

# SURFACE TEMPERATURE INVERSIONS AND SPRAYING

## FACT SHEET

**GRDC**  
Grains  
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## The influence of surface temperature inversions on spray operations

In cooling night conditions airborne pesticides can concentrate near the surface and unpredictable winds can move droplets away from the target. Understanding weather conditions can help spray applicators avoid spray drift.

### KEY POINTS

- Where surface temperature inversion conditions exist it is unsafe for spraying due to the potential for spray drift.
- Spray applied at dawn, dusk and during the night is likely to be affected by a surface temperature inversion.
- During surface temperature inversions, air near the ground lacks turbulence. This can lead to airborne pesticides remaining at high concentrations in the air at or near the surface.
- The direction and distance that pesticides can move in the air close to the ground is very hard to predict when surface inversions exist.

During daylight hours the temperature of the soil surface gradually increases. Air in contact with the ground also warms (Figure 1). In this situation the air temperature normally becomes cooler with height.

Wind speeds during daylight hours will generally be more than 3 to 4km/h and the air movement across the surface will tend to be turbulent.

Turbulence close to the ground causes the air to mix, due to the rolling motion of the air across the ground surface. Mixing is also caused by thermals, which interrupt airflow.

This mixing of the air assists in diluting airborne droplets and helps to drive many of them back towards the ground.

When this dilution occurs, a safe buffer distance between the sprayed area and potentially sensitive areas downwind from the application site can be estimated.

### Surface temperature inversions

Inversion conditions can differ significantly from the broader forecast weather patterns.

During the night the ground loses heat and the low-level air cools (Figure 1). This results in air temperature increasing with height and the temperature profile is said to be inverted. When this occurs close to the ground it is called a surface temperature inversion.

In a surface temperature inversion the point where the temperature stops increasing and begins to decrease is the top of the inversion layer.

When a strong surface temperature inversion has established, it can act like a barrier, isolating the inversion layer from the normal weather situation, especially the normal wind speed and direction (Figure 2).

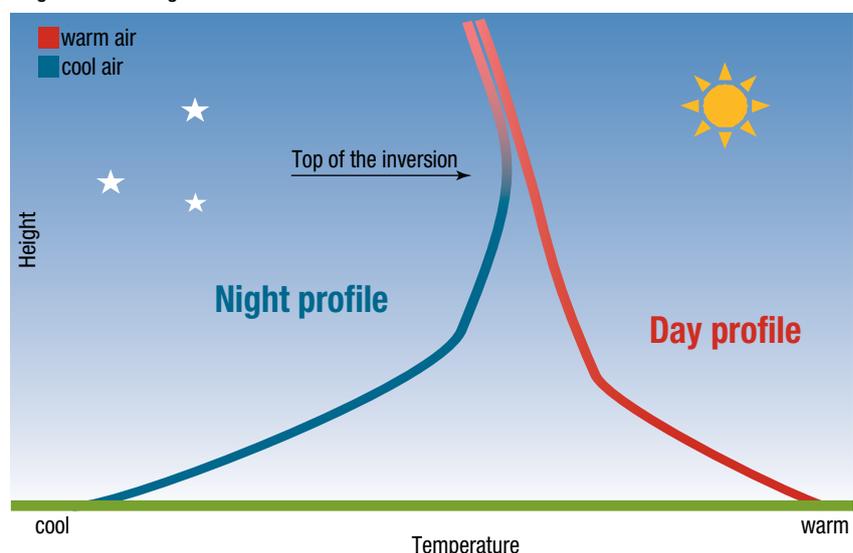
Surface temperature inversion conditions are unsafe for spraying as the potential for spray drift is high.

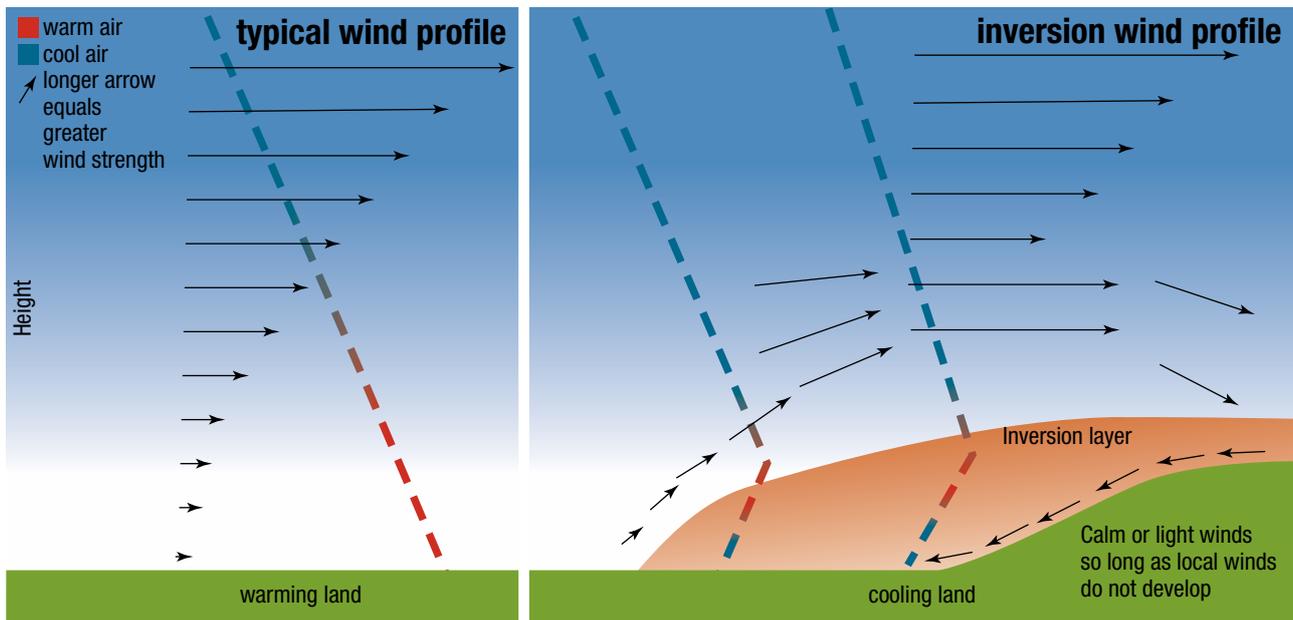
Under a surface temperature inversion:

- air movement is much less turbulent so the air does not mix in the same way as during the day;
- airborne droplets can remain concentrated in the inversion layer for long periods of time;
- the direction and distance pesticides movement is very hard to predict;
- the movement of airborne droplets will vary depending on the landscape; and
- droplets or their remnants can move in different ways (Figure 3).

Research supported by the GRDC is further investigating the development and implications of temperature inversions in relation to spray application.

**FIGURE 1:** Typical vertical temperature profiles for a point in time during the night and day. At low levels, the day profile typically cools with height and the night profile typically warms with height. Little change occurs at elevated altitudes. SOURCE GRAEME TEPPER





**FIGURE 2:** Air movement under a surface temperature inversion differs from a typical wind profile (left). Surface winds de-couple from the surface, accelerate and flow over the inversion. Within the inversion, winds are typically light and often drain down slope, regardless of the overlying wind direction. Under an inversion the shape of the landscape also influences the direction in which airborne droplets will move (right).

SOURCE GRAEME TEPPER

## When and why do surface temperature inversions occur?

Surface temperature inversions usually develop overnight and can persist well into the next day.

They can result from a number of processes that cause the air closest to the ground to become cooler than the air above. The three main reasons experienced in broadacre agriculture are:

### 1. Radiation inversions (created by radiation cooling)

Radiation inversions can form at any time during the night when wind speed is less than about 11km/h and cloud cover does not severely restrict surface cooling. In calm and clear sky conditions they may form just before sunset. Once the sun has set and has stopped heating the ground, heat radiates back into space, causing the ground to cool. In turn, the air in contact with the ground becomes cooler than the air higher in the atmosphere. This generates the surface temperature inversion.

Radiation inversions are the *most dangerous* for spraying operations as they cause airborne droplets to remain

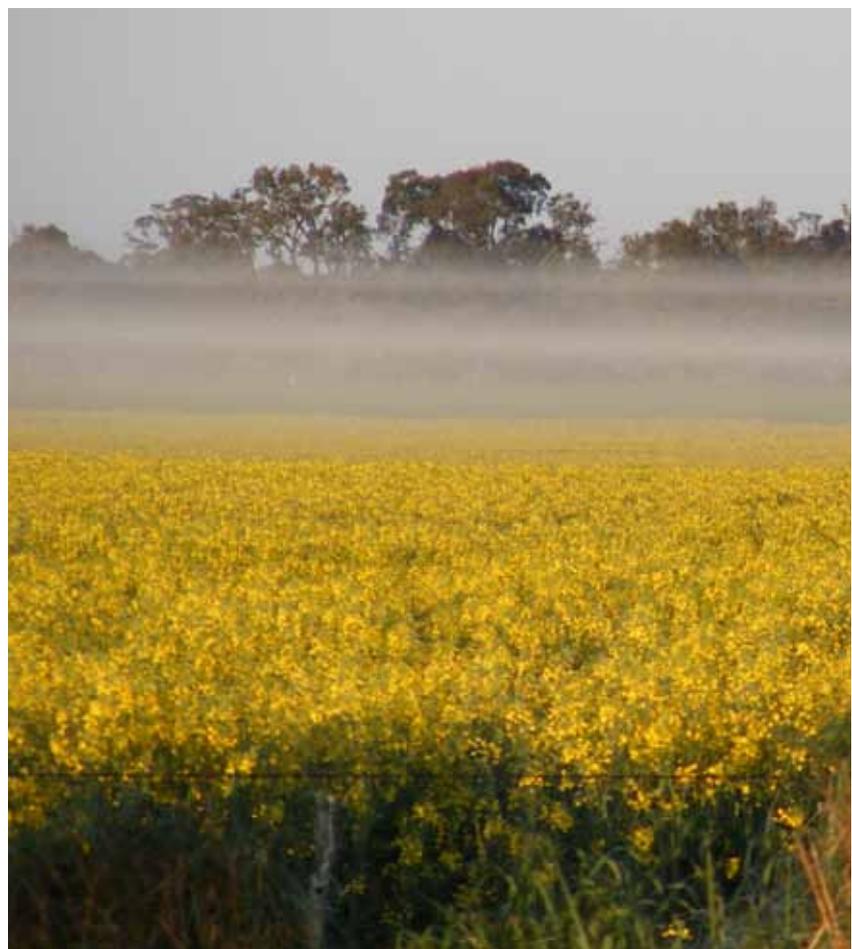


PHOTO: BILL GORDON

Under a surface temperature inversion air can separate into very stable layers (laminates) that can concentrate and transport airborne pesticides.

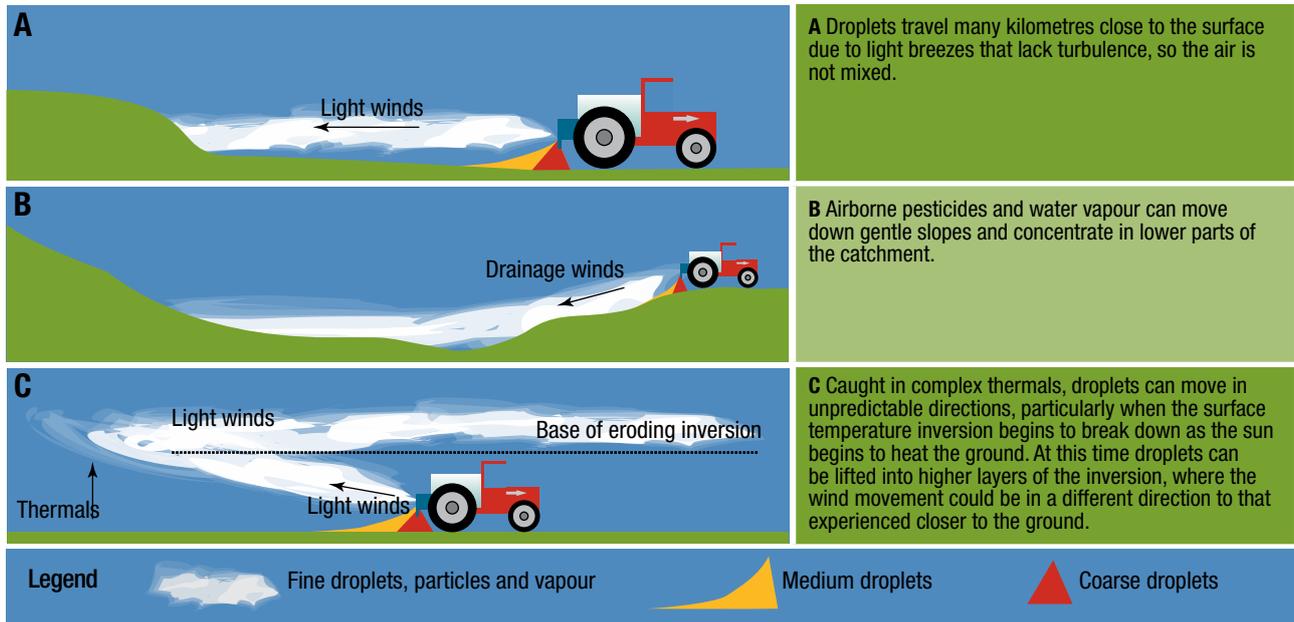


FIGURE 3: Possible movement of airborne droplets in surface temperature inversion conditions.

SOURCE GRAEME TEPPER

concentrated at a low level for long periods. Winds within the inversion can carry these droplets long distances.

On gentle slopes, concentrated droplets can be transported many kilometres by drainage winds towards the lowest point in the catchment. Under an inversion, where water runs from a property, droplets can move. See Figure 3 (c).

## 2. Inversions created by advection (cool or warm air movement)

Cooler, denser air can move into an area and slide under layers of less dense, warm air.

This can happen when a cold front moves into an area, or a sea breeze pushes cooler air inland. It can also happen when denser cool air moves down a slope and slides underneath layers of warm air in lower parts of the catchment. If this occurs, the intensity of a radiation inversion increases.

Warm air can move over cool surfaces; some of the air closest to the ground becomes cooler while the higher air stays warmer.

## 3. Inversions created by vegetation

Vegetation and crops can shade the ground underneath them. The air in contact with the ground will stay cooler than adjacent areas where there is less groundcover. This often occurs just after sunrise. The air moving above the vegetation or crop may be warmer than the air below the vegetation. This can allow airborne droplets to travel over, rather than through, vegetation.

Transpiration from a dense crop canopy on a hot day can form a cool layer of air just above the crop. Later in the day (when wind speeds tend to reduce) this layer of cooler air can act like an inversion over the crop, making penetration of smaller spray droplets into the canopy very difficult and increasing the risk of off-target movement.

## Recognising a surface temperature inversion

The scientific method for detecting a surface temperature inversion requires the accurate measurement of the air temperature close to the ground and at a height of at least 10m. On-farm, this is usually not practical, so most spray applicators must rely on visual clues.

### Visual clues

A surface temperature inversion is likely to be present if:

- mist, fog, dew or a frost have occurred;
- smoke or dust hangs in the air and moves sideways, just above the surface; and
- cumulus clouds that have built up during the day collapse towards evening.

### Other clues

A surface temperature inversion is likely to be present if:

- wind speed is constantly less than 11km/h in the evening and overnight;
- cool, off-slope breezes develop during the evening or overnight;
- distant sounds become clearer and easier to hear; and
- aromas become more distinct during the evening than during the day.

## Clues that a surface temperature inversion is unlikely

Applicators should always expect that a surface temperature inversion is most likely to have formed at sunset and will persist for sometime after sunrise. However, a surface temperature inversion is unlikely if one or more of the following has occurred:

- continuous overcast weather, with low and heavy cloud;
- continuous rain;
- wind speed remains above 11km/h for the whole\* time between sunset and sunrise; and
- after a clear night, cumulus clouds begin to form.

\*Sometimes the overnight wind speed can pick up from virtually calm to speeds greater than 11km/h during a surface temperature inversion. This is why the wind speed must be constant all night to ensure the air continues to mix and prevent airborne droplets from becoming concentrated and moving away from the sprayed area.

## Minimising the potential for spray drift

- Read product labels carefully to check what spray drift restraints may be applicable.
- Be aware of sensitive areas around the area to be sprayed. Sensitive areas include lower points in the catchment and where sea breezes occur.
- Pay close attention to weather forecasts (predicted differences in maximum and minimum temperatures, low overnight wind speeds and predictions of fog or frost).
- Monitor weather conditions, particularly wind speed at the site of application. This should be done at least every 15 to 20 minutes if spraying at night. If the wind drops, spraying should stop.
- Use the coarsest spray quality that will provide efficacy. Every nozzle can produce small, driftable droplets. Using coarser spray qualities reduces the amount of driftable droplets produced.
- Select the correct nozzle and eliminate fine droplets.
- Minimise boom height (while maintaining overlap) and avoid excessive speeds when spraying at night.
- Select an adjuvant that does not increase the amount of driftable fines produced by the nozzles.
- Use common sense.

## Frequently asked questions

### *What is a surface temperature inversion?*

This refers to when the air at the ground level becomes cooler than higher air. Unlike warm air that rises, cool air is dense and remains at the surface. Sprays applied in these conditions can become trapped in this cool air layer. Once trapped, they can move in different directions than indicated by the general weather pattern.

### *Will a surface temperature inversion always occur at night?*

You would expect a surface temperature inversion to occur unless conditions at night are overcast with heavy cloud that restricts overnight cooling by less than 5 degrees, or there has been continuous rain, or wind speed during the whole night is greater than 11km/h.

### *When is a surface temperature inversion likely to have dissipated?*

After sunrise when the air temperature has risen by more than 5°C above the overnight minimum and wind speed has been constantly above 7km/h for more than 45 minutes after sunrise.

### *What happens to my spray if I spray just before or as a temperature inversion is forming?*

Pesticides already floating in the air can be trapped by the inversion.

Pesticides trapped within a surface temperature inversion will tend to remain suspended within the inversion, typically moving to places wherever the relatively slow moving air within the inversion layer ends up. This movement is likely to continue until the inversion breaks, which releases the trapped droplets. Often the air movement

during an inversion will be towards the lowest part of the catchment, but as the inversion breaks the released droplets have the potential to go in almost any direction.

### *Are there tools to help me identify a surface temperature inversion?*

Confirming the presence of a surface temperature inversion with measurements is difficult, so growers must rely on visual clues that indicate if the atmosphere is stable. Smoke pots and smoking devices fitted to the sprayer's exhaust can help indicate if the atmosphere has become stable or the wind has become less turbulent, which are strong indicators that a surface temp inversion may have formed. Other tools such as on-board weather stations or simple tell-tale flags placed in the line of sight, can indicate if the wind has dropped out.

## Useful resources:

■ Bill Gordon	<a href="http://www.ispray.com.au">www.ispray.com.au</a> or <a href="mailto:bill.gordon@bigpond.com">bill.gordon@bigpond.com</a>
■ Graeme Tepper	<a href="mailto:g.tepper@bigpond.net.au">g.tepper@bigpond.net.au</a>
■ Weather for pesticide spraying	<a href="http://www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf">www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf</a>
■ GRDC Spray drift fact sheet	<a href="http://www.grdc.com.au/factsheets">www.grdc.com.au/factsheets</a>
■ Bureau of Meteorology website – marine and aviation tabs for detailed wind information	<a href="http://www.bom.gov.au">www.bom.gov.au</a>
■ Spraywise	<a href="http://www.spraywisedecisions.com.au">www.spraywisedecisions.com.au</a>
■ Willyweather	<a href="http://www.willyweather.com.au">www.willyweather.com.au</a>
■ Agricast	<a href="http://www.syngenta.com/country/au">www.syngenta.com/country/au</a>

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