Air Temperature Inversions:

Their Impact On Pesticide Applications

A Deep Dive!

Andrew A. Thostenson, Pesticide Program Specialist, NDSU Extension, Fargo, ND USA—May 2019

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PESTICIDE PROGRAM
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What's the big deal about inversions?

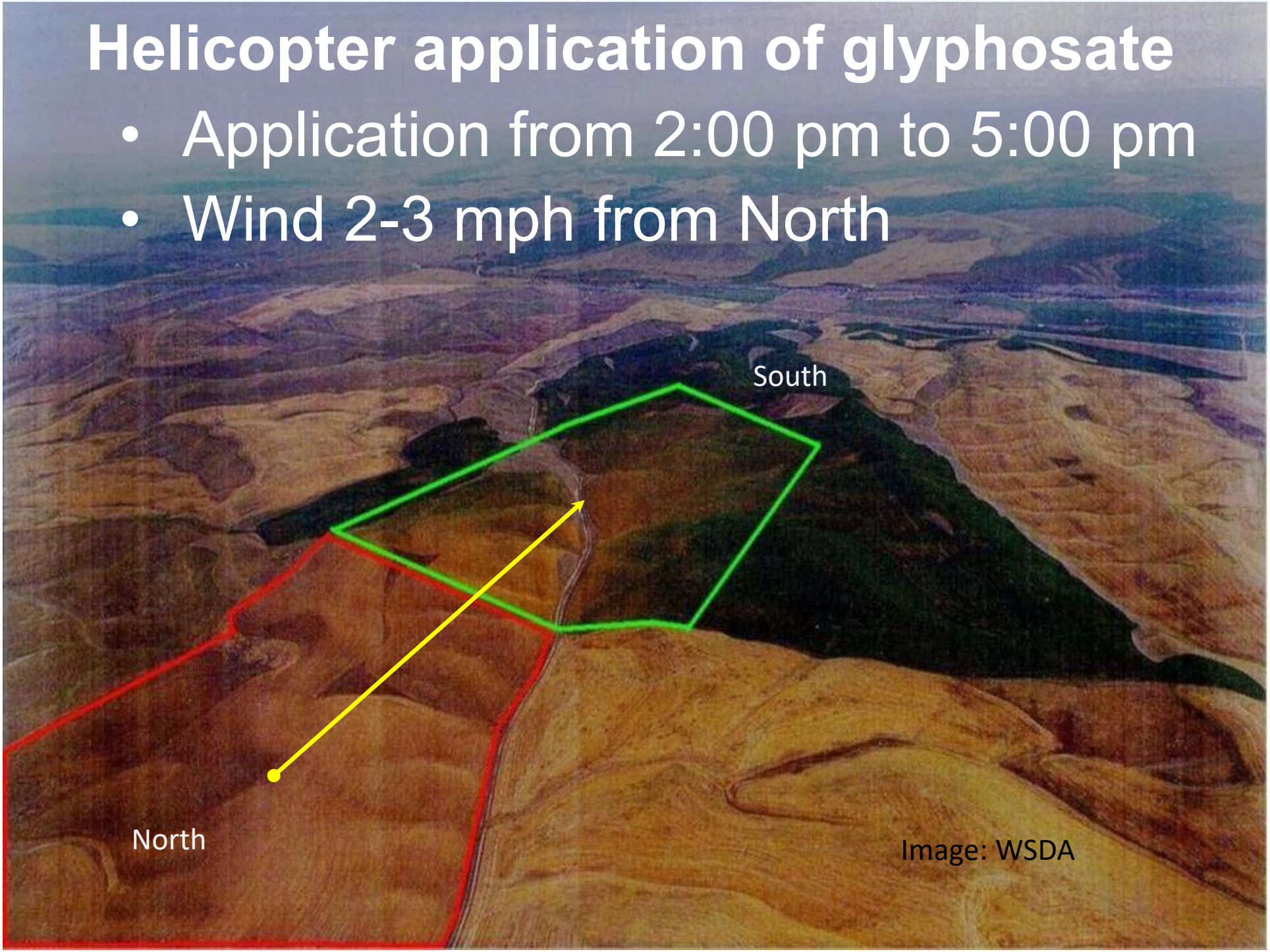
- They can dramatically impact the deposition of pesticide droplets and volatile pesticide gasses
- They are poorly understood
- Making an application during or before an inversion can result in significant off target movement
- Off target movement of pesticides can cause:
  - Exposure to people
  - Significant property damage or environmental harm
  - Violation of state and federal pesticide laws

Story behind the story

- Inversions have been with us since creation
- Referred to in the Old Testament Book of Judges
- Major impact on battles in the 1860's
- Used to spread poison gas in WWI
- Likely responsible for the sinking of the Titanic
- Contributed to several thousand deaths in U.S. and the United Kingdom in the 1940-1950s
- Killed a farm worker in Wisconsin in 2016
- Let's go back to their impact on pesticides

Helicopter application of glyphosate

- Application from 2:00 pm to 5:00 pm
- Wind 2-3 mph from North



This is physical drift, the spray drops, as they are discharged from the nozzle, become suspended in dense cool air and move off target.

FARM PRESS
TIMELY RELIABLE INFORMATION
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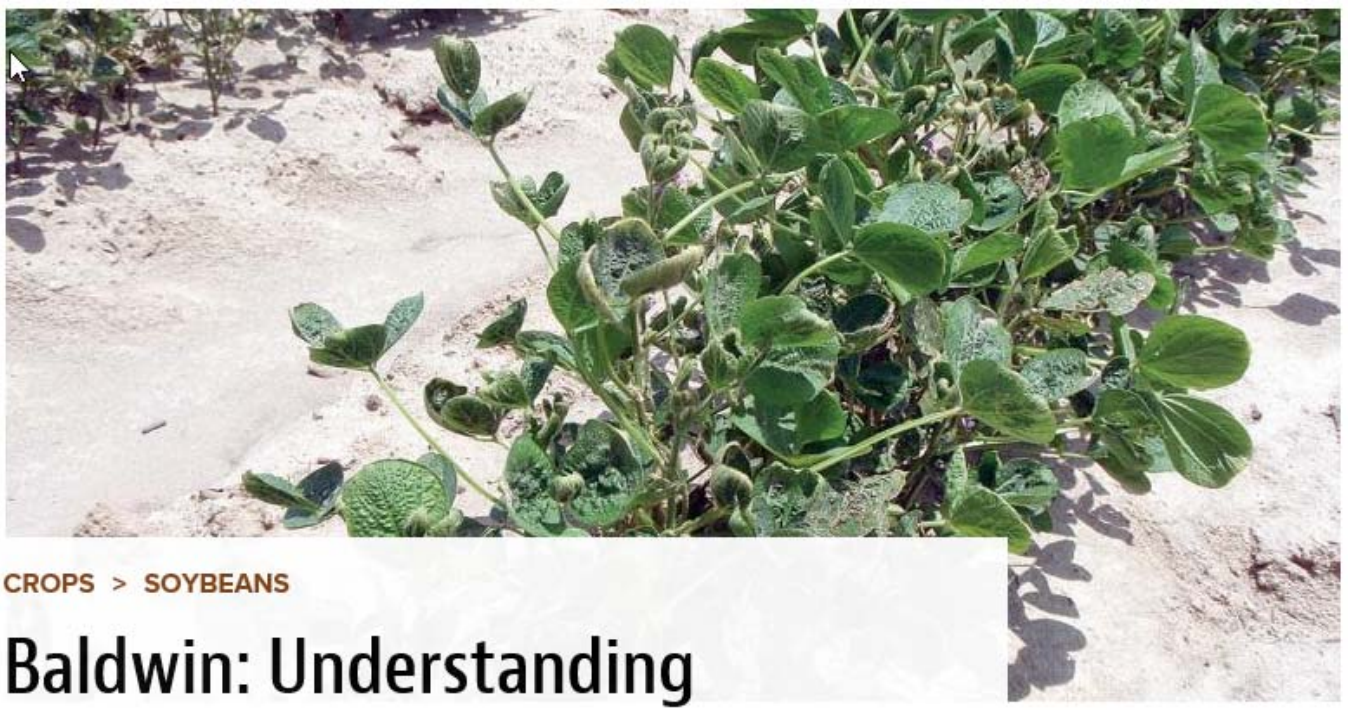
2,4-D herbicide drift damage stuns east Arkansas cotton

David Bennett
Aug. 11, 2006 4:00pm

The young, east Arkansas cotton farmer turns in a slow circle trying to find a plant within his line of sight that isn't "smoked" by herbicide drift. There isn't one — leaves in the top third of every plant are off-color, curling and blistered.

He says excuses won't cut it. He wants those responsible for the 2,4-D drift that's harmed more than half his crop held liable. After that, he suggests banning or restricting 2,4-D might be a good idea.

"This is beyond ugly and has got to stop," he says throwing up his hands in frustration. "We're trying to make a living and this bush-league (stuff) starts happening. It's the same story up and down the road here. It's on everyone's cotton.



CROPS > SOYBEANS

Baldwin: Understanding herbicide volatility during inversion conditions

Ford Baldwin | Aug 16, 2017

DELTA FarmPress

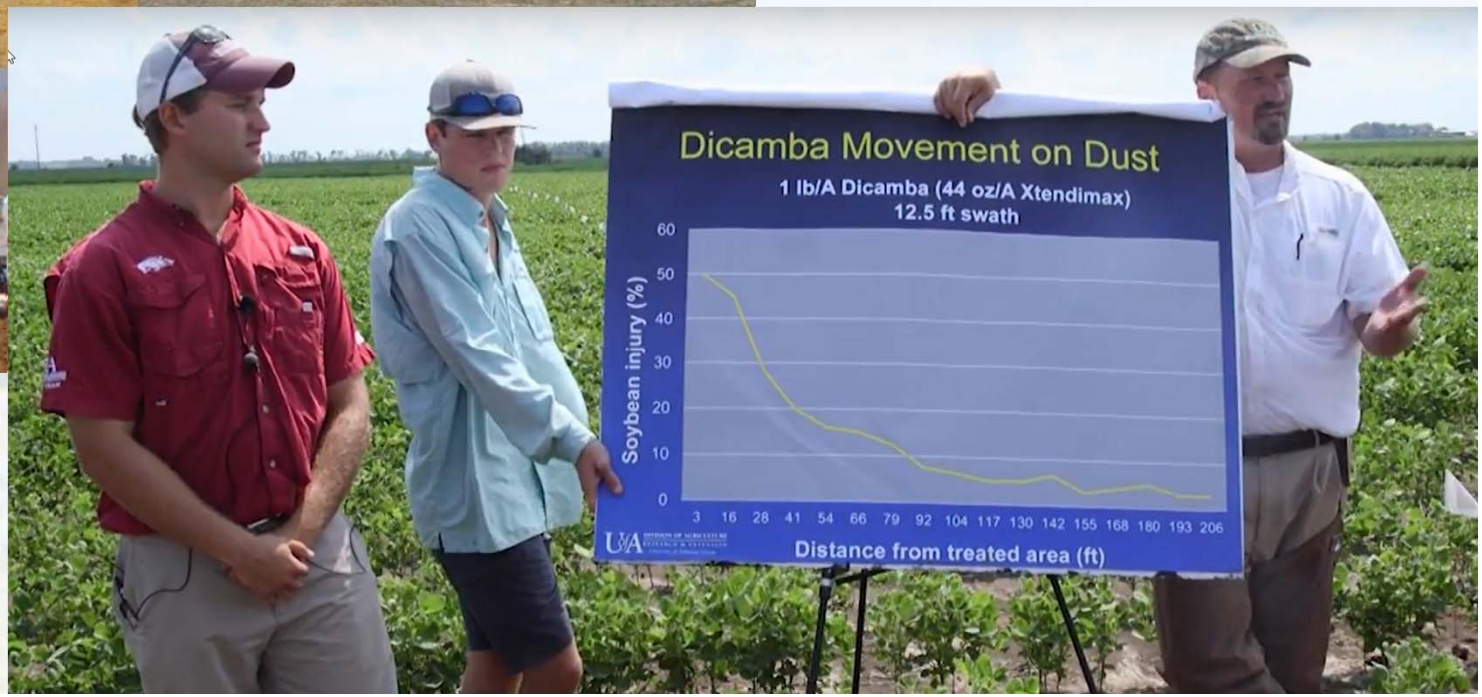
Undoubtedly played an important role in the off target movement of dicamba

This is a combination of physical drift & vapor drift, the spray droplets reach the target but vaporize off the foliage or soil and become held in dense cool air).

Two lesser known impacts

Poor soil sealing = gas loss into cold dense air

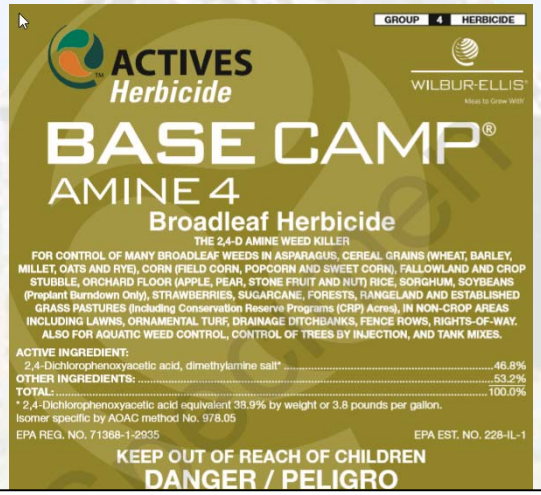
Dust held in dense air



Recognizing and dealing with an inversion is a label requirement

Engenia®

Herbicide

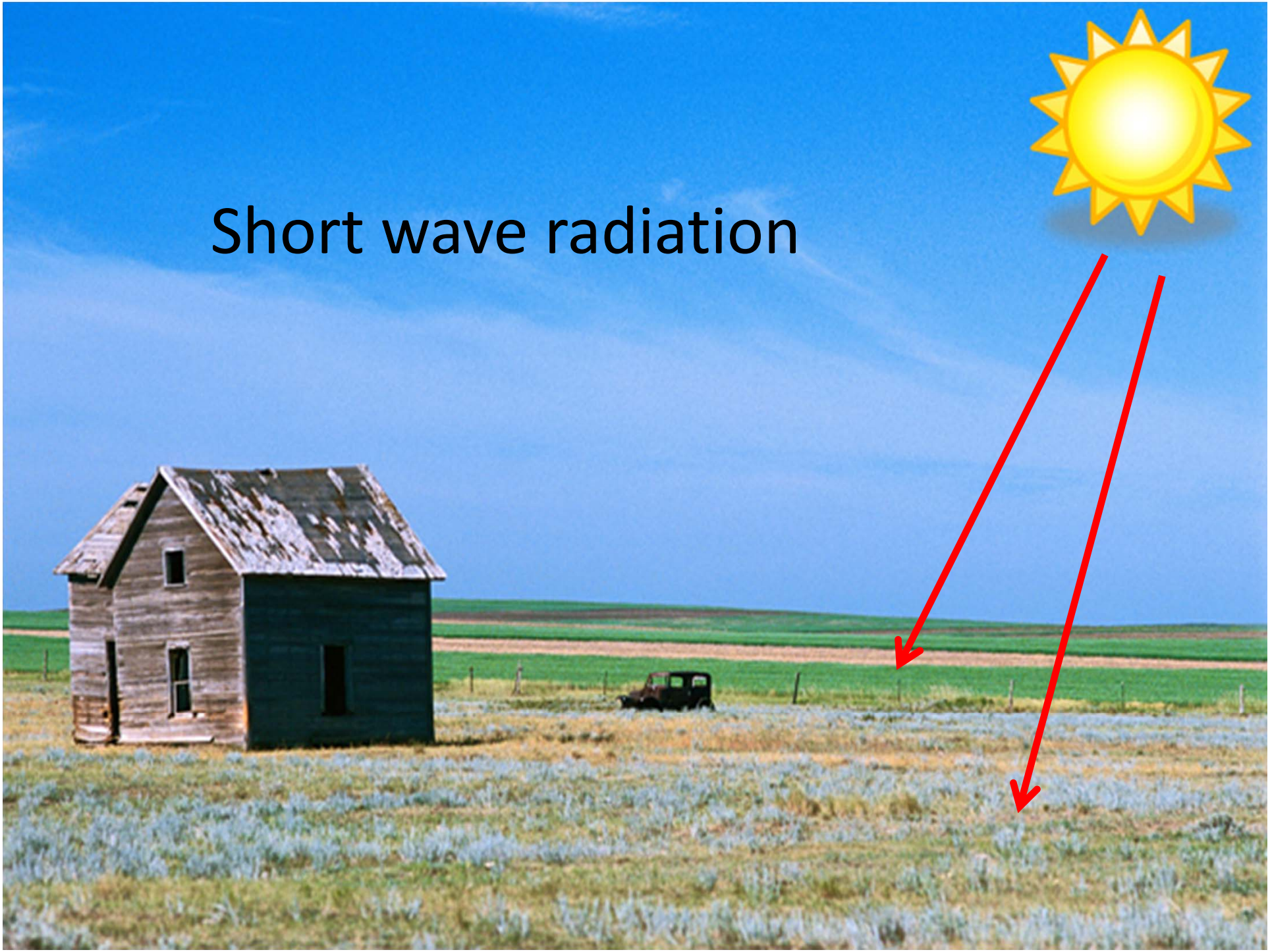


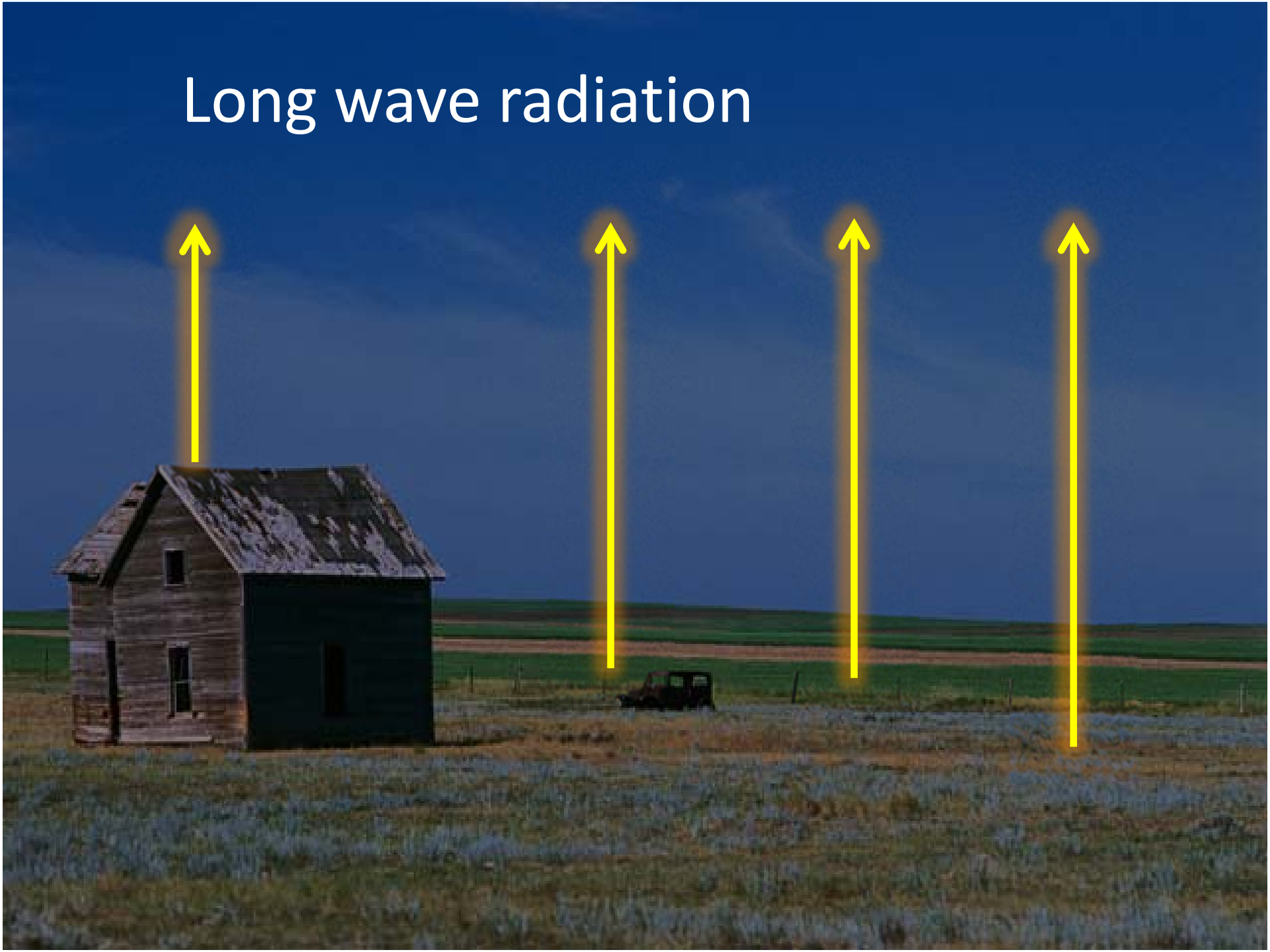
Temperature Inversions
If applying at wind speeds less than 3 mph, the applicator must determine if: a) conditions of temperature inversion exist, or b) stable atmospheric conditions exist at or below nozzle height. Do not make applications into areas of temperature inversions or stable atmospheric conditions.

Temperature Inversions

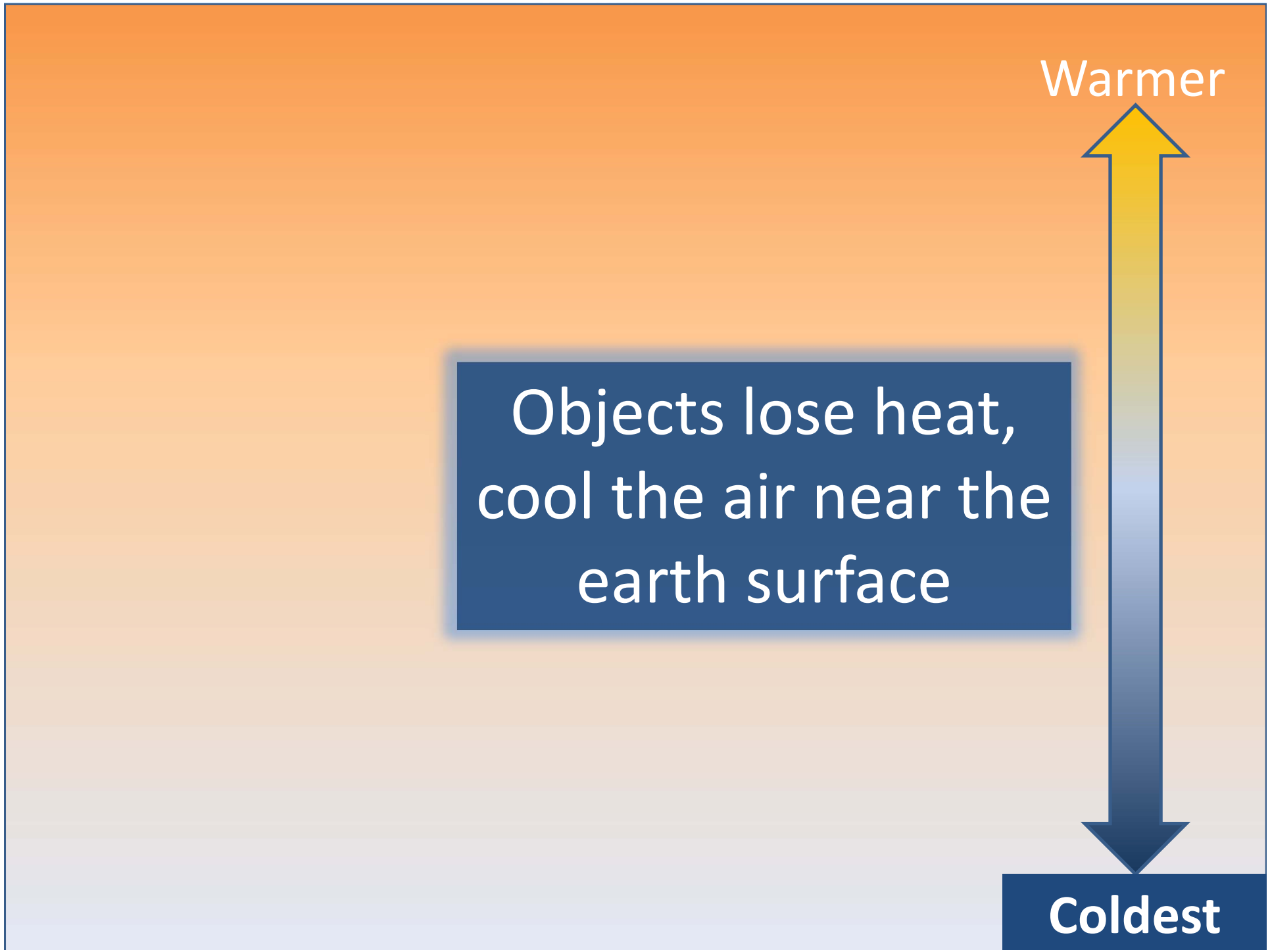
- **DO NOT** apply **Engenia** when temperature inversions exist at the field level.
- **Apply only during the following period: DO NOT** make applications at night. Applications are only permitted beginning one hour after sunrise, and ending two hours before sunset.

Temperature inversions increase drift potential by reducing atmospheric mixing and dispersion of any suspended spray mixture. Suspended spray residues can move in unpredictable directions because of the light, variable winds common during inversions. Temperature inversions are characterized by increasing temperatures with altitude and are common on nights with limited cloud cover and light-to-no wind.

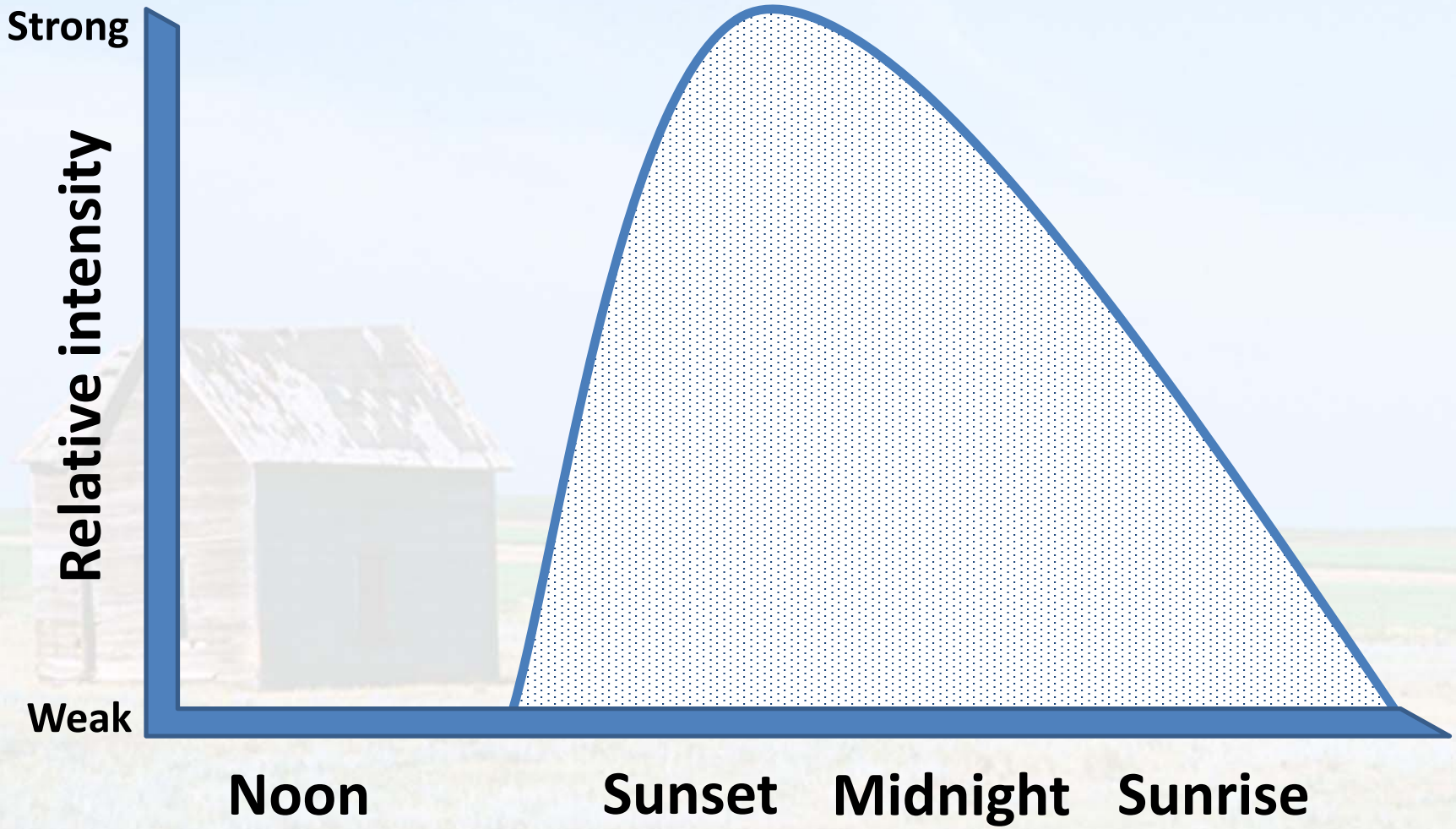

Short wave radiation

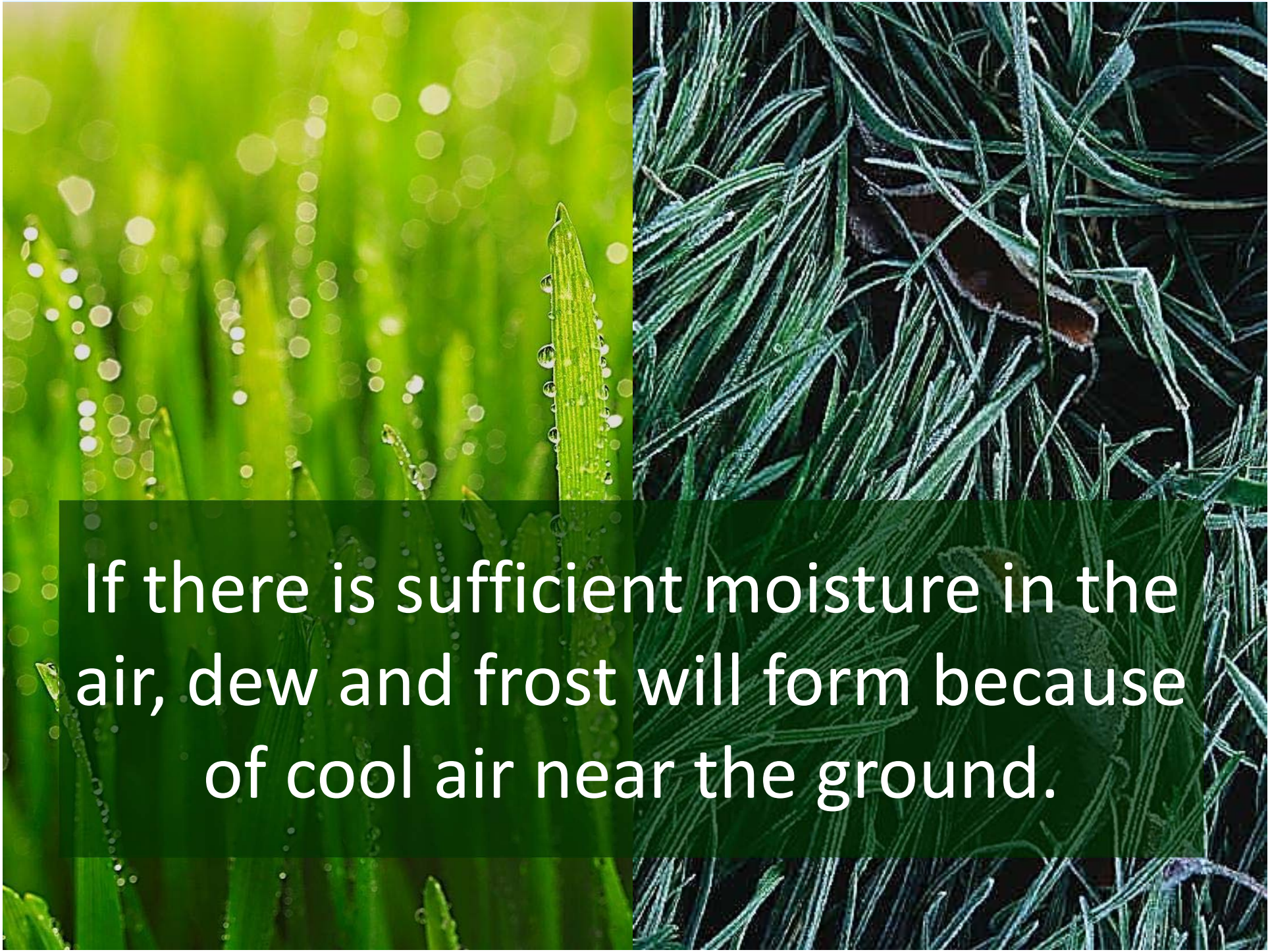

Long wave radiation

Radiation waves from objects move in all directions into the air


Warmer
Objects lose heat, cool the air near the earth surface
Coldest

On a clear & calm 24 hour day, when will inversions begin and end?



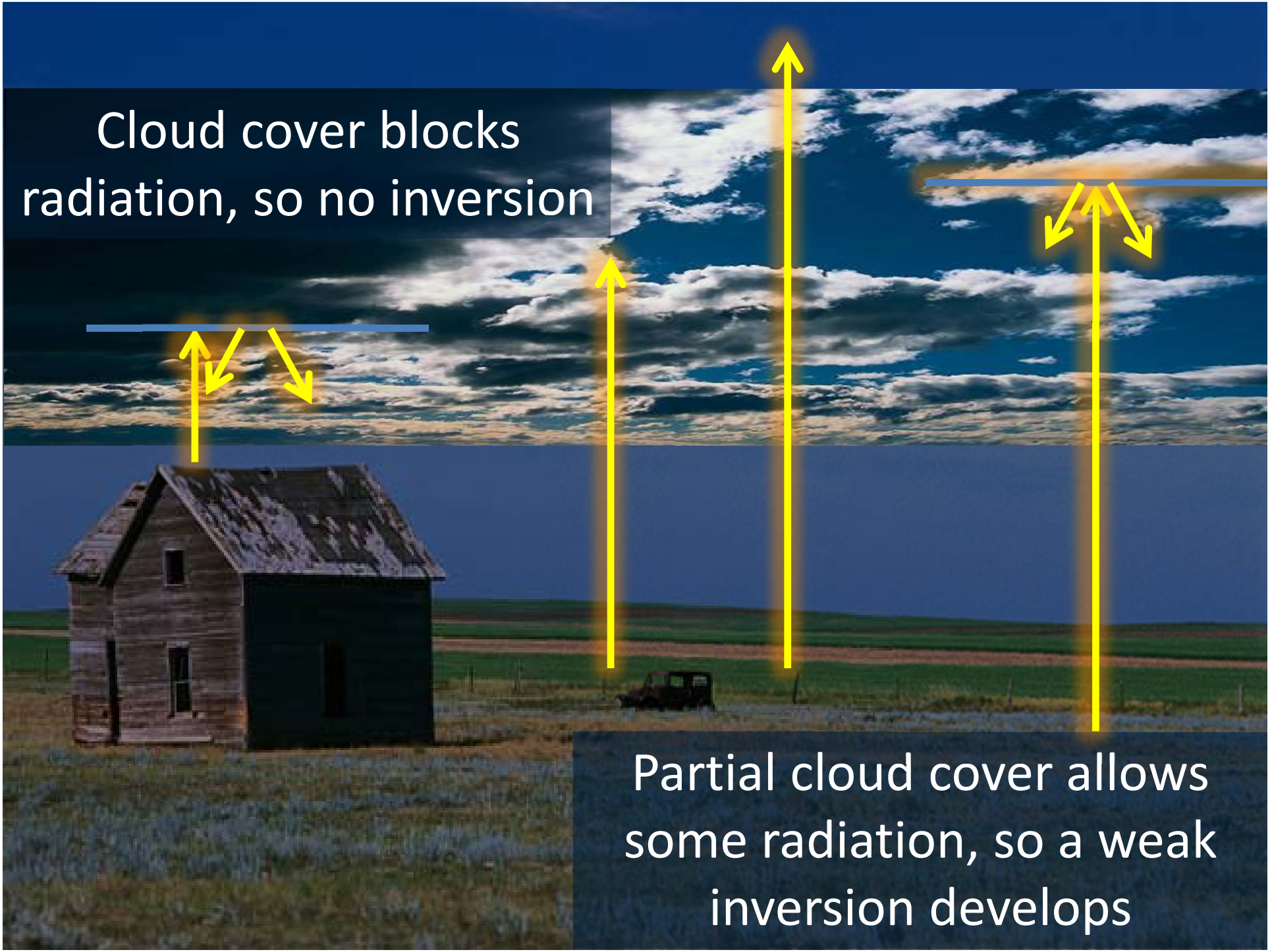

If there is sufficient moisture in the air, dew and frost will form because of cool air near the ground.

If there is sufficient moisture in the air, fog will also form.

If the light and fog reflect just so, one can actually see the inversion.

All the conditions we've talked about assumes very little wind.

Sufficient wind will mix the air, thus preventing or destroying the inversion.


Cloud cover blocks radiation, so no inversion
Partial cloud cover allows some radiation, so a weak inversion develops

Inversions that cause problems for pesticide applicators are like:

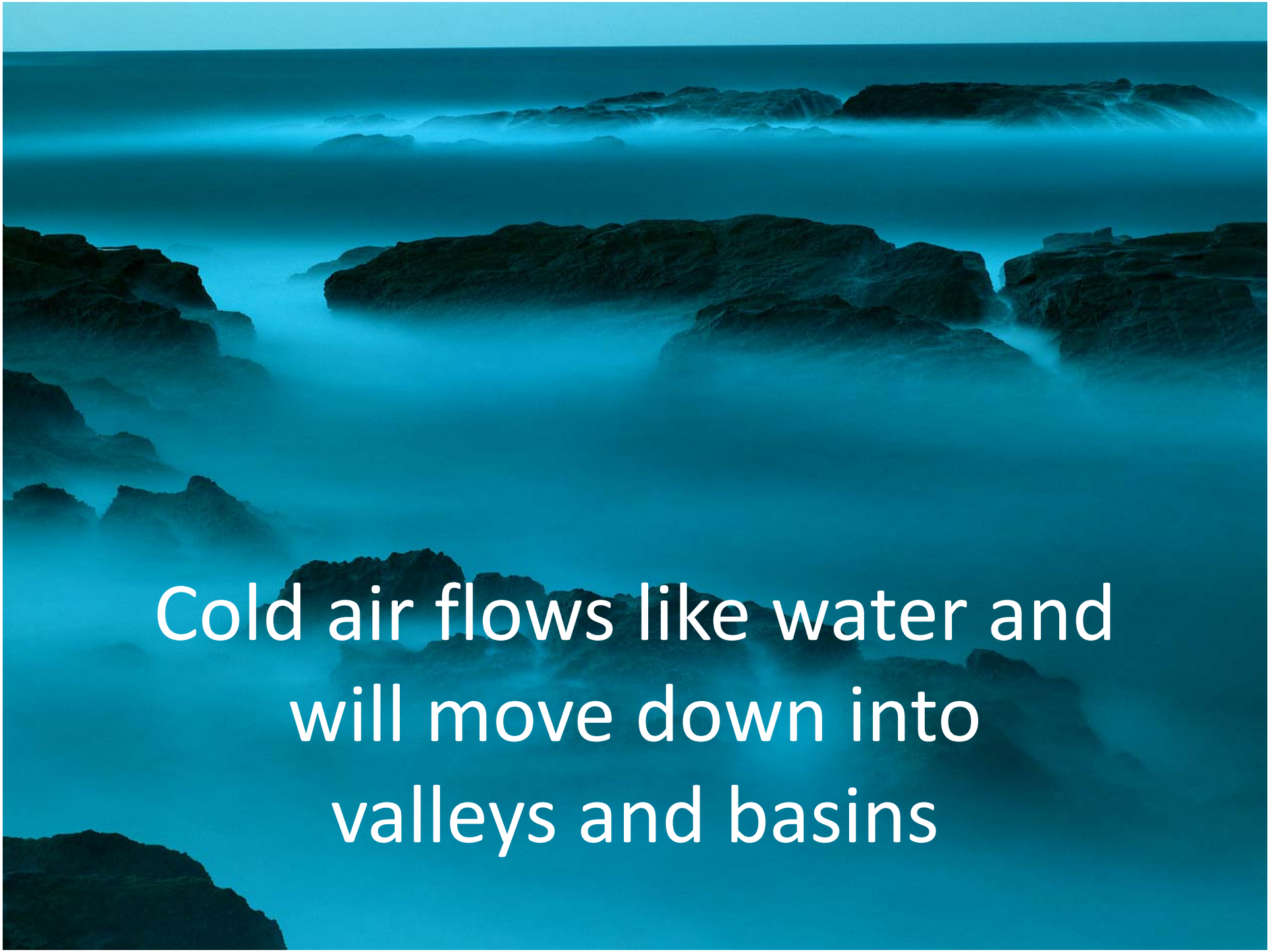
The Perfect <u>Inversion</u> Storm

A Perfect ***Inversion*** Storm

1. Requires radiation from surface objects into a cloudless or near cloudless sky
2. Requires light and variable winds with minimal mixing of the lower atmosphere.
3. Begins in the mid to late afternoon and intensifies into the night. (The inversion will then dissipate into mid-morning.)
4. Includes an unsuspecting applicator who does not recognize there is a problem until it is too late.

Environmental conditions making matters worse

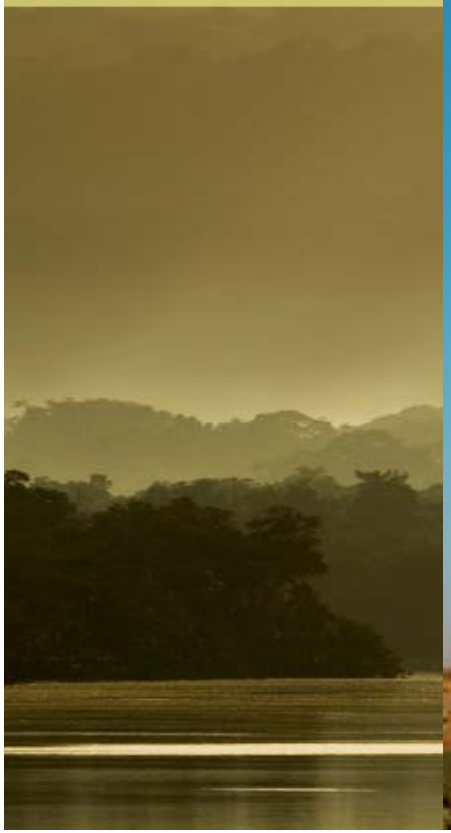
- Topography—low lying area or a protected area shielded from the sun and / or wind.
- Stagnant and / or intense high pressure system
- Relatively low humidity conditions


Cold air flows like water and
will move down into
valleys and basins

Cold air moves into a low lying pasture

Humidity

High humidity rainforest



Low humidity desert

- inversion builds faster
- intensity is greater
- dissipates faster

Surface conditions making matters worse

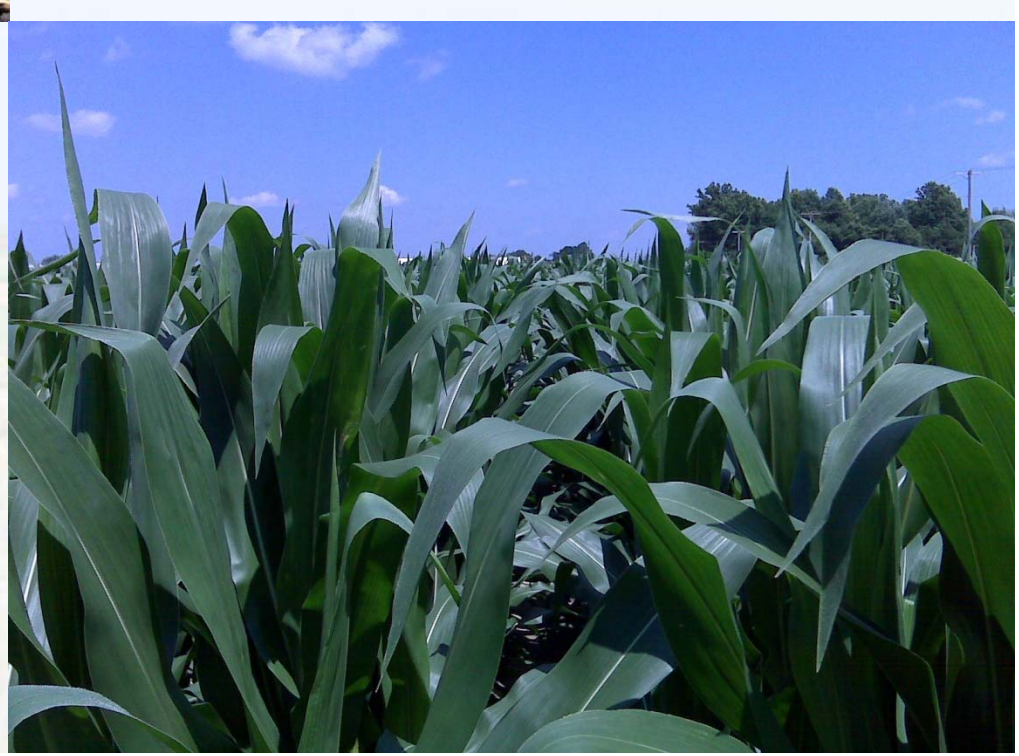
- Exposed soil that:
  - Has a low moisture content
  - Is sandy or coarse textured
  - Has been freshly tilled
- Soil that is heavily mulched and/or covered with heavy crop residue
- Closed crop canopy and or complete vegetative ground cover
- Wind breaks and/or shelter belts

Warmer Surface

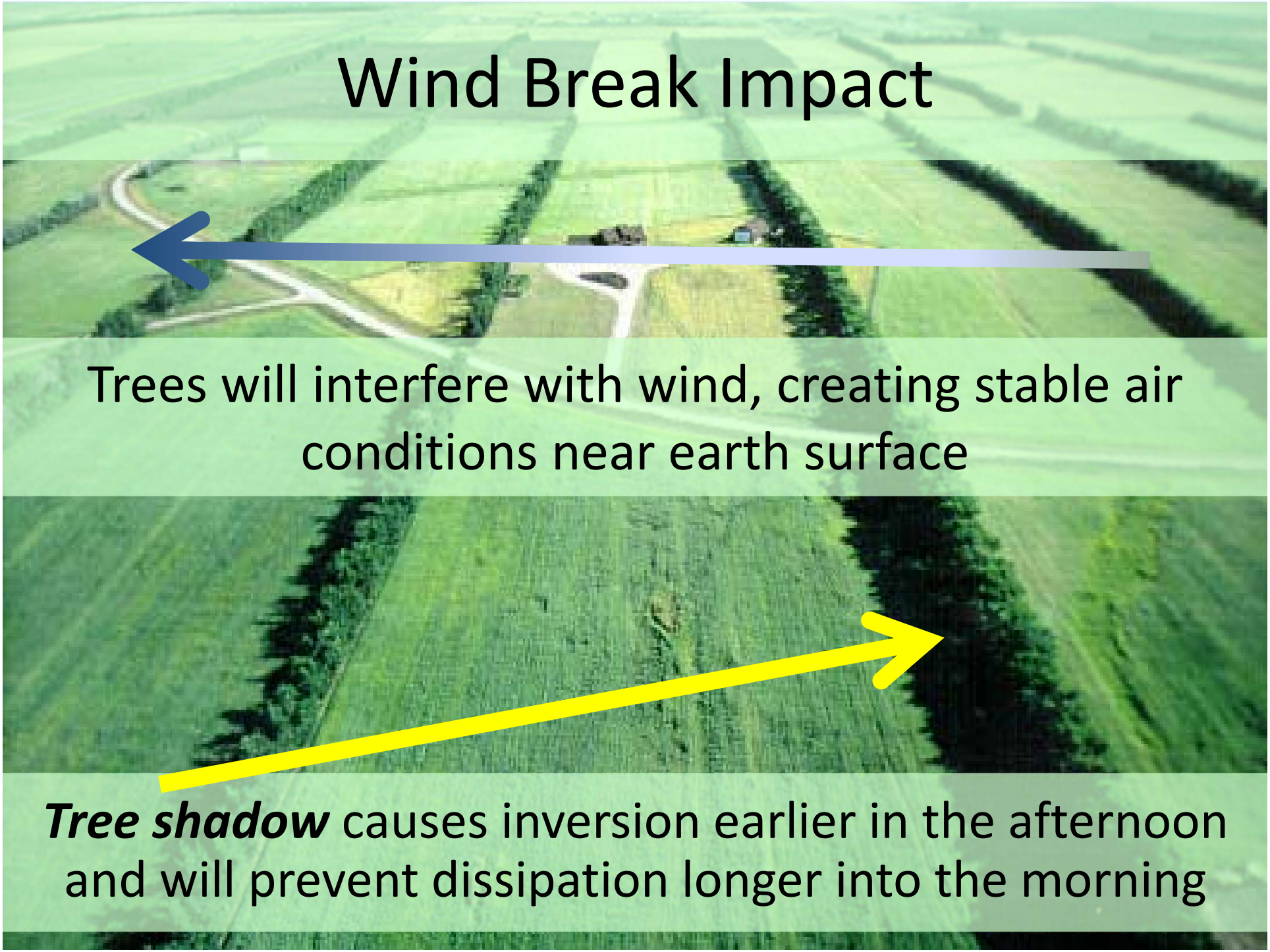
Colder Surface

Open row
surface temperature *slightly* colder than bare ground

Closed row
surface temperature *much* colder than bare ground



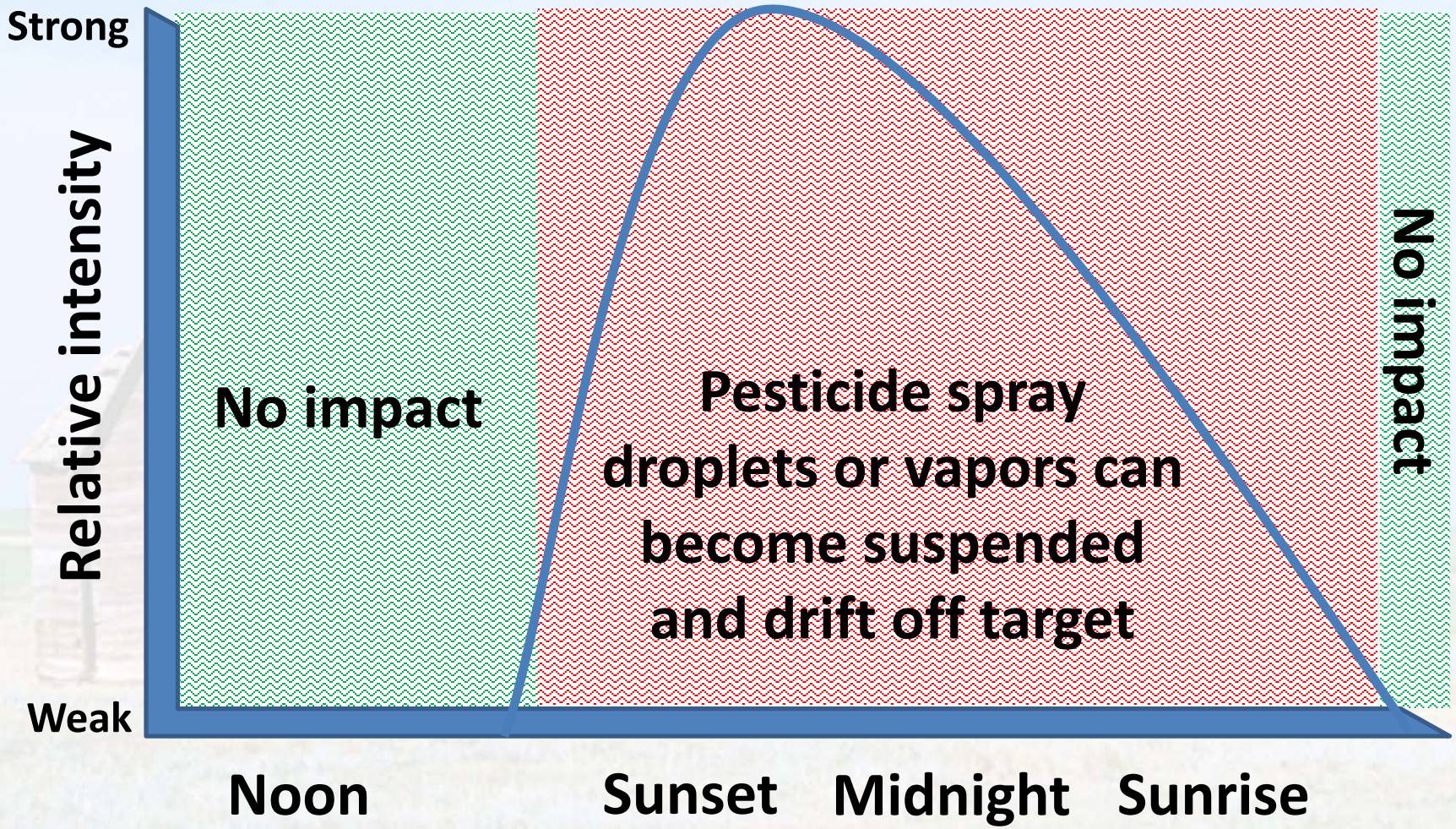
Wind Break Impact



Trees will interfere with wind, creating stable air conditions near earth surface

Tree shadow causes inversion earlier in the afternoon and will prevent dissipation longer into the morning

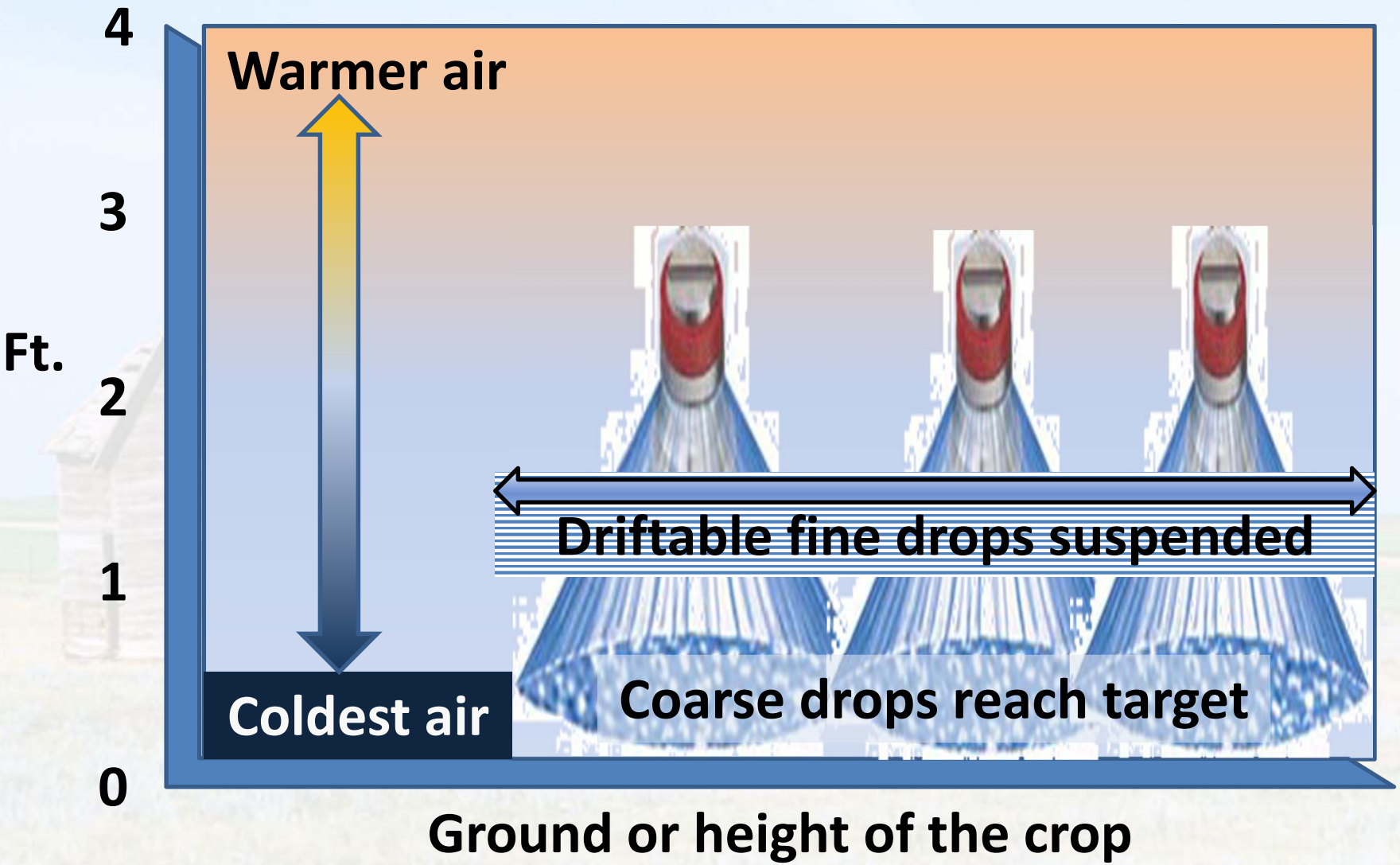
When will an inversion impact my spray operation?



What happens when I spray during an inversion?

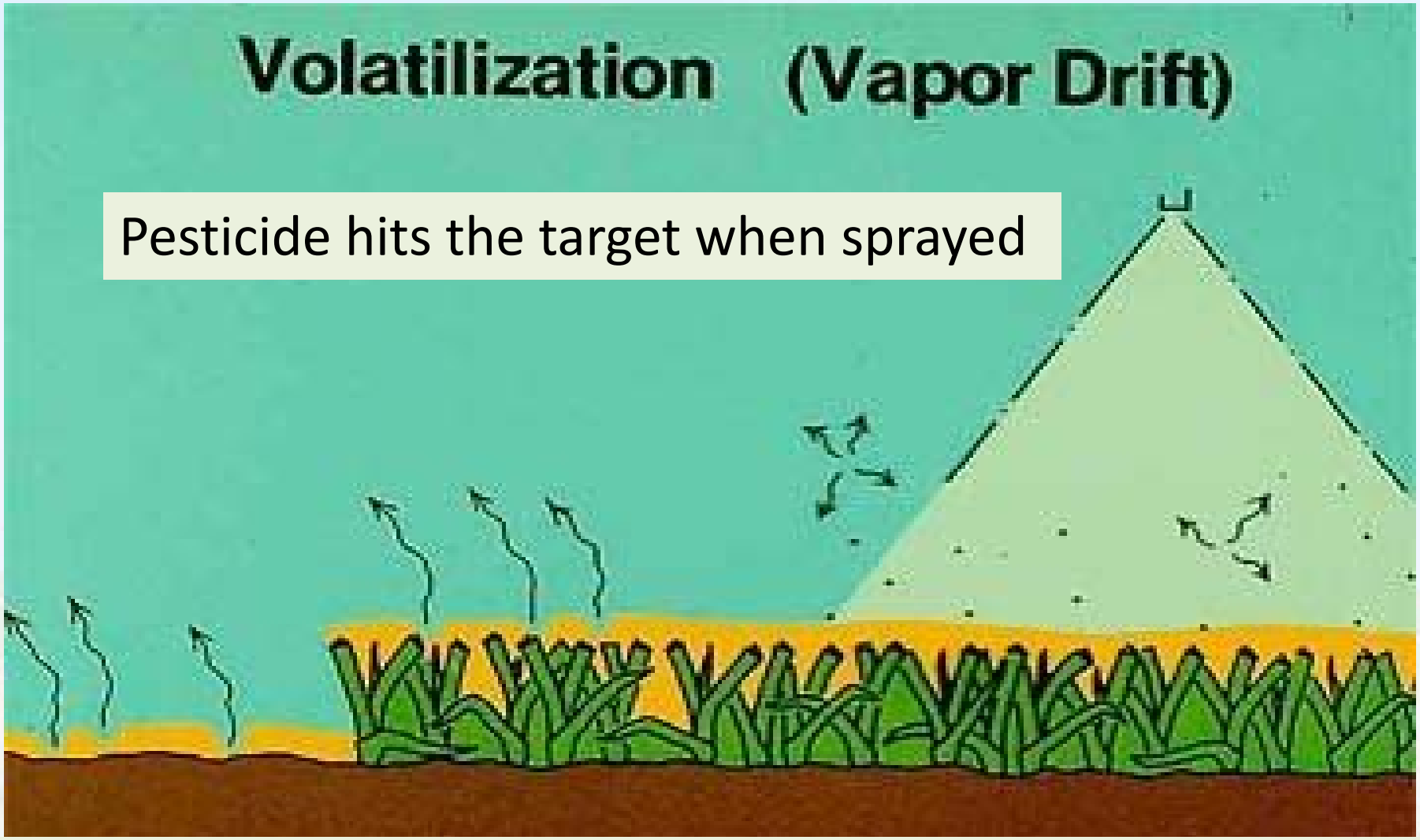
It depends on the type of application and the inversion intensity.

Spraying during an inversion = suspension of fine droplets



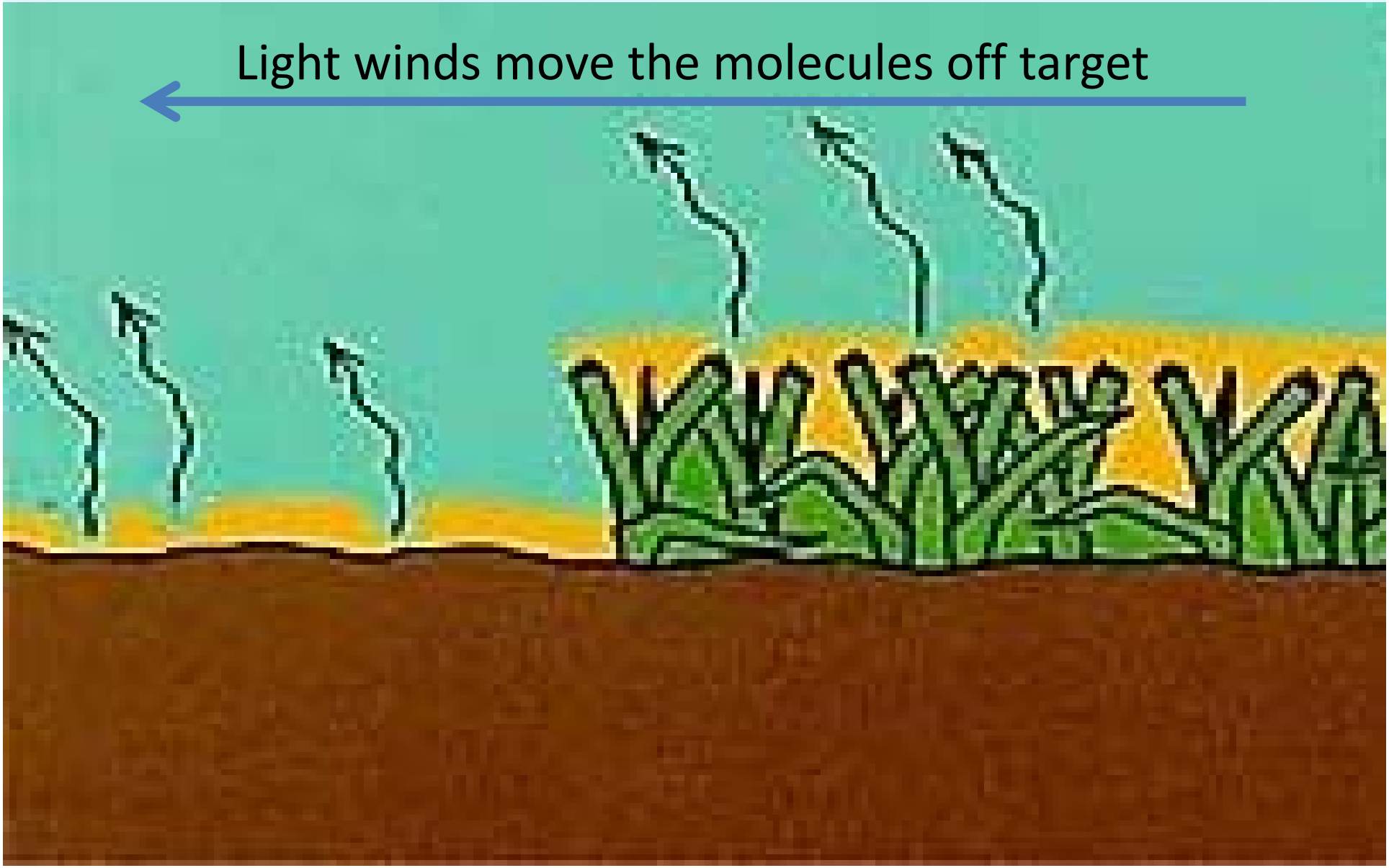

Fine spray drops hang in the air
Tracer dye, late afternoon spray, conducted in early May

Be wary of volatile pesticides



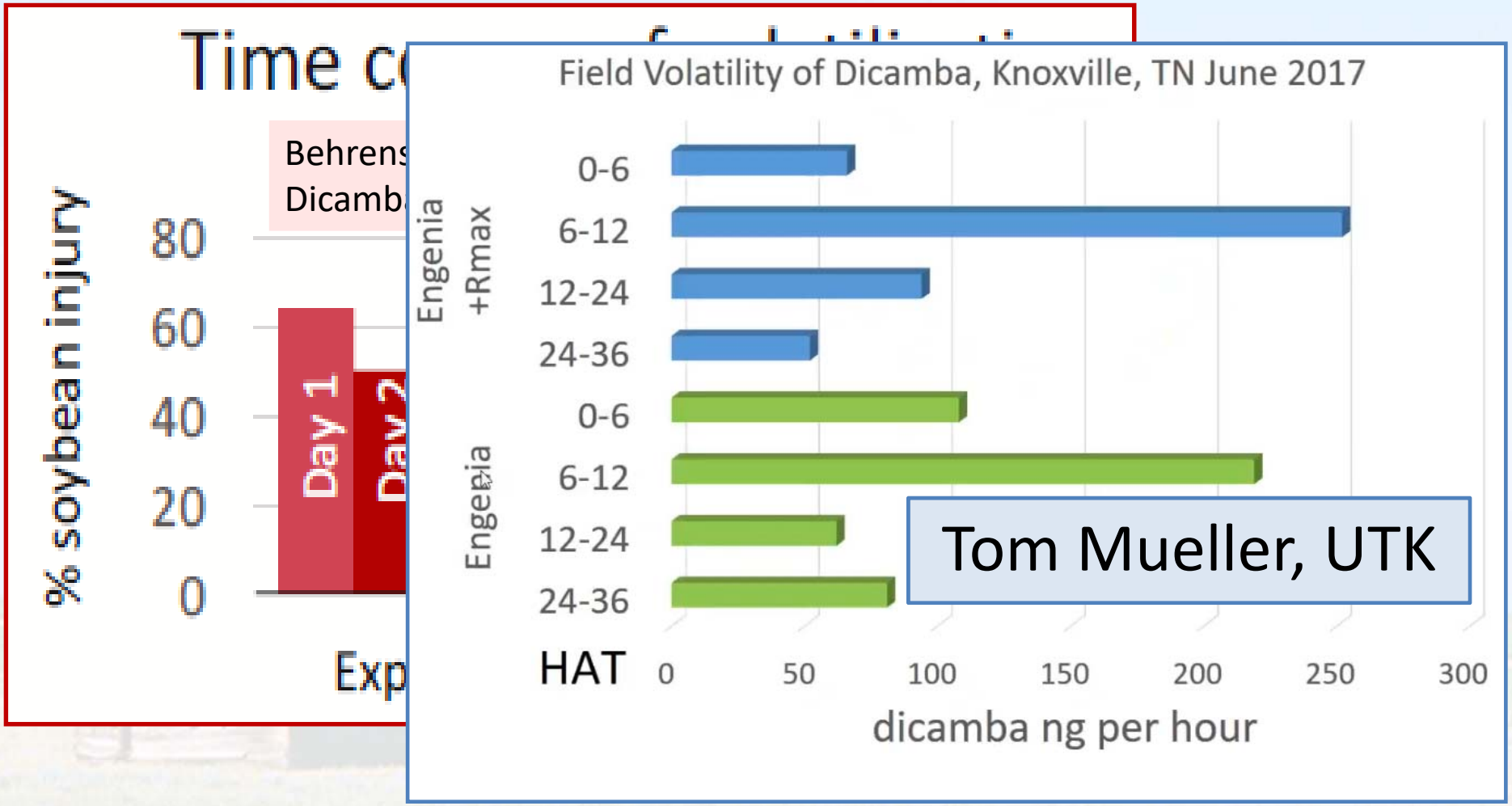
But then vaporizes or gasses off during or after application

Pesticide molecules mix with air



Volatility animation, University of Missouri

Volatile pesticides gas off over several days



thus they can become suspended in multiple inversion cycles

Clues about inversions

You can smell them

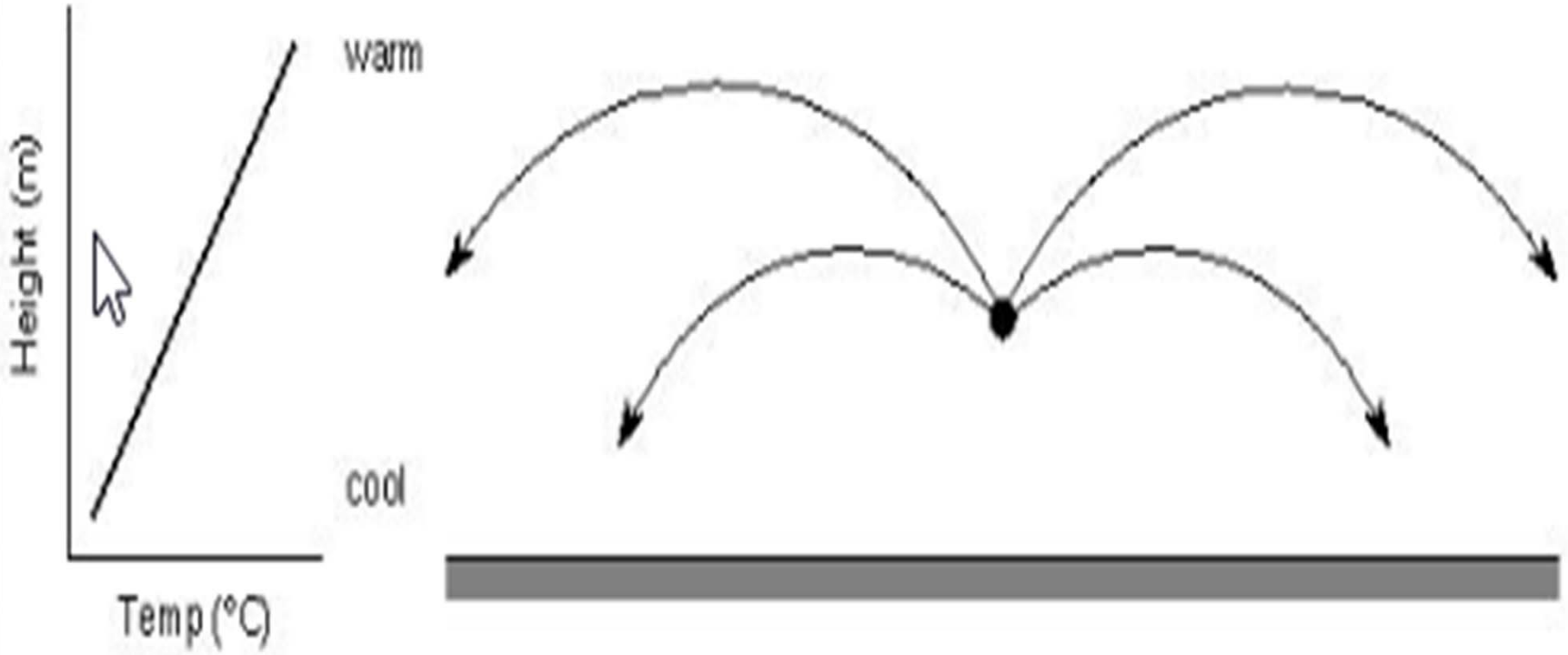

You can see it in a morning
or evening mirage

Looming mirage sank the Titanic?


Dust from vehicles or farm machinery will hang in the air

You can hear it

Inversions distort sound waves



A Perfect ***Inversion*** Storm

1. Requires radiation from surface objects into a cloudless or near cloudless sky
   - 25% or less cloud cover
2. Requires light and variable winds with minimal mixing of the lower atmosphere.
   - Especially 0 to 3 mph
   - Remain cautious with winds of ***4 to 6 mph***

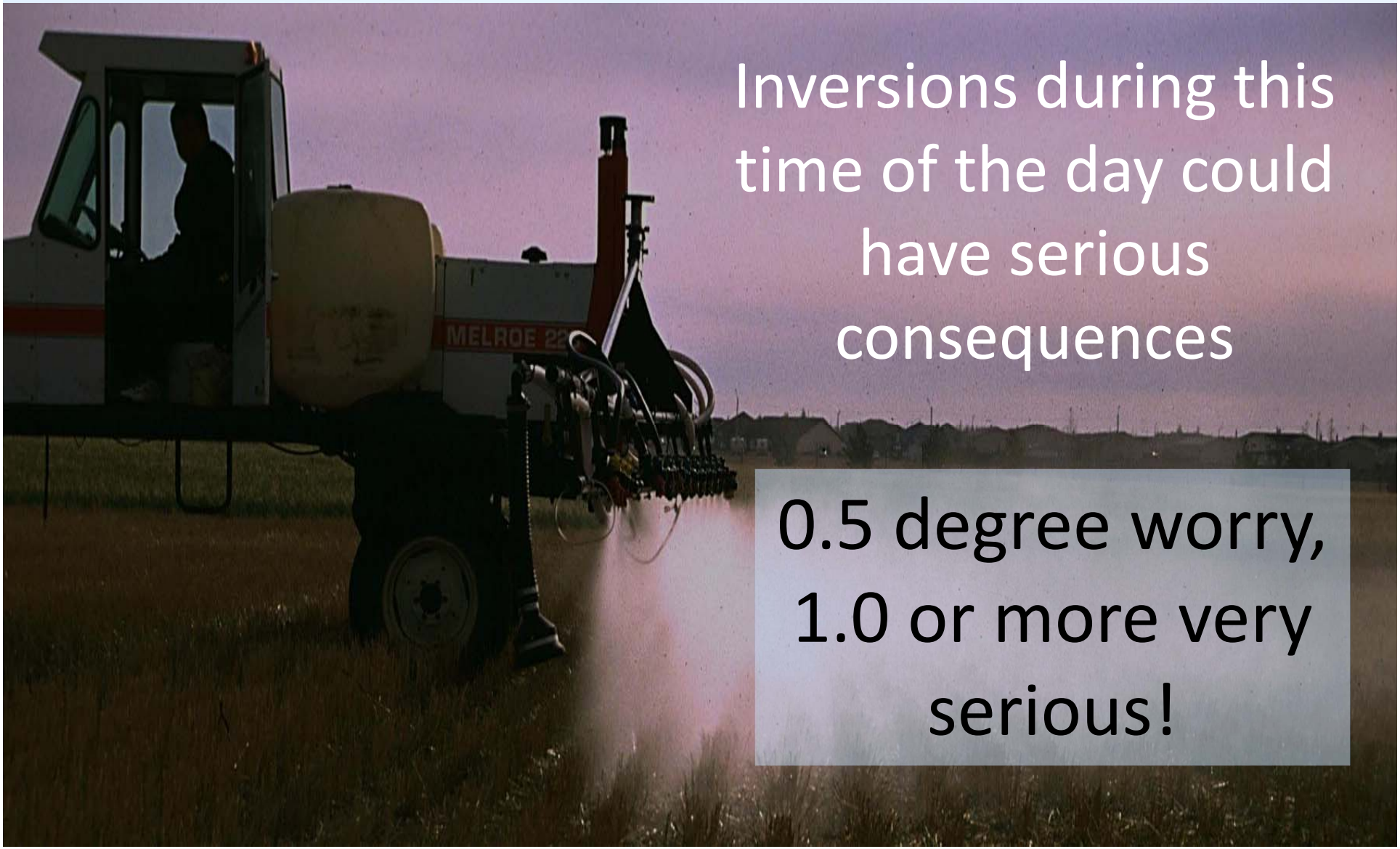
A Perfect ***Inversion*** Storm

4. Begins in the mid to late afternoon and intensifies into the night. (The inversion will then dissipate into mid-morning.)
   - Especially 1-4 hours before sunset
   - Especially 1-2 hours after sunrise

A Perfect ***Inversion*** Storm

5. Includes an unsuspecting applicator who does not recognize there is a problem:
   - Applicator who has been shut down for several days (due to high winds) and is desperately looking for an opportunity to spray
   - Applicator who is has been spraying for many hours and loses track of weather conditions, especially in the late afternoon / early evening

Late afternoon / evening spraying



Summary of Investigations Continued…

- Physical Drift
- Tank Contamination
- Temperature Inversions
- Volatility
- Misuse

Presented to EPA's Pesticide Program Dialogue Committee on November 1, 2017

Now's the time for a fact check on Air Temperature Inversions