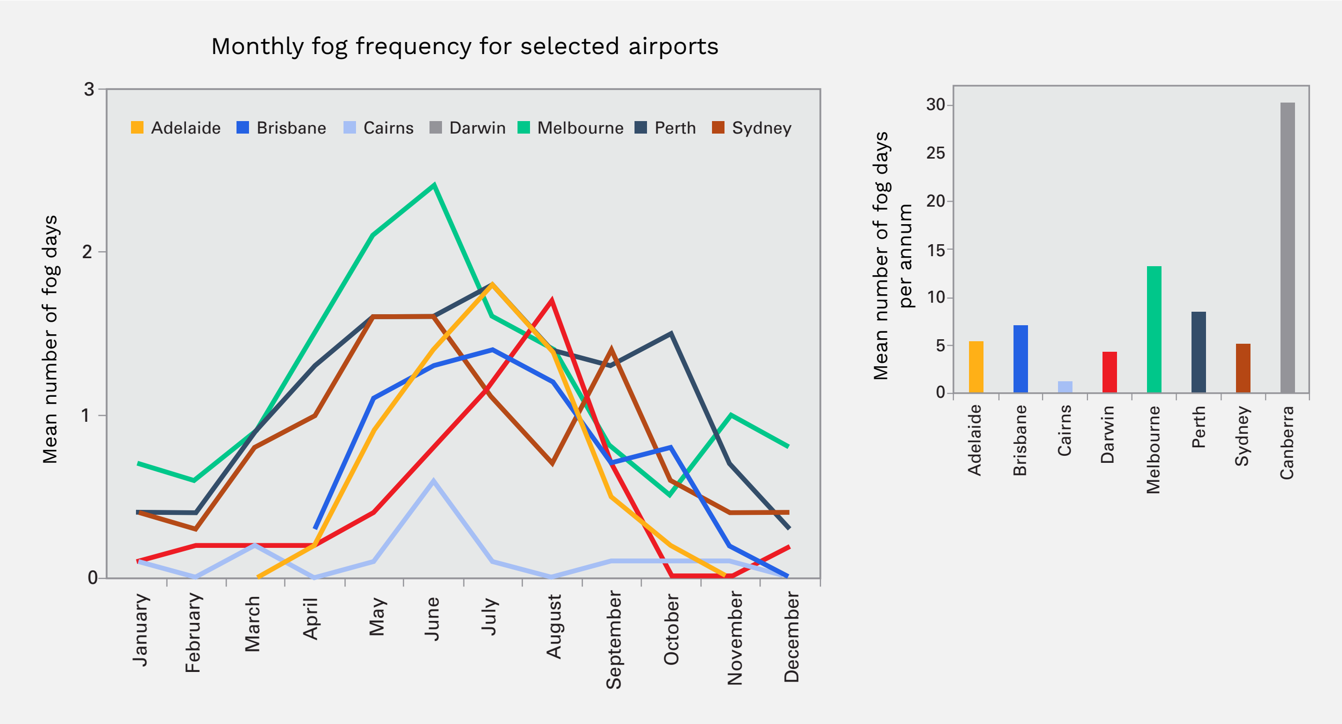
Hilltops are often observed to be fog free while adjacent valleys are enshrouded in fog, even though the moisture availability may be similar. The main reason for the disparity is the difference in the depth of cool air. Thick and deep fog is more likely in the valleys because katabatic winds funnel cool air downwards to the valleys, away from hilltops, therefore inhibiting the depth of cooling on hilltops. The fog formed by this process is frequently observed to initially form in the upper reaches of a valley while, at the same time, fog is advected by katabatic winds down the valley into regions that otherwise may not have been fog prone.

Fog climatology

The occurrence of fog generally follows a seasonal trend, being less likely in summer than in winter and transition months.

In south-west Australia, radiation fogs are common inland in winter when the subtropical ridge lies over the southern states, resulting in clear skies and light winds. These fogs are usually isolated and dissipate by mid-morning. More widespread fogs tend to form in the wake of cold fronts when rapid ridging behind the front forms a temperature inversion which traps the moisture deposited as rainfall. The West Coast Trough can produce fog about the coastal plain when it moves inland with moist maritime air. Additionally, sea fog can form with the trough offshore, and may be advected inland if the trough moves inland.

In south-east Australia, the incidence of fog is generally low at aerodromes close to the coast, but increases rapidly a short distance inland. Aerodromes such as Richmond (NSW), Launceston, Mount Gambier and aerodromes along the Great Dividing Range generally experience in excess of 40 fogs per annum. On the western slopes of the Great Dividing Range, particularly in southern regions, locations experience in excess



of 25 fogs per annum, while the incidence tapers off further inland. In the fog-prone parts of Australia, in late autumn or winter, fog may form in the early evening and persist until midday or longer; on isolated occasions fog may persist unbroken for 2 days at aerodromes such as Canberra and Launceston.

Fogs in tropical Australia are most common near the coast in the dry season. Fogs are reported at major coastal airports in Western Australia (e.g. Broome, Port Hedland) about 15 times a year. Fogs also occur in North Queensland, the number of fogs occurring being largely dependent on the topography near the airport. Fogs can be expected at Rockhampton more than 30 times each year, while at Cairns fogs are very rare. Often radiation fogs forming in tropical areas are shallow and do not significantly affect aviation operations. A few times each year, sea fogs form along the coast and persist for much of the day. Sea fogs are a regular occurrence during the dry and transition seasons about the coastal parts of the Gulf of Carpentaria and frequently affect aerodromes such as Ngukurr, Borroloola and McArthur River Mine. Fogs and low stratus also occur about coastal valleys in the Northern Territory's top end during the dry season, occasionally extending as far inland as Tindal.

Detection and monitoring

Fog can be detected by manual (human) observations, automatic surface observations (visibility sensors and runway visual range instrumentation), satellite imagery, web cameras and inference from vertical temperature and sea surface temperature information. Surface trends of wind, temperature, humidity, cloud and visibility provide the basic observational support for likely fog conditions, both in the formative and dissipative stages. Satellite observations provide the best estimate of aerial coverage and trends in fog cover, especially at night when direct observations are limited. However, fog is very hard to differentiate from low cloud. Inference from vertical temperature profiles provides important indicators of moisture depth, wind regimes and conditions conducive to radiative cooling.

Forecasts and warnings

Fog forecasts are included in graphical area forecasts (GAF) and aerodrome forecasts (TAF and TAF3), with specific reference to timing and horizontal visibility at ground level. Warnings are issued for fog in the form of an AIRMET, if not already contained in the current GAF.

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