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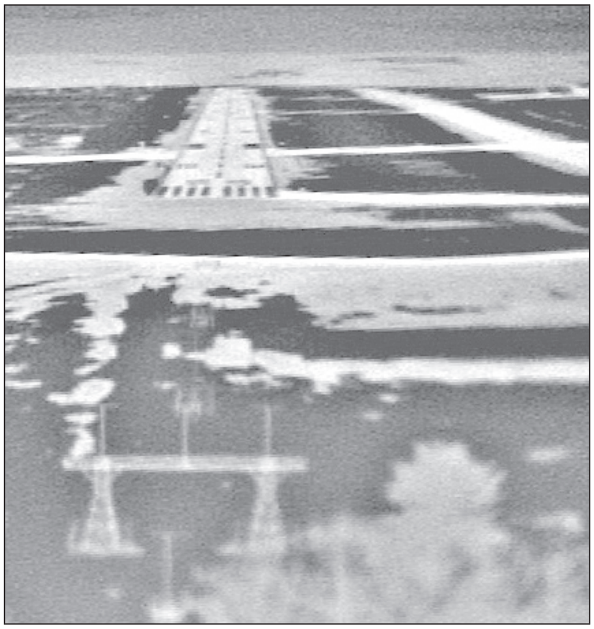
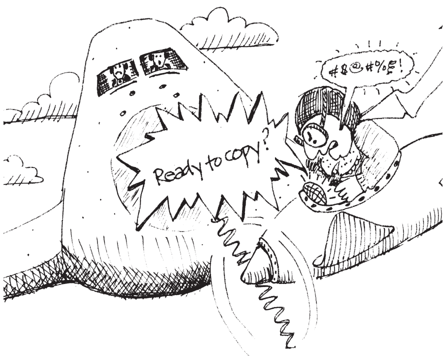


The grainy view your eyes can't see ... page 6



Bum steer ... page 9

More than NRST ... page 18

6 THE CLOUD ERASER

How'd you like to see the mountains, trees, and runway from the FAF even when the field is at minimums?

9 ATC CARPING 101

Your controller just got his retirement slashed. Here's what to do if he takes it out on you.

15 COOL-EARTH FOG

It's thick, it's fast, and tough to predict. There are some good clues, though, if you know where to look.

18 A MAYDAY GPS APPROACH

That Nearest button is only as useful as the skill with which you use it.

22 THE FOUR HORSEMEN

It's the little things that kill you.

ALSO INSIDE THIS ISSUE ...

2 REMARKS
Good deeds for flight time

3 BRIEFING
Not exactly cheap

4 READBACK
How to pass gas

12 KILLER QUIZ
You're a jet setter

20 APPROACH CLINIC
Know your arrival areas

24 ON THE AIR
Recycling your altimeter

COOL-EARTH FOG

Unless you fly heavy iron with autoland, fog can make finding the pavement impossible. Predicting it isn't easy either.

by Scott C. Dennstaedt

Many pilots don't realize that radiation cooling is the leading producer of fog, especially dense fog. Radiation fog is stealthy in its formation and may fool the most astute forecaster. It can appear swiftly — going from VFR conditions to below IFR minimums in 20 minutes — and consume large areas of real estate. Diversion can be beyond the fuel reserves of some aircraft.

The good news is that radiation fog is a nocturnal or early morning event when most general aviation pilots are safely on the ground. For the sake of this discussion, fog is defined as a ceiling less than 200 feet and visibilities less than or equal to one-half a statute mile.

The Basic Ingredients

The 1975-revised Advisory Circular 00-6A (Aviation Weather) says, "Conditions favorable for radiation fog are clear sky, little or no wind, and small temperature-dew point spread (high relative humidity)." While this definition is in the ballpark, it leaves out details that can make or break the fog event. With respect to radiation fog, the devil is in the details.

Several years ago, UPS did research that became required reading at all National Weather Service Weather Forecast Offices (NWS WFOs) and the Aviation Weather Center (AWC). With over 100 destination airports, UPS did not like being surprised by a radiation fog event. Fog, it turned out, was rather complex.

The big picture is important but not obvious. There are no red, blue, or purple symbols or dashed lines that warn the pilot, "Look out, radiation fog headed your way." Fog associated with an approaching warm front rarely catches pilots or forecasters by surprise. Radiation fog is locally grown and does not typically arrive courtesy of the wind.

This does not mean the surface analysis chart should be cast aside. Radiation-induced fog is favored under an anticyclone (high pressure system) or in weak pressure regimes, especially in the area just to the west of the center of the surface high. High pressure is associated with subsidence (sinking air) that helps keep the sky clear, which helps fog to form, but, as we shall see later, not mandatory.

Recent rainfall followed by a clearing just before sunset is a catalyst for fog. The rain enriches the moisture available in the boundary layer (layer nearest the earth).

Snow-covered soil should also raise a red flag. Snow prevents this thermal transfer from the soil that delays or degrades the onset of radiation fog. Coastal locations with onshore flow can be highly susceptible to radiation fog.

No Simple Forecast

Unfortunately for forecasters, radiation fog is not purely a surface event. The critical area extends from the pavement through the depth of the potential fog layer. Forecasters must answer two critical questions: What is the vertical distribution of humidity in the potential fog layer and what is the turbulent mixing potential in the fog layer?

Short of a timely radiosonde (weather balloon) launch or a few precious aircraft reports, there is a dearth of information about the 500 feet of air just above the ground.

As the heating of the day vanishes and day turns into night, the surface temperature begins to fall. The earth begins its nocturnal cooling process, losing heat by longwave radiational cooling into the atmosphere just above the surface. This produces a distinct temperature inversion — warm air on top of cool air — normally within the first 1000 feet above the ground. The depth and magnitude of the inversion depends on many factors; however, an inversion 10 degrees C or more is common.

As the temperature cools into the early morning hours it may catch

Right: *Radiation fog can produce some of the thickest fog on the planet. It's easy to miss a turn and discover you've taxied onto an active runway.*

WHAT UPS FIGURED OUT ABOUT RADIATION FOG

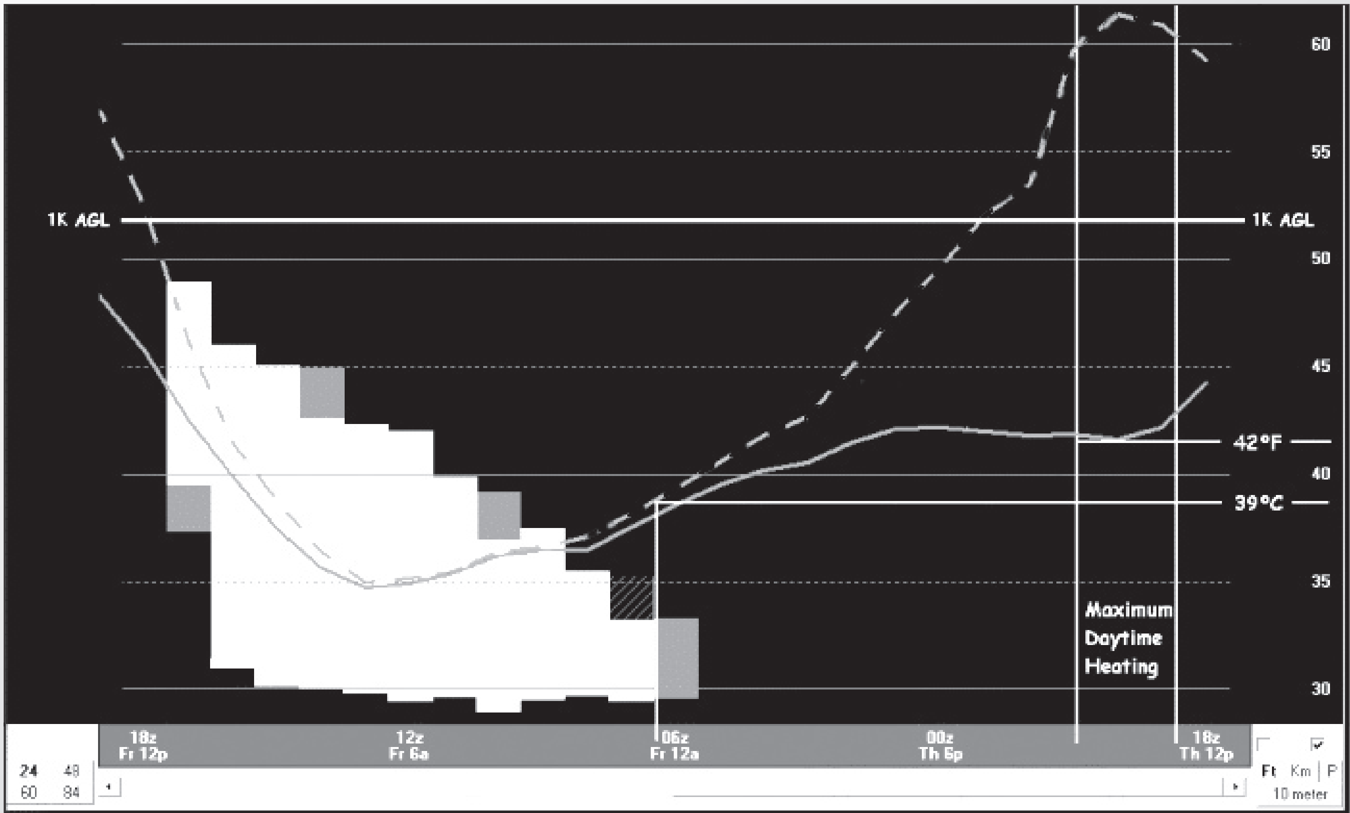
Forecasting models can sometimes predict the onset of radiation fog, as it did in this example from a fog event at Washington-Dulles Airport (KIAD).

Time on this diagram increases from right to left. Forecast temperature and forecast dewpoint temperature are depicted by the dashed and solid wavy lines, respectively. The maximum daytime temperature is forecast to occur between 1900 UTC and 2100 UTC with a minimum dewpoint at this time of 42 degrees F.

The minimum dewpoint temperature during the maximum heating of the day is referred to as the *crossover temperature*. When evening temperature is forecast to drop below the crossover temperature, visibilities will tumble — assuming other favorable conditions such as clear skies and decoupled winds.

If the temperature continues to fall three or more degrees Fahrenheit below the crossover temperature then fog is highly likely with visibilities approaching zero. In this fog event the temperature was forecast to reach 39 degrees shortly after 0600 UTC, warning a forecaster of an impending fog event.

On the same diagram, a depiction of cloud heights (tops and bases) is shown by the columns in white with each column representing an hour of the forecast. The ceiling is predicted to be less than 100 feet throughout the fog event from 0600 UTC before lifting around 1800 UTC. Tops remain below 1000 feet AGL for the entire fog event. — *S.D.*



up with the dew point, resulting in saturated air. Surface winds are light, but fog has not yet formed. You may have tuned in the ATIS, AWOS, or ASOS broadcast before an early morning flight only to hear that the temperature and dew point are equal. Even with saturated conditions at the surface, the sky remains clear. How can that be?

This typically occurs when the boundary layer just above the surface remains dry. In other words, the temperature and dew point are equal at the surface and rapidly diverge from each other, giving rise to an unfavorable *hydrolapse*. A hydrolapse is the vertical distribution of water vapor. A dew point depression (the difference between the temperature and the dew point) that remains or becomes small within a full 500 feet of the surface, equals a favorable, low-level hydrolapse.

While the surface temperature and dew point temperature are measured at most airports, the hydrolapse is not a directly observable meteorological field. One way to get past this is using numerical weather prediction (NWP) to accurately model the hydrolapse in the potential fog layer. Consequently, the forecast hydrolapse in this layer must indicate uniform moisture content within the first 500 feet of the surface.

Since the hydrolapse is not readily available, UPS Airlines developed a way to predict the humidity in the lowest 500 feet by using a value called the *crossover temperature*. The crossover temperature represents the minimum dewpoint temperature observed during the maximum heating of the day.

At the point the maximum temperature is reached, thermal transfer of heat and moisture has reached its greatest depth. This transport of moisture lowers the dewpoint temperature at the surface, giving rise to the magic crossover temperature.

A fog event is likely when the temperature is forecast to dip to at least three degrees F below this observed crossover temperature — and there won't be turbulent mixing in the fog layer.

Where the Wind Blows

It's a common misconception that the littlest bit of wind limits the potential for the formation of fog. Turbulence or turbulent mixing instead of wind speed is really what forecasters seek. Even with calm or light and variable winds at the surface, the wind just above the surface can be large enough to cause a turbulent mixing within the potential fog layer, preventing or delaying fog formation.

Similar to knowing the vertical profile of humidity, winds at the surface only tell part of the story. The more mixing that occurs in the layer just above the surface, the less likely fog is to form even with completely calm surface winds.

Turbulent mixing is calculated by considering the atmospheric stability and the magnitude of the forecast winds the first few hundred feet above the ground. In other words, if the layer above the surface is stable and the winds are light in the first few hundred feet, the winds are decoupled from the surface and fog formation is favored.

Radiation fog does not always require clear skies as was previously embraced. A stratus layer can "build down" to the surface producing a radiation fog event. The presence of a stratus cloud layer does reduce the amount of radiation cooling, but may not totally eliminate it.

The top of the stratus cloud deck can become its own radiation-cooling surface. The cooler the ground surface, the more likely the build-down event will occur. Warmer ground temperatures tend to delay or prevent radiation fog from forming. Airports that are in urban areas may build down slower if the ground temperatures are higher.

Seeing it Coming

Area forecasts (FAs) are not helpful for isolated radiation fog events. Coastal events covering a large area may be captured by the area forecast, but the FA may simply say, "OCNL VIS 3-5SM," with no fog warning.

The five statute mile radius of the Terminal Forecasts (TAFs) is not generally a good way to capture the weather at airports between TAFs. It's not unusual for two airports 10 miles from each other to see an onset of radiation fog many hours apart.

Terminal forecasts have been getting better since the UPS study. But the lack of data in the lower 500 feet of the atmosphere is still what challenges terminal forecasters.

Radiation fog can take the visibility below one eighth of a statute mile in the time it takes you to preflight and taxi to the runway. Predicting it will be tough for some time to come.

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