



Temperature Inversions and off-target movement of herbicides

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PURDUE | AGRONOMY
AGRICULTURE

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**Mississippi Row Crop
Short Course**

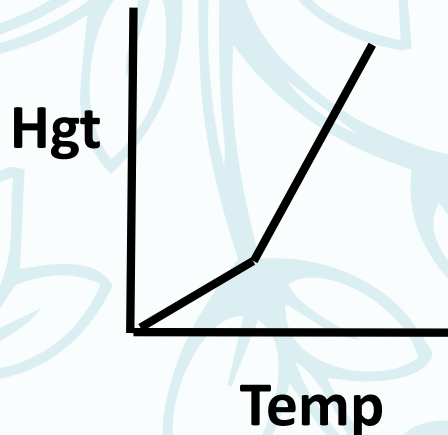
The issue: off-target dicamba damage

USEPA-approved use has various application restrictions:

- restricts use relative to time of year and winds
- provides guidance on times of day and air conditions when applications might be during temperature inversions

What are temperature inversions, why do they cause problems, and when can I expect them?

Surface temperature inversions



Air temperature increases with height

- Depth of inversion varies: few feet to 100s of feet
- Varies according to conditions
- Poor mixing in air layer

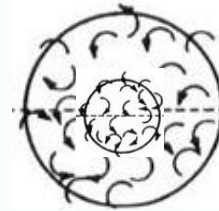
Results from

- Surface cooling (typically at night, clear skies) or
- Warm air being brought in over cooler surface
- Cold air brought in under warm air (swales)

Winds and mixing in inversions

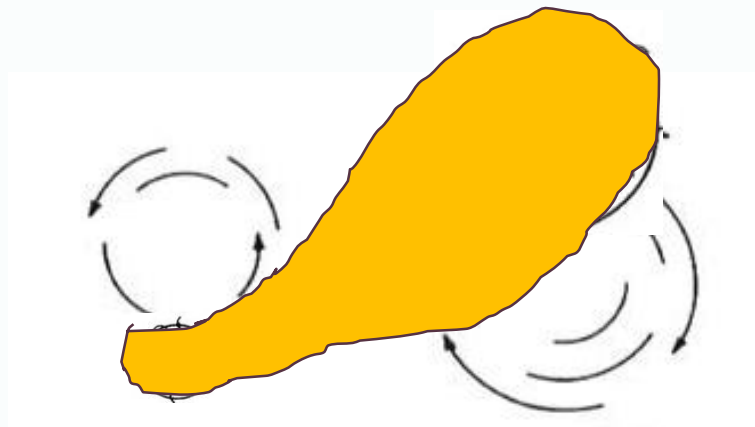
Mixing at different space scales results in **diffusion** and **dispersion** creating meandering plumes

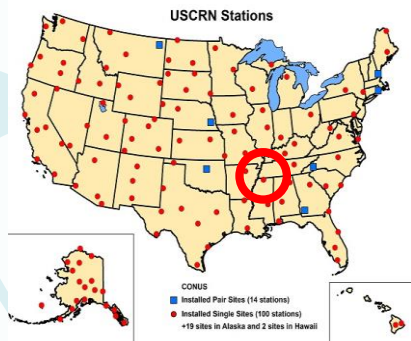
'Puff' of air **diffusing** over time



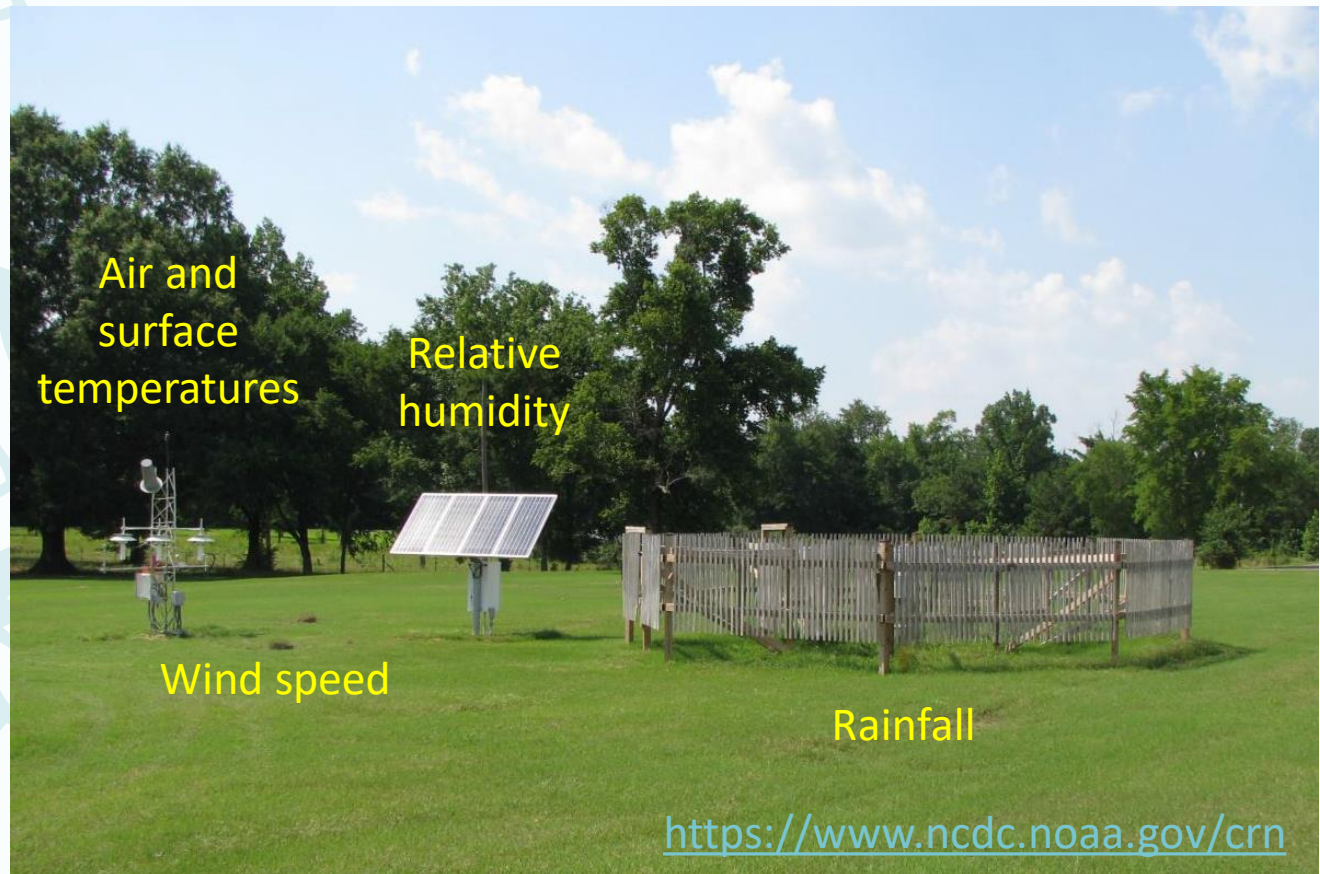
And that air moves in large meanders downwind:
Dispersion

Creating a
meandering plume

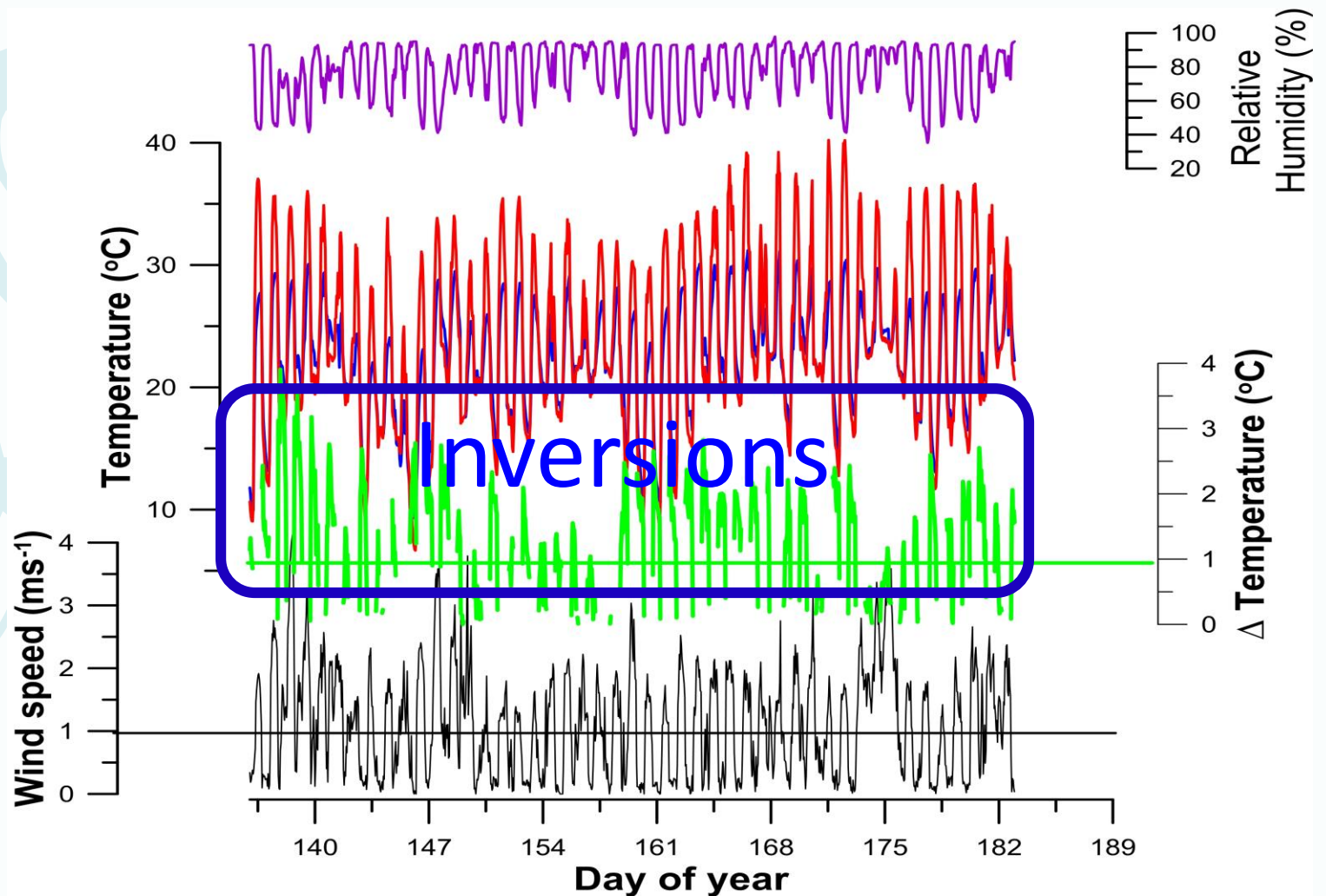




Case Study: Holly Springs 4N (US Climate Reference Network)



Holly Springs 4N: 2017



Holly Springs 4N short term climate for 15 May – 30 June (2013-2017)

3 hour interval	Wind (mph)	Air T (°F)	Ground T (°F)	Inversion occurrence (%)	Dew occurrence (%)
00-03	1.2	66	65	25%	43%
03-06	1.2	65	65	10%	24%
06-09	2.9	72	78	0%	0%
09-12	3.9	79	94	0%	0%
12-15	4.0	81	97	0%	0%
15-18	3.2	80	88	0%	0%
18-21	1.3	73	72	16%	13%
21-24	1.3	68	68	19%	30%

Variability in Holly Springs 4N short term climate for 15 May – 30 June (2013-2017)

	Inversion hours (% of all hours)	# Days with 3 hr or longer inversions	Average Duration of evening inversion (hr)	Average start of inversion (hour)
2013	10	31	4	20:59
2014	5	13	5	20:09
2015	6	26	3	20.26
2016	11	42	3	20:10
2017	28	50	8	19:17

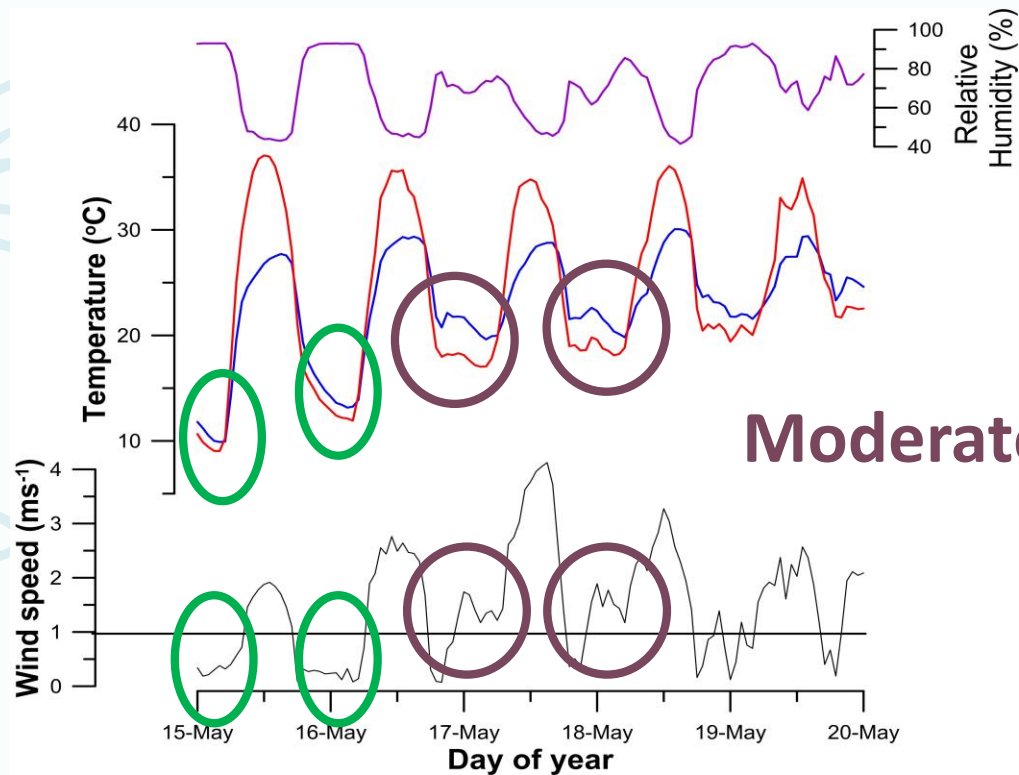
The big question

How can we know when an inversion with poor mixing is present?

- Do low wind speeds (<1 mph) indicate an inversion?
- Does fog indicate an inversion?
- Does dew indicate an inversion?
- Do inversions form only after sunset?
- If I do not have an inversion over my field, does my neighbor?

Do inversions only happen during low winds?

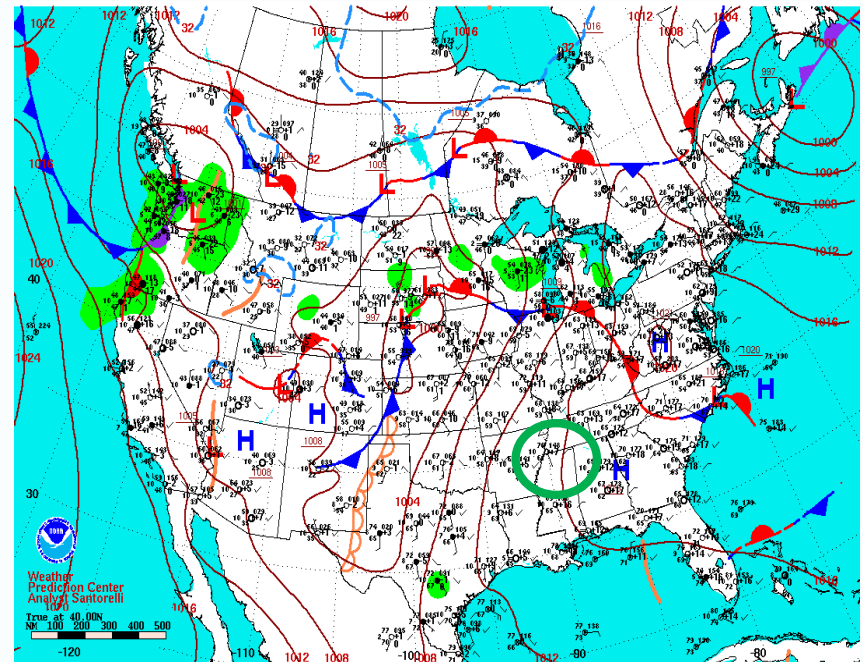
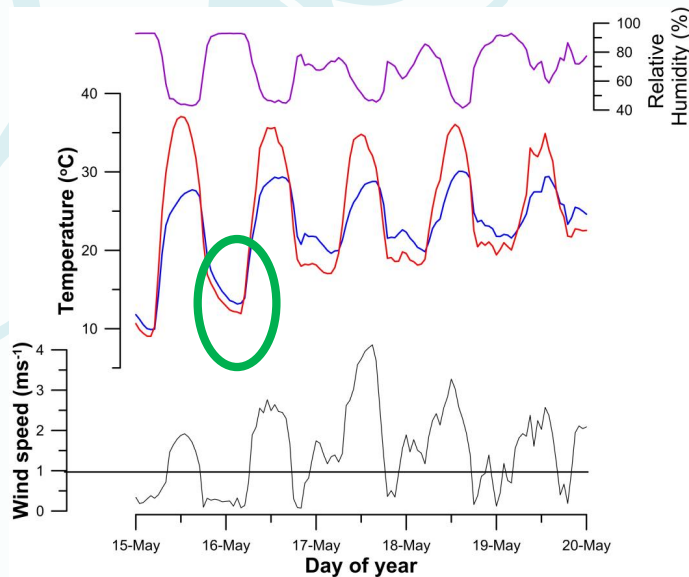
Low winds



Moderate winds

Inversions with low winds: Holly Springs 4N

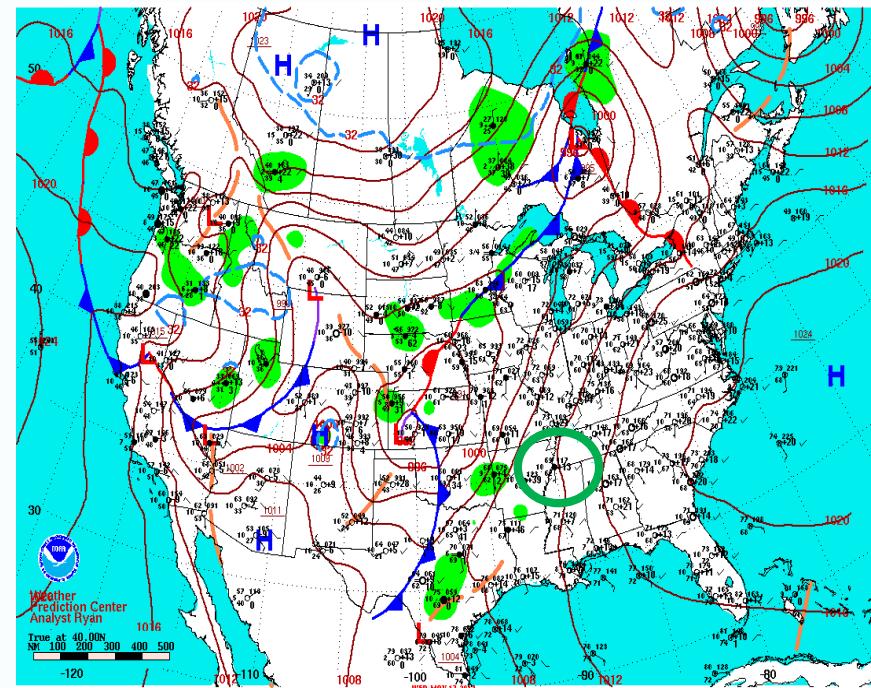
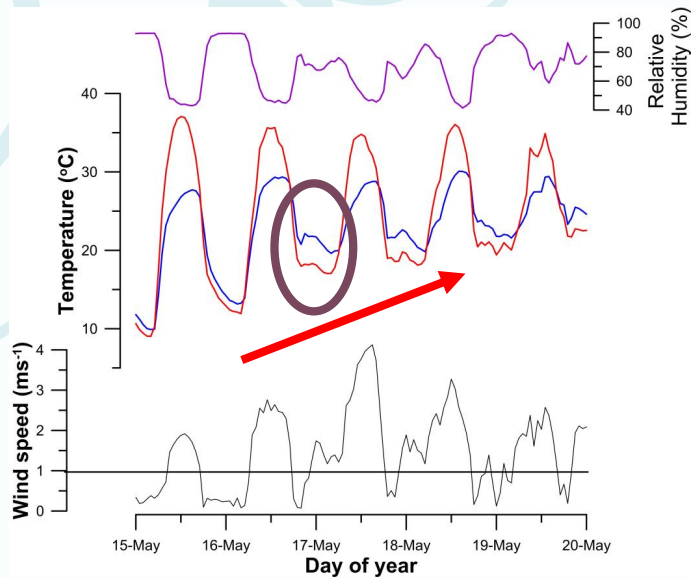
Clear skies and regional High pressure



Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

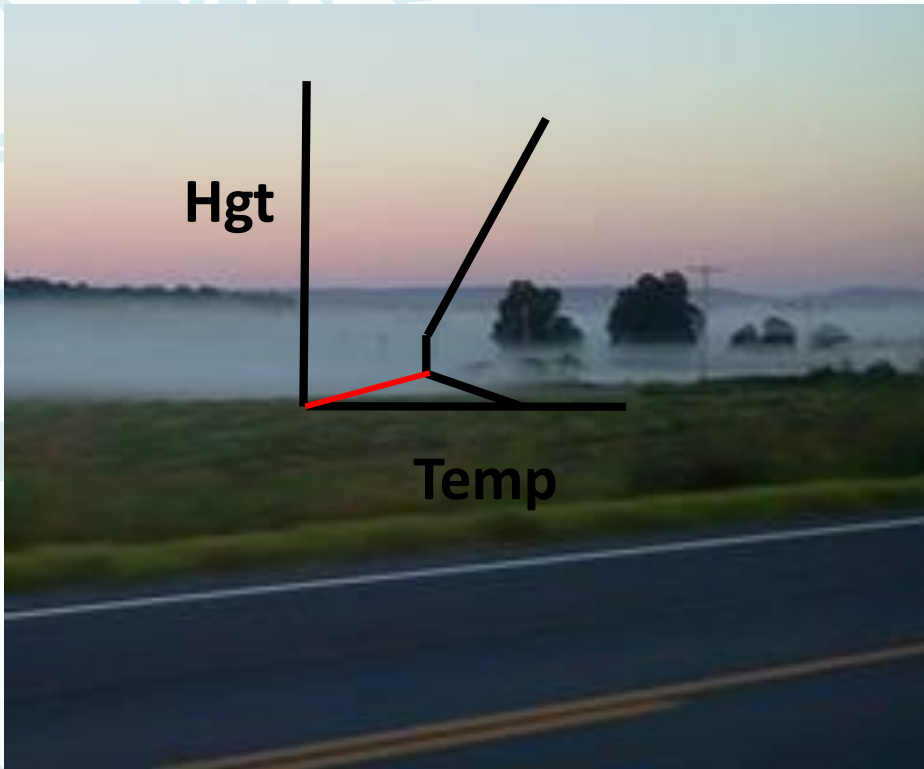
Inversion with moderate winds: Holly Springs 4N

Ahead of weather fronts



Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Is fog an indicator of inversions?



Source: iWitness on weather.com

Fog forms when the air temperature is less than dew point temperature

- Ground fog reaches the ground
- Often fog does not reach the ground

Are inversions indicated by fog? **NO**

Status	Time interval	Average Humidity (%)	Fog (% of time)	Average Wind speed no fog (mph)	Average Wind speed during fog (mph)
No inversion					
	2300-1800	74%	2%	2.9	0.6
	1900-2200	88%	2%	1.3	0.2
Inversion					
	2300-1800	84%	4%	1.3	0.3
	1900-2200	83%	2%	1.1	0.4

Is dew an indicator of inversions?



<http://www.dewbow.co.uk/bows/dew10.html>

Dew forms when the ground temperature is less than dew point temperature

- Most common in early morning

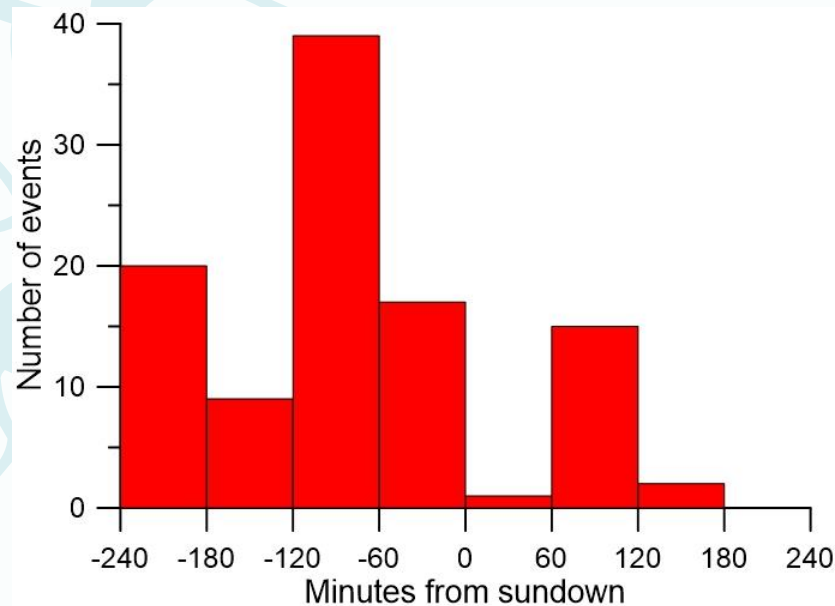
Are inversions indicated by dew? **YES**

Status	Time interval	Average Humidity (%)	Dew (% of time)	Average Wind speed no dew (mph)	Average Wind speed during dew (mph)
No inversion					
	2300-1800	74%	7%	3.0	0.5
	1900-2200	88%	17%	1.5	0.3
Inversion					
	2300-1800	84%	82%	2.3	1.0
	1900-2200	83%	77%	2.2	0.8

Do inversions begin at sunset?

Most inversions begin **before** sunset

- 20% start between 3 and 4 hours before sunset



Inversions 15 May – 30 June

	Average start of evening inversion (hour)	Inversions starting before sunset (%)	Average Duration of evening inversion (hr)
2013	20:59	35%	4
2014	20:09	54%	5
2015	20:26	46%	3
2016	20:10	48%	3
2017	19:17	68%	8

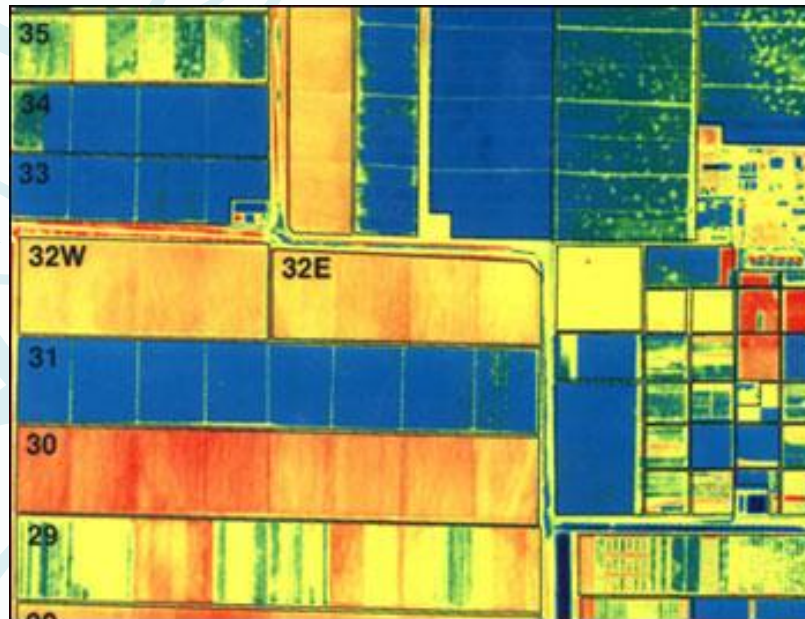
Mean sunset time for 2017 20:08

How different are the air surface temperatures during inversions?

Time interval	Air T (°F)		Surface T (°F)	
	Inversion	No Inversion	Inversion	No Inversion
00-03	67	66	64	65
03-06	69	65	66	65
06-09	70	72	67	78
18-21	75	+3° 72	71	-2° 73
21-24	73	+6° 67	69	-2° 67

Are inversions in your field also likely in everyone else's around you?

Overlying air likely to be similar, BUT Surface temperatures can vary greatly with land use



**NOT
ALWAYS**

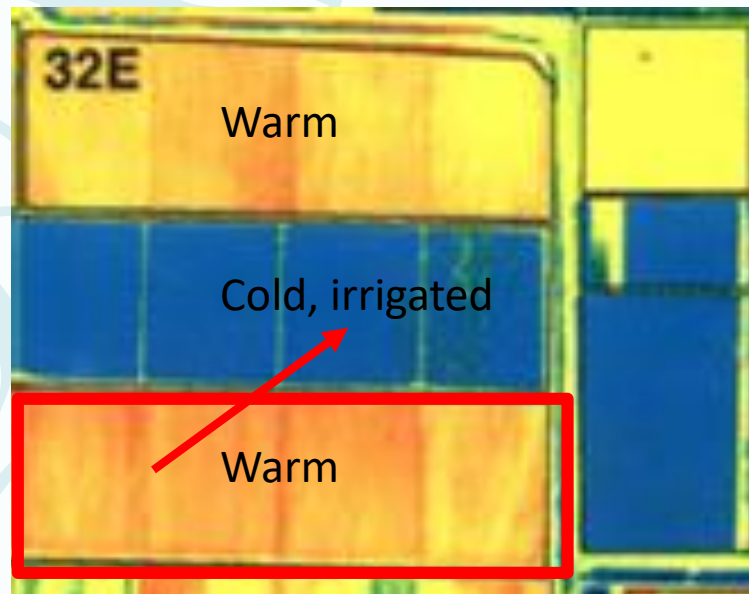
Is inversion and mixing across your field likely to be all the same?

Surface temperatures can vary greatly within land use by soil type, and terrain



Affects of inversions on mixing between fields

You could be spraying under suitable conditions while your neighbor with colder ground has an inversion



Air with your well-mixed herbicide could spread into neighbors field and not continue to mix

Summary

- Inversions can form when winds are moderate
- Inversions often begin before sunset
 - 20% started by 5PM
- Fog is not a good indicator of an inversion
- Dew is a good indicator of inversion
- Inversions and low mixing not consistent across the landscape

Unknowns

- Only one case study for MS
- Case study over grass surface, not soybeans or cotton
- No study across fields to verify between-field affects



<https://www.ncdc.noaa.gov/crn>



<http://www.dewbow.co.uk/bows/dew10.html>



gaddingaboutwithgrandpat.blogspot.com

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