

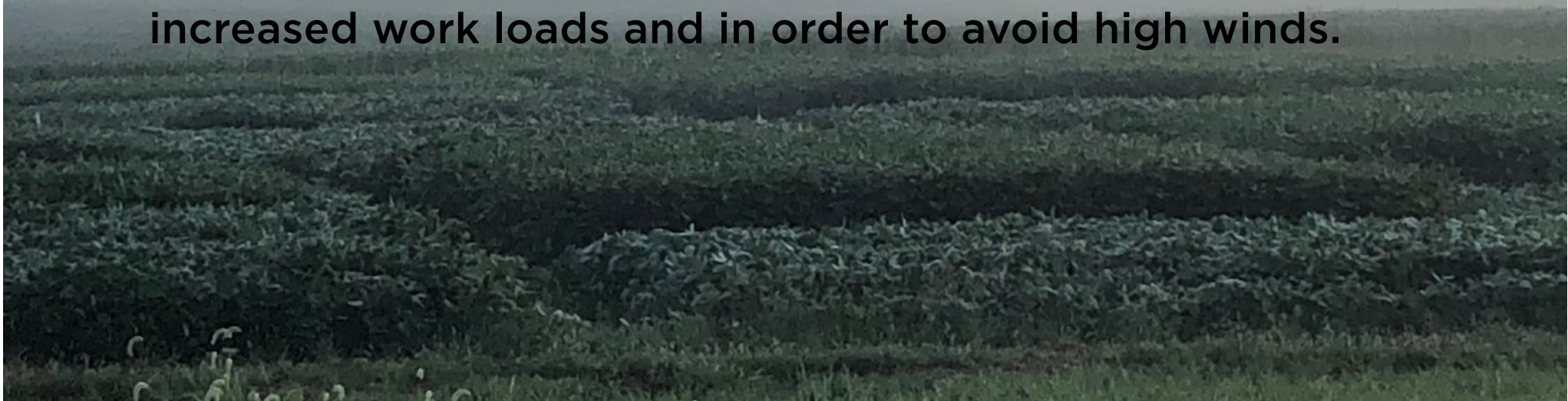
# Inversions and Ground Pesticide Applications

Mandy Bish, Ph.D.  
Kevin Bradley, Ph.D.  
University of Missouri  
April 2019



# **Inversions are NOT new, so: what's the deal with inversions + synthetic auxin herbicides?**

1. Sensitive plants are really sensitive; it takes a very small amount moving in the air to cause damage:  
<https://www.youtube.com/watch?v=JXGc-XQDdSg>
2. Synthetic auxins are prone to volatility and can return to the air after reaching the target, possibly during an inversion.
3. Longer work days. We spray later in the evening because of increased work loads and in order to avoid high winds.



## **So... What is a Temperature Inversion?**

Weather event that occurs when air temperatures near the earth's surface are cooler than air temperatures higher in the atmosphere.

## **How Do They Contribute to Off-Target Movement?**

Cause stable air masses to form. Herbicides and other particles disperse more slowly, if at all, when trapped in the stable air mass.

## **What's the Evidence Inversions Contributed...**



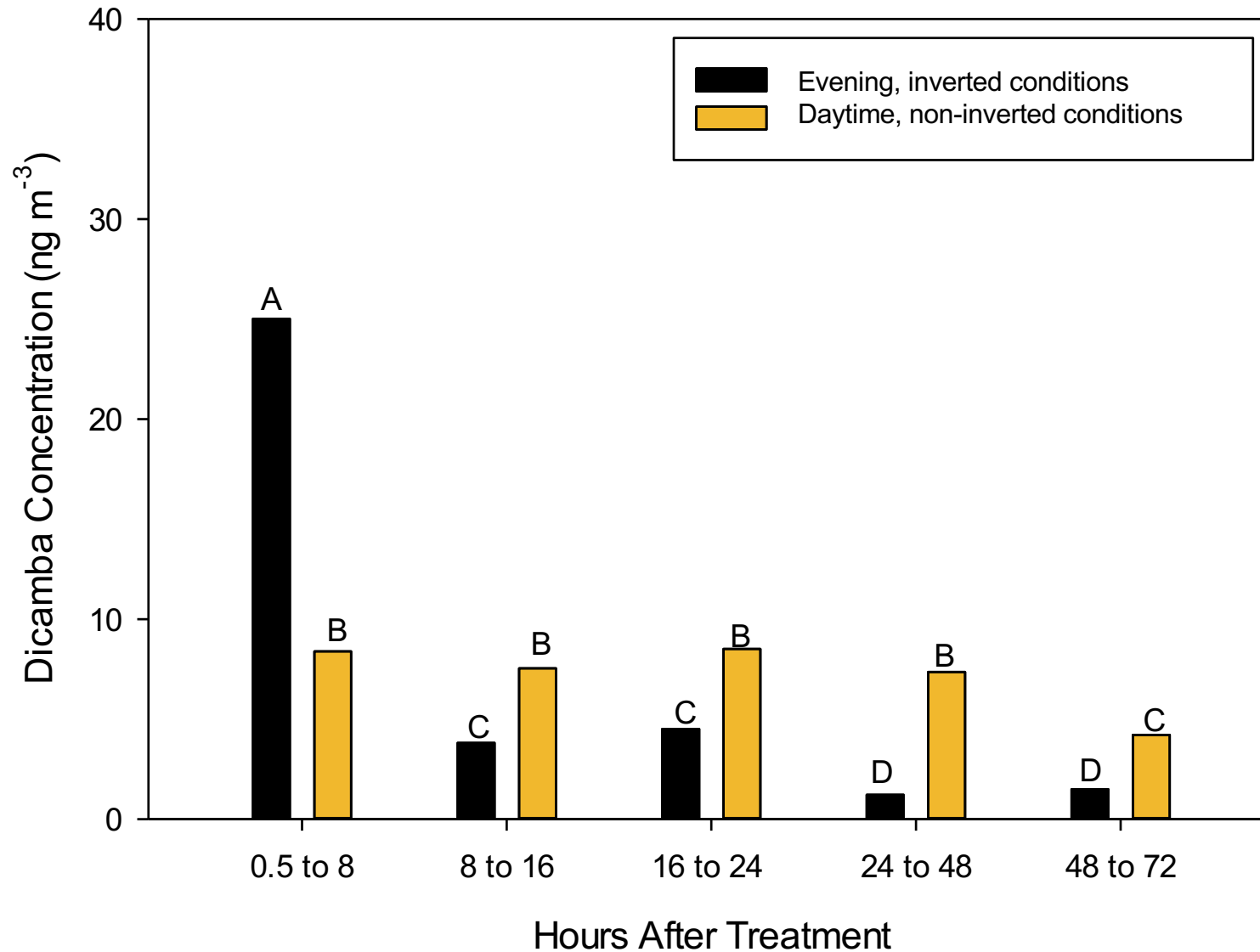
# 1. Field observations:

Time of some applications + pattern of injury in field



## 2. Research observations:

Dicamba is detected at higher levels when applied during an inversion

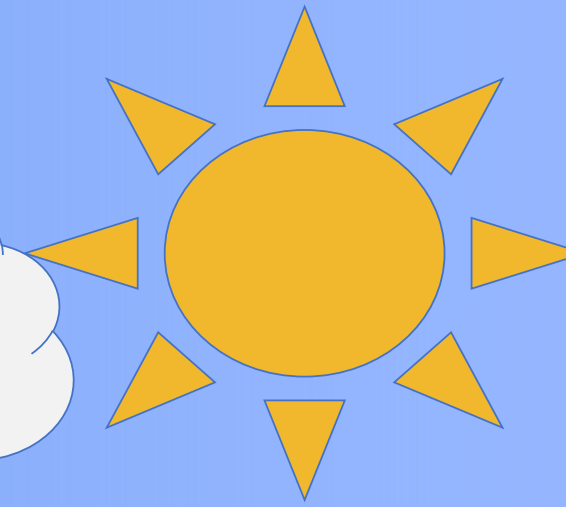
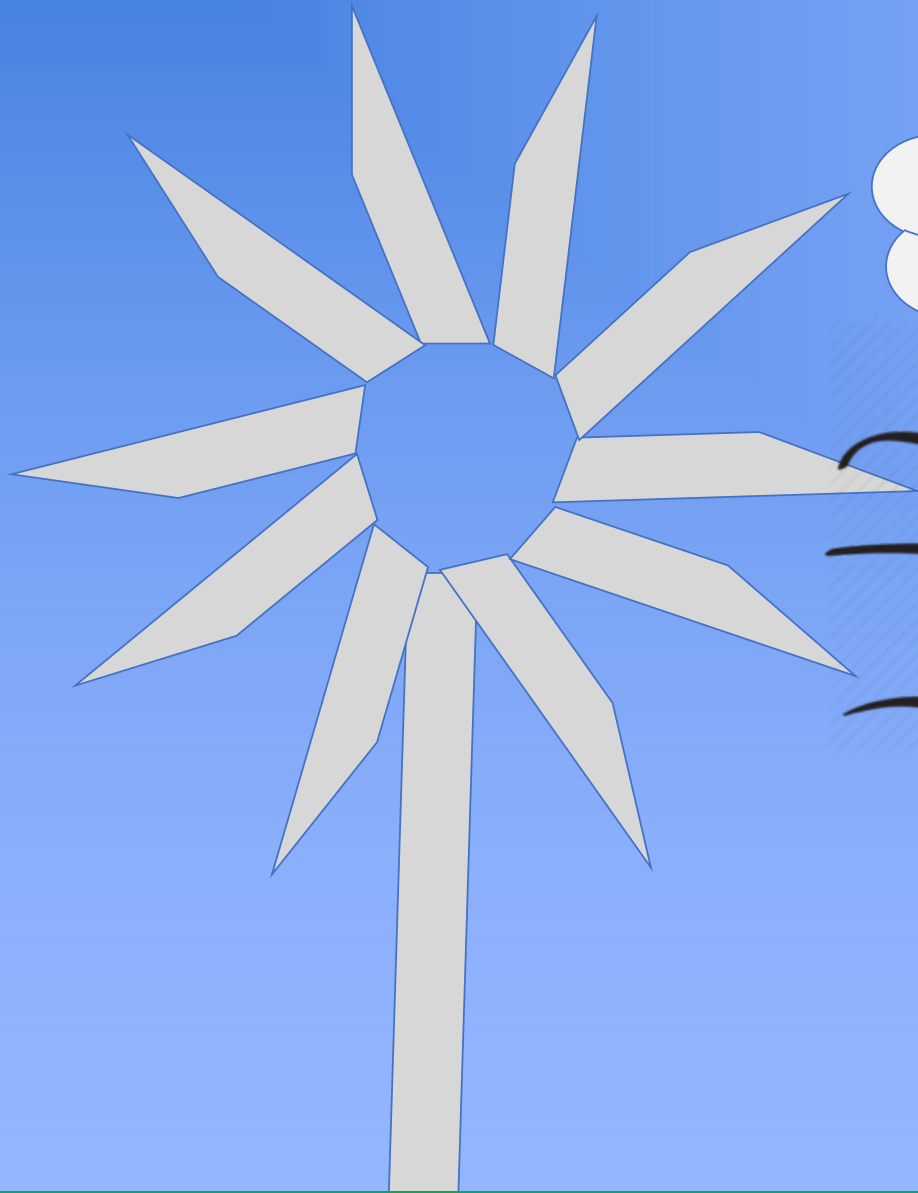


# What causes a temperature inversion?

- Subsidence inversions - air moving over valleys is heated via friction as it passes over the hills
- Radiation Inversions\*
- Frontal inversion (cold front moves in under a warm front)
- Others

\*Radiation inversions are influenced by sunset and thus of interest to all cropping regions

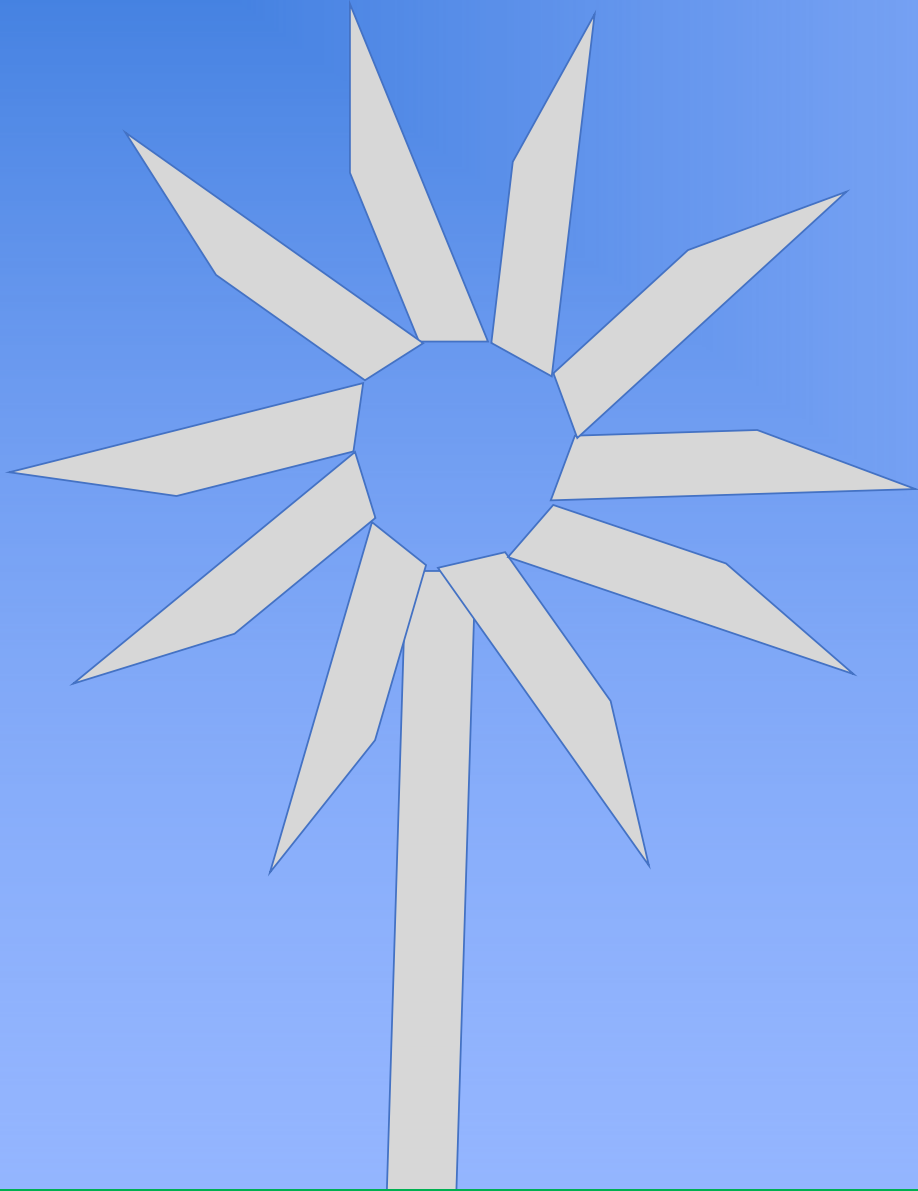
Wind, clouds, and sun are indicative of unstable, **non-inverted** air temperatures



**Cooler air**

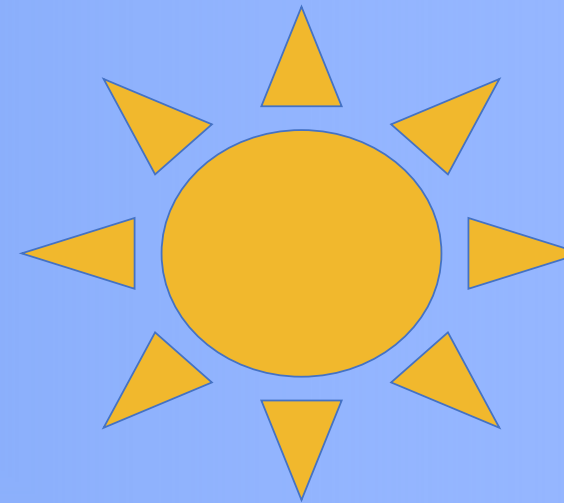
**Warmer air**

**Radiation inversions** occur when the wind lessens, clouds dissipate, and the sun begins setting



**Warmer air**

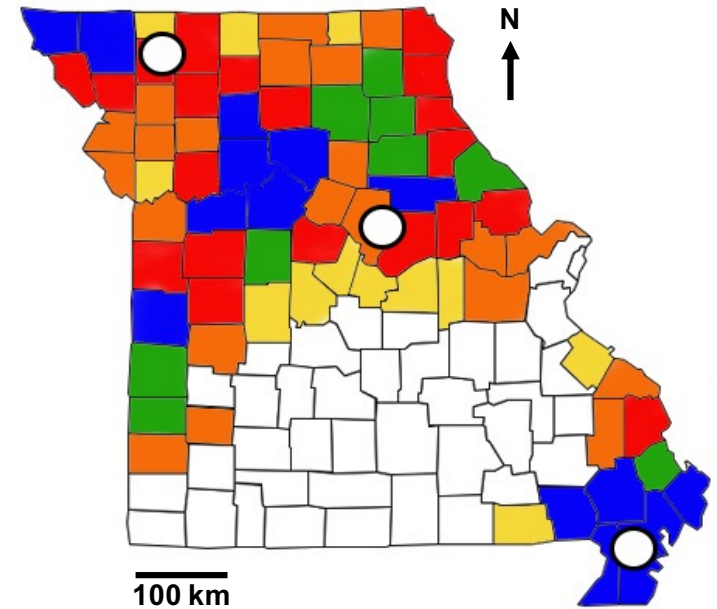
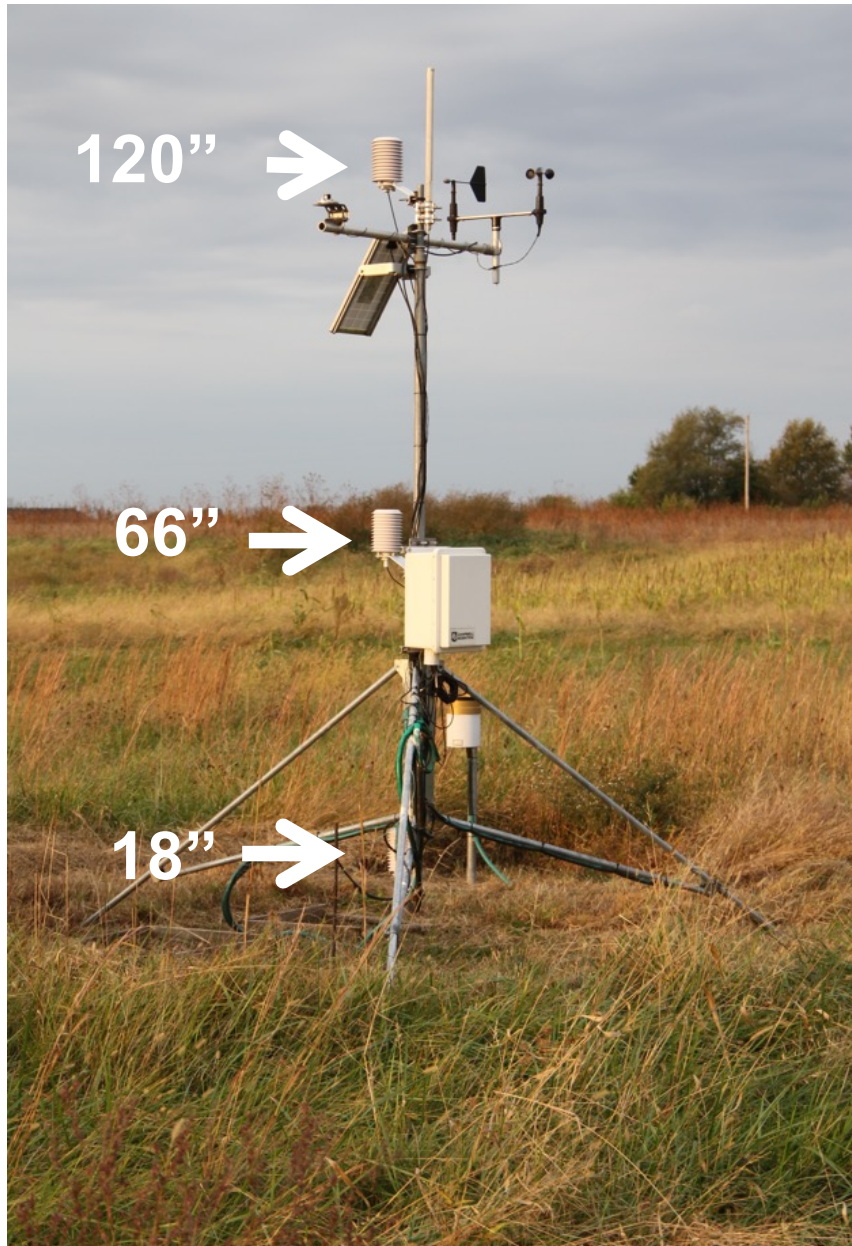
**Cooler air**





# Monitoring Inversions in Missouri

2015 to 2017 - Albany, Columbia, and Hayward, MO



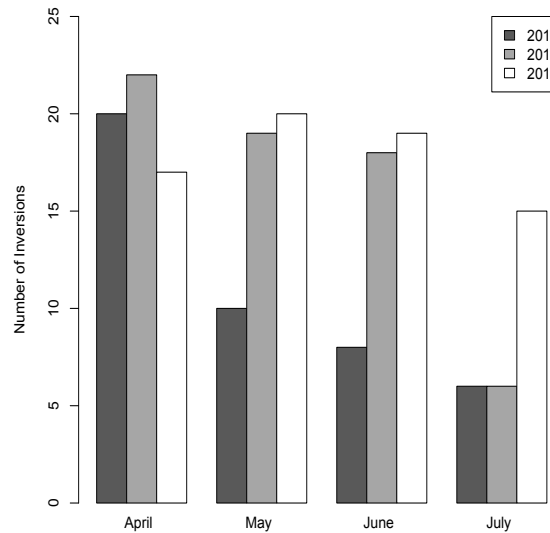
Pat Guinan, University of Missouri  
Associate Extension Professor of Climatology

# Inversions are Common in Missouri

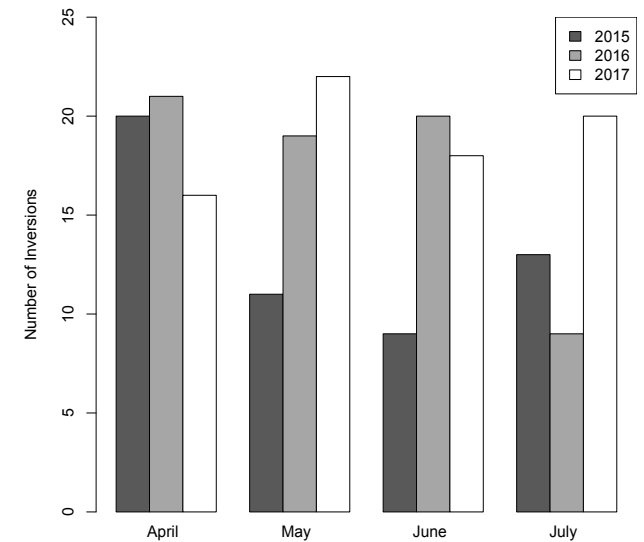
2015 to 2017 - Albany, Columbia, and Hayward, MO

- Inversions occurred in all months and sites studied
- The rain and cloud cover in 2015 seemed to interfere with inversion formation in many months.
- Frequency is not drastically different among sites.
- **What about the time that inversions form?**

Albany



Columbia



Hayward

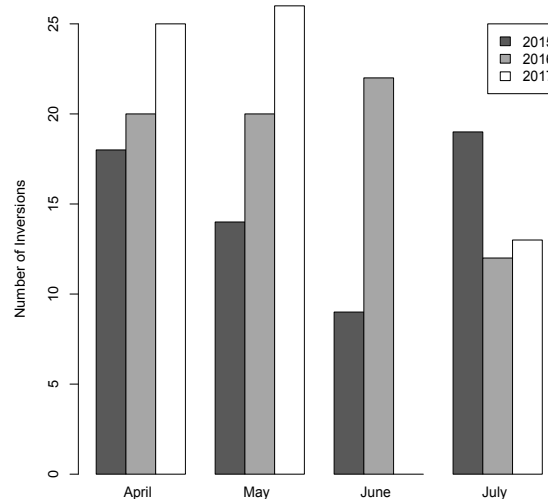


Figure 6: Number of days per month in which inversions formed.  
\*Inversion events from June 2017 at Hayward were not included due to interference by nearby vegetation that resulted in artificial shading of the 45 cm sensor.

# What Times did Inversions Form?

2015 to 2017 - Albany, Columbia, and Hayward, MO

- Inversions formed earlier at Hayward than the other sites.
- Inversions typically formed between **5:20 and 8:05 PM** depending on month and site.

Appendix B Table 1. Three-year trend for time that inversions began forming (2015-2017)

	Month	n <sup>†</sup>	Start Time (hh:mm)				
			Mean <sup>†</sup>	Median	Mode	Earliest	Latest
Albany	April	64	18:55 ± 2:33	18:10	18:20	0:40	23:35
	May	70	19:15 ± 2:05	18:50	18:15	0:00	23:35
	June	66	19:11 ± 1:32	18:55	18:10	0:05	23:10
	July	33	20:47 ± 2:21	20:05	19:30	0:00	22:40
Columbia	April	58	18:01 ± 1:03	18:00	18:00	15:50	23:25
	May	52	18:27 ± 1:03	18:25	18:45	0:15	19:25
	June	48	18:32 ± 0:38	18:35	18:55	1:00	21:00
	July	42	19:00 ± 0:37	19:10	19:15	17:45	20:40
Hayward	April	64	17:30 ± 1:43	17:20	17:45	2:45	21:30
	May	60	17:17 ± 1:10	17:30	18:30	14:20	18:55
	June <sup>‡</sup>	32	18:01 ± 0:53	18:20	18:30	3:30	19:05
	July	33	18:10 ± 1:03	18:28	18:00	13:50	20:40

# When did Inversions Dissipate?

2015 to 2017 - Albany, Columbia, and Hayward, MO

- Inversion dissipation was similar at the Hayward and Columbia sites, from 5:40 to 6:50 AM depending on site and month.
- Inversion dissipation was less consistent at Albany; topography may contribute to this.

Table 2. Three-year trend for time that inversions dissipated (2015-2017)

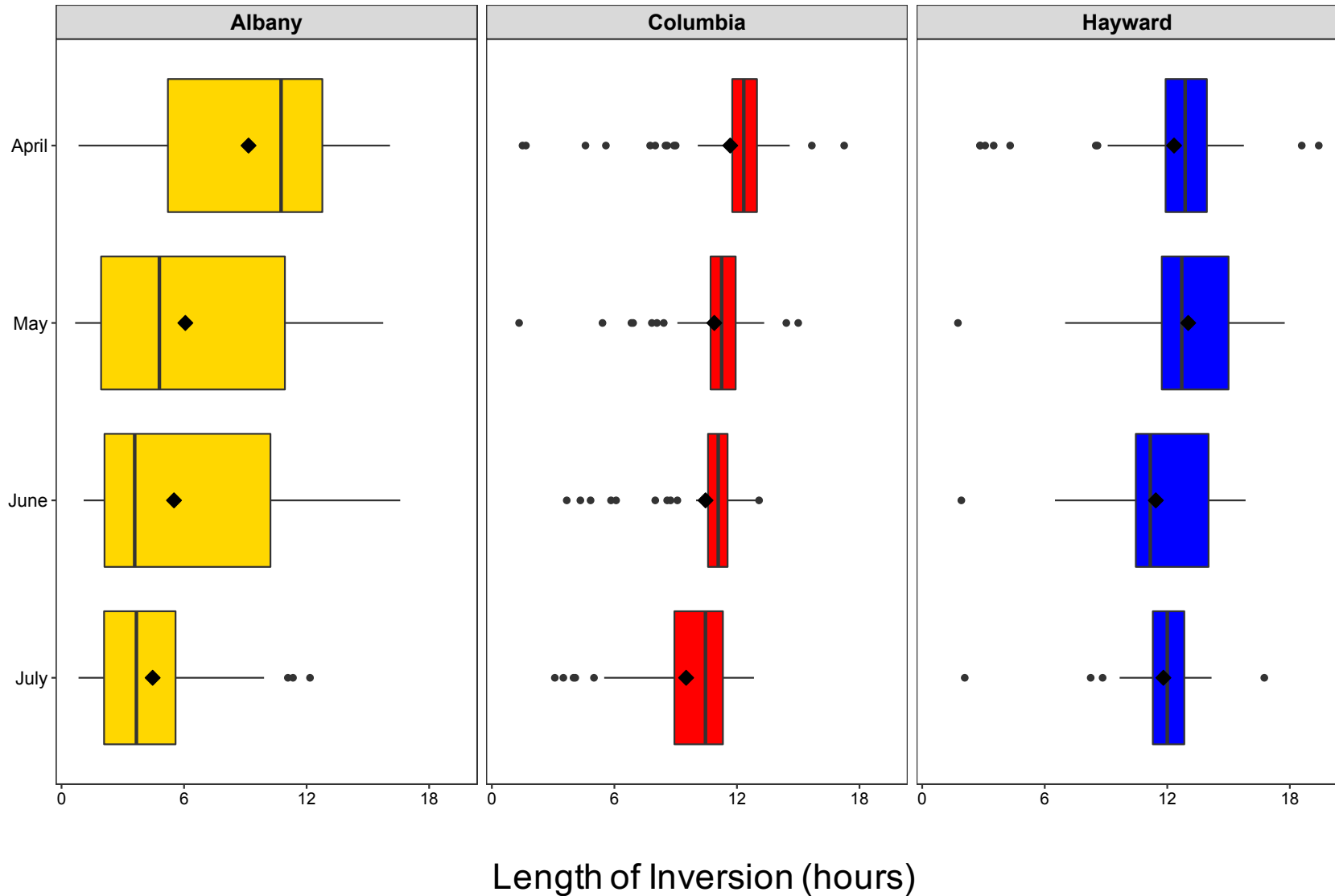
	Month	n	End Time (hh:mm)				
			Mean <sup>‡</sup>	Median	Mode	Earliest	Latest
Albany	April	64	7:22 ± 5:26	6:40	6:40	0:35	23:55
	May	70	8:01 ± 6:15	6:30	6:35	0:05	23:55
	June	66	10:34 ± 8:21	6:25	6:20	0:15	23:45
	July	33	7:57 ± 9:04	5:40	1:05	0:05	23:50
Columbia	April	58	6:18 ± 2:46	6:25	6:35	0:55	23:05
	May	52	6:12 ± 3:20	5:55	5:45	1:05	23:05
	June	48	6:08 ± 3:43	5:45	5:50	0:30	23:05
	July	42	6:48 ± 5:30	5:45	5:45	0:00	23:15
Hayward	April	64	6:48 ± 2:47	6:30	6:15	0:35	20:25
	May	60	6:49 ± 2:07	6:30	5:55	0:45	18:35
	June <sup>‡</sup>	32	5:53 ± 1:20	5:40	2:20	2:20	8:00
	July	43	6:34 ± 1:55	6:30	6:40	3:25	17:45

<sup>‡</sup>June 2017 was excluded from the analysis due to interference of the 46 cm air temperature probe by shading from a pollinator plot.



# How Long do Inversions Last?

2015 to 2017 - Albany, Columbia, and Hayward, MO

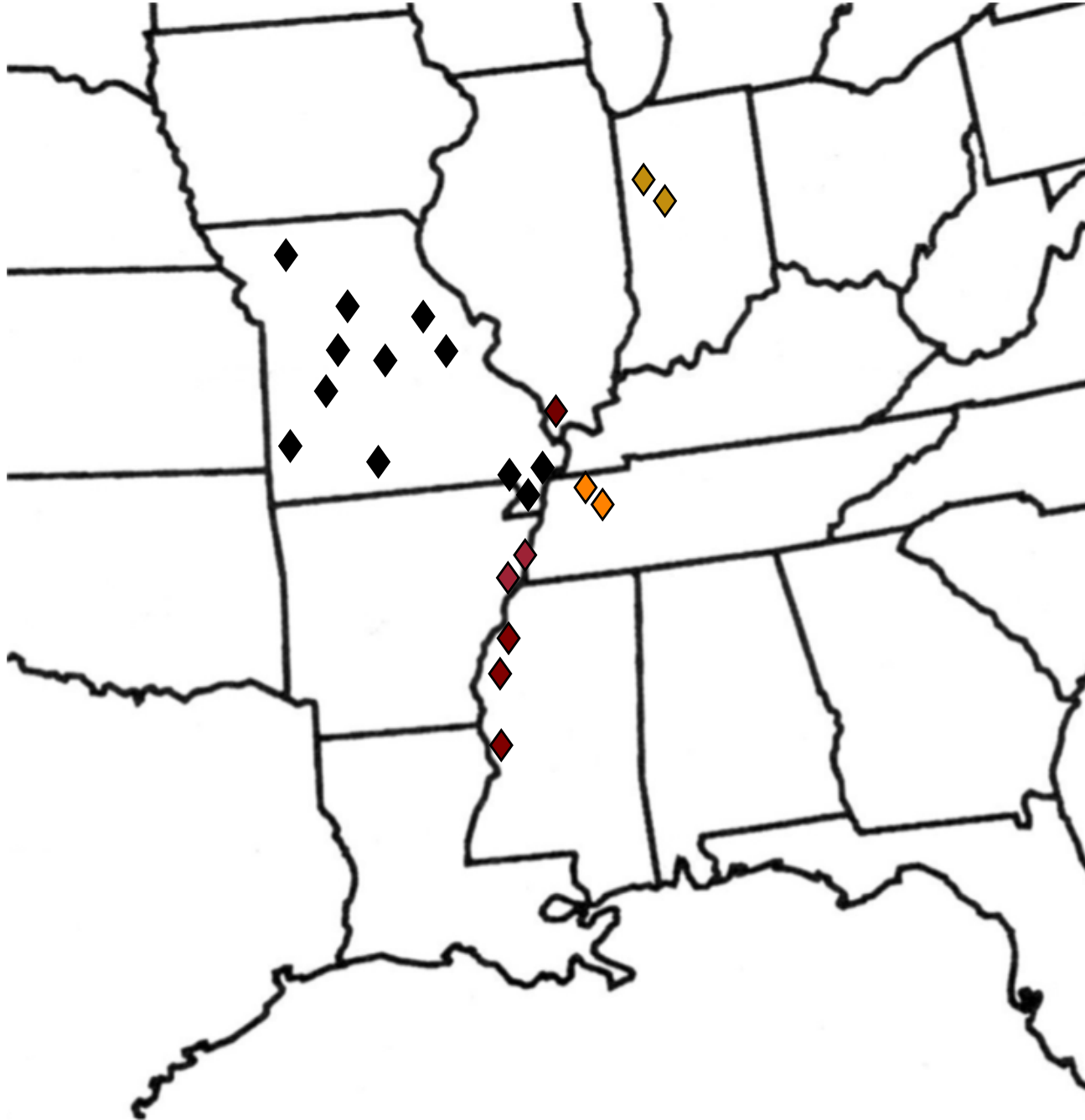


The wider the box = the more variation.

The black diamond = the average inversion duration.

(Bish, Guinan, and Bradley 2019, accepted with revisions to *J of Applied Meteorol & Climatol.*)

# Expanding the Monitoring Network

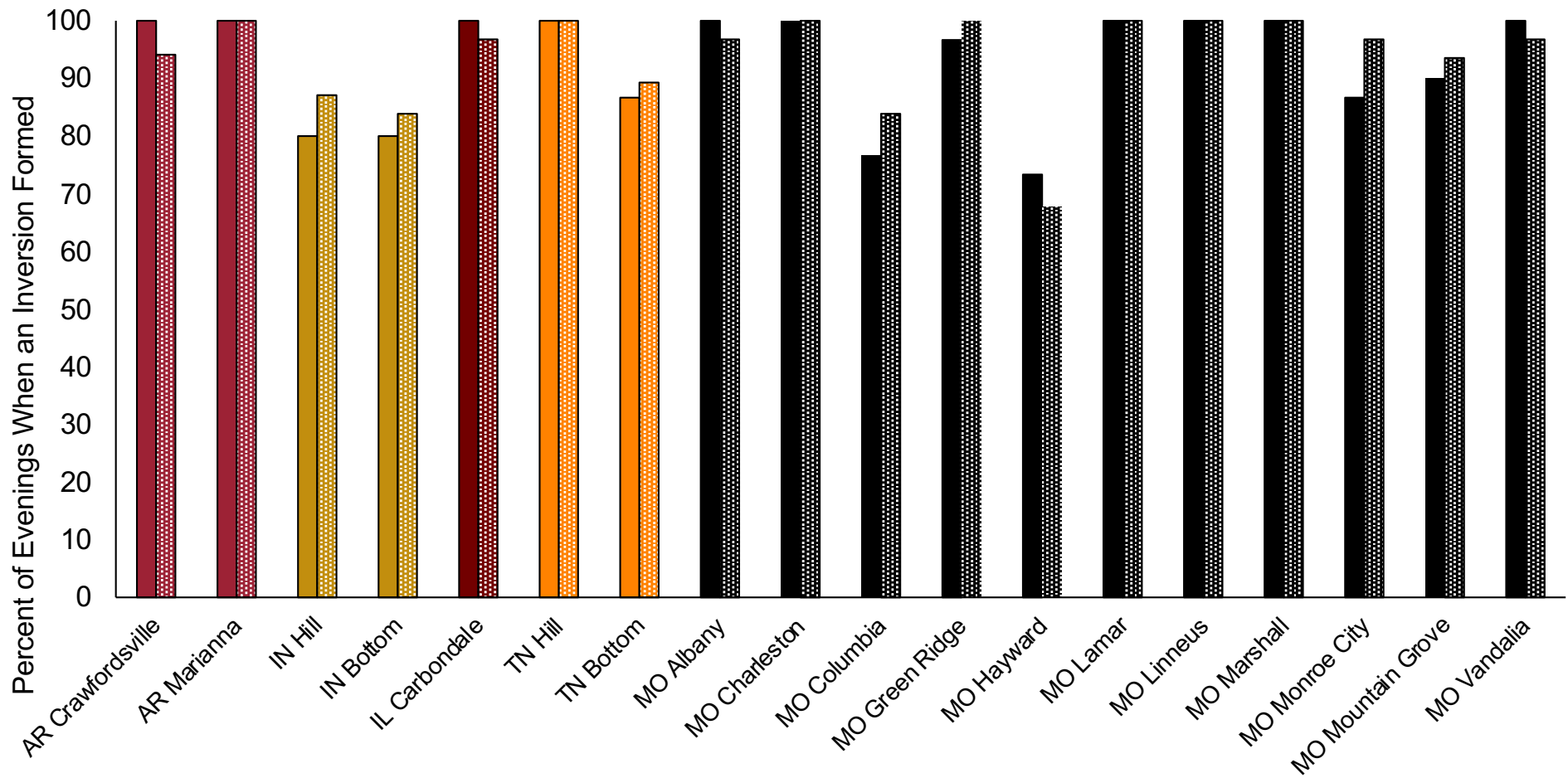


In Collaboration with:  
Bryan Young, Purdue University  
Larry Steckel, University of Tennessee  
Karla Gage, Southern Illinois University  
Jason Norsworthy, University of Arkansas  
Dan Reynolds, Mississippi State University  
Pat Guinan, University of Missouri



# Monitoring Inversions in 2018

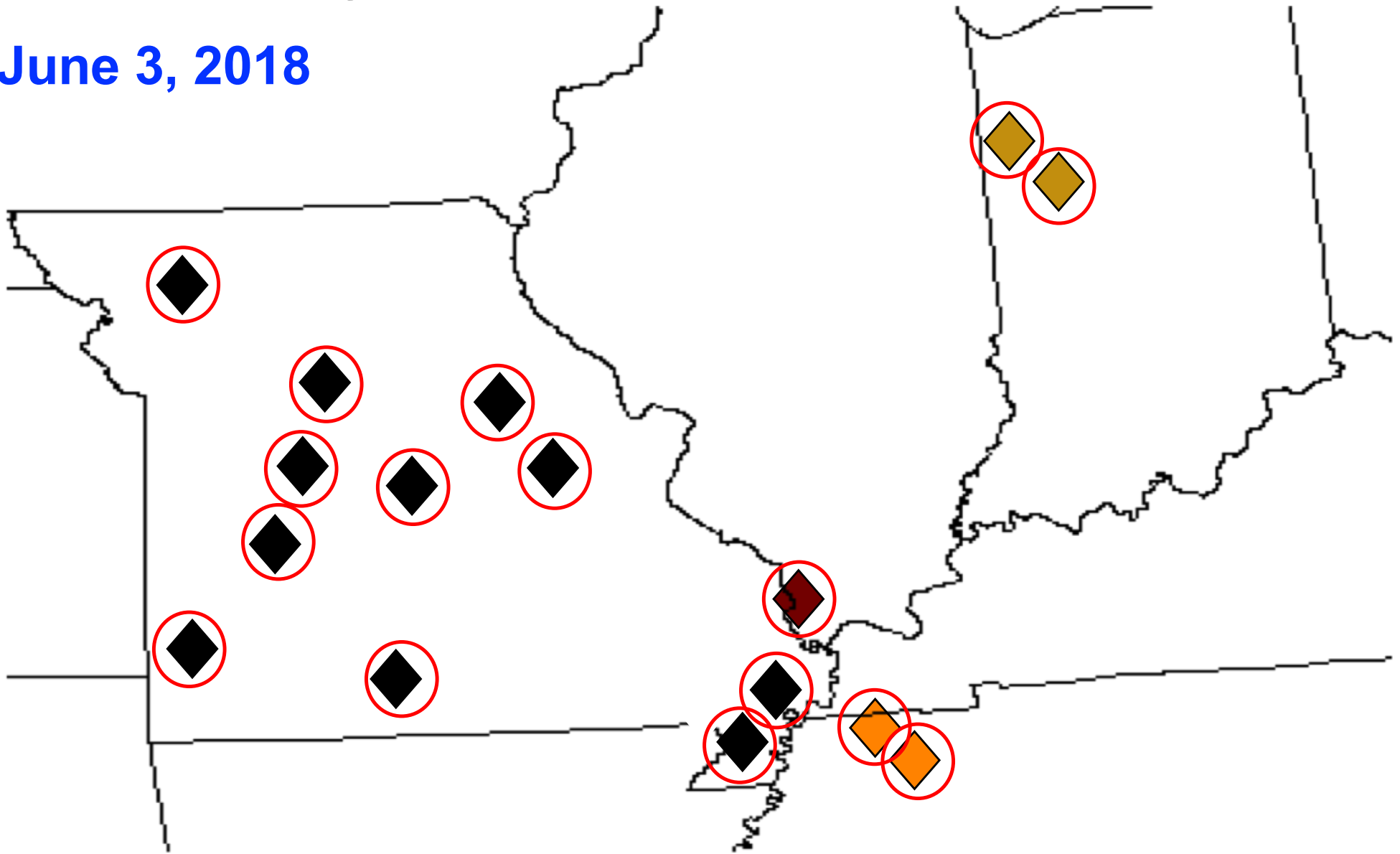
- Inversions were common at all sites tested.
- Inversions defined as 120" air temperature > 18" air temperature.

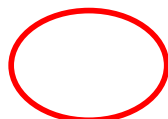


Solid bars = June; Checkered bars = July

# Some Evenings All Stations Recorded Inversions

June 3, 2018

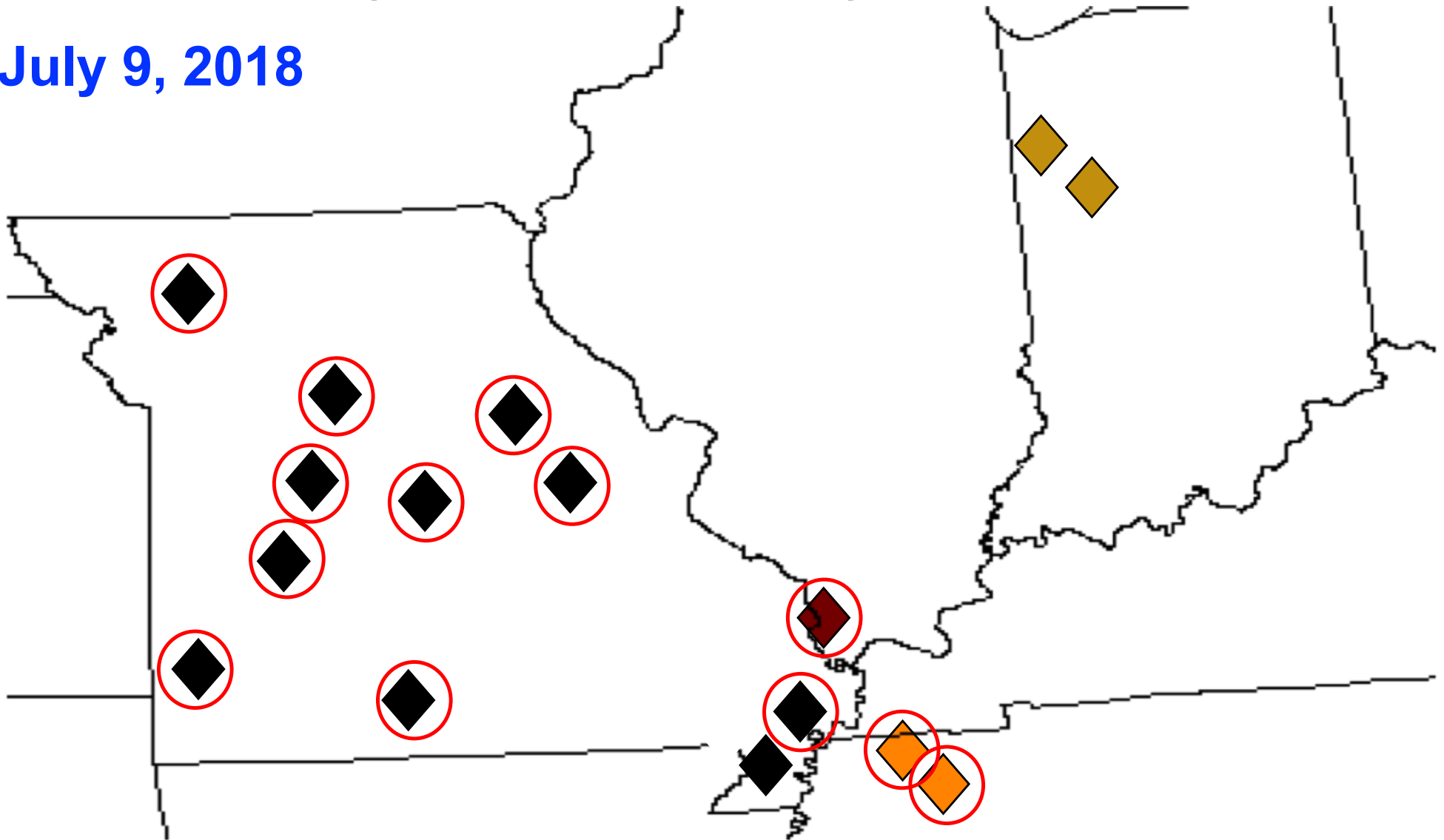


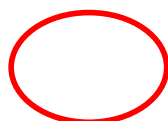
 Indicates an inversion occurred at that site on the evening of June 3, 2018



# Other Evenings Were More Regional

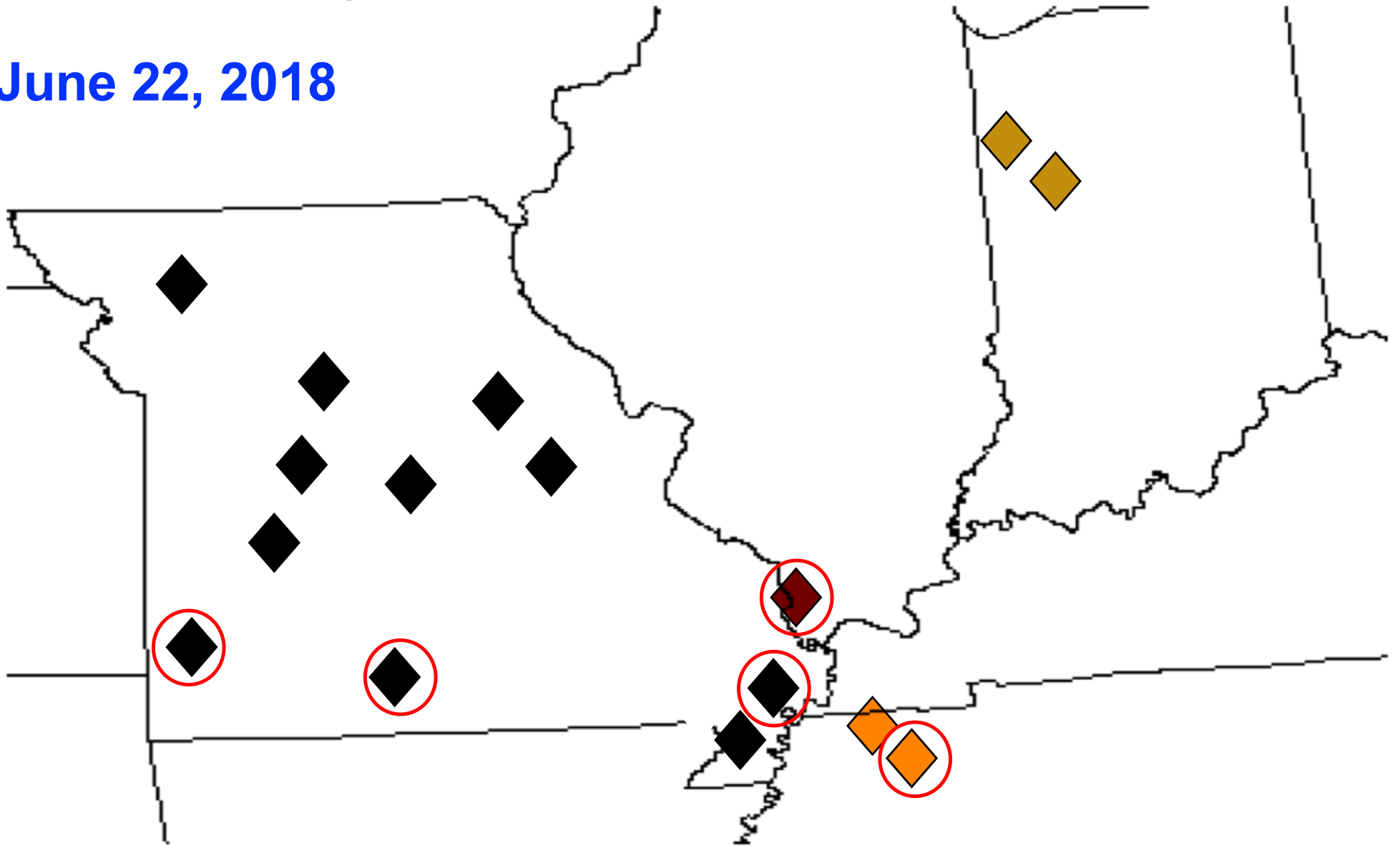
July 9, 2018

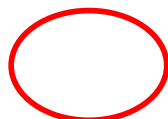


 Indicates an inversion occurred at that site on the evening of July 9, 2018

# Some Evenings Had More Localized Events

June 22, 2018



 Indicates an inversion occurred at that site on the evening of June 22, 2018

# Topography seems to affect the time when inversions begin forming.

Martin, TN 2018



- Tree lines can serve as wind obstructions.
- Less wind is going to allow inversions to form earlier.
- Cool air will settle in lower areas.
- Site 2 has a tree line to the south.
- Prevailing wind is out of the south.
- Site 2 is lower than Site 1.
- In 2018 inversions formed earlier at Site 2 than Site 1.
- Pay attention to field surroundings and prevailing wind direction.

# Indicators of inversions

Clear sky at night



Lack of wind



Dew or frost present



Low-lying fog





# Smoke bombs can indicate inversion conditions

**4:00 PM No Inversion Present**

at release



during



50 seconds after release



**7:30 PM Inversion Present**

at release



during




50 seconds after release



# Temperature Inversion Monitoring

TIPS – real time data  
mesonet.missouri.edu



## Missouri Mesonet

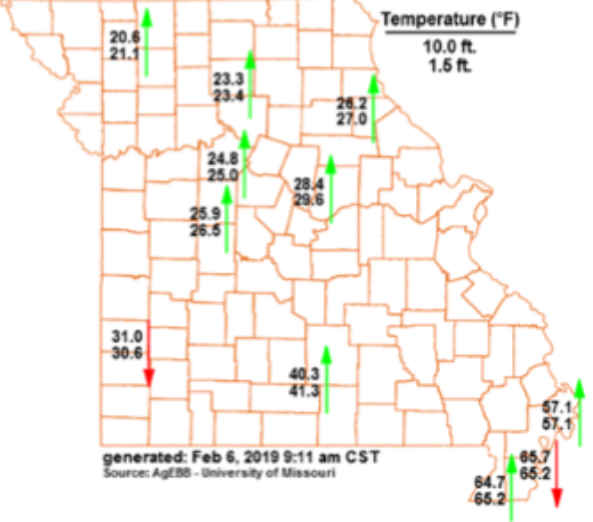
University of Missouri Extension - CAFNR

Real-Time Weather Stations | Missouri Climate Center | School of Natural Resources

- Air Temperature
- Rainfall
- Relative Humidity
- Dew Point Temperature
- 2-inch Soil Temperature
- 4-inch Soil Temperature
- Solar Radiation
- Temperature Inversion Potential

- Albany Station  
Chart -- Graphs
- Charleston Station  
Chart -- Graphs
- Columbia Station  
Chart -- Graphs
- Green Ridge Station  
Chart -- Graphs
- Hayward Station  
Chart -- Graphs
- Lamar Station  
Chart -- Graphs
- Linneus Station  
Chart -- Graphs
- Marshall Station  
Chart -- Graphs
- Monroe City Station  
Chart -- Graphs
- Mountain Grove Station  
Chart -- Graphs
- Senath Station  
Chart -- Graphs
- Vandalia Station  
Chart -- Graphs

### Missouri Mesonet Real-Time Temperature at 10 and 1.5 feet



Temperature (°F)

10.0 ft.  
1.5 ft.

generated: Feb 6, 2019 9:11 am CST  
Source: AgEBB - University of Missouri

Downward arrow -- Inversion potential  
Upward arrow -- Little to no inversion potential

Questions or comments about this site?  
AgEBB - University of Missouri  
Email: [agebb@missouri.edu](mailto:agebb@missouri.edu) / Phone: 573-882-4827

Contact us at [agebb@missouri.edu](mailto:agebb@missouri.edu)  
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Program of University of Missouri Extension | Published by AgEBB Staff

# What is a meaningful inversion?

We still do not know with certainty what temperature difference is needed to allow for herbicide suspension in the air.

**It is possible that any temperature difference is sufficient to cause a stable air mass that will trap too much dicamba.**

Arkansas, southeast Missouri, and western Tennessee typically have less wind and more stable atmosphere than other regions.

These same regions also have more reported injury than other areas.

Results from our research suggests that as temperature difference increases by 1°C, the amount of dicamba in the air increases by 1.3 ng/m<sup>3</sup>.

# Temperature Inversions - Summary

1. Pay attention to the forecast – a week in which meteorologist are calling for clear skies at night is a week that is likely going to have multiple inversions.
2. Each field is not the same—the label says 2 hours before sunset, but if the wind dies before that time point an inversion is likely forming.
3. We are not there with apps yet. It is extremely difficult to build an inversion monitoring app for air temperatures so close to the ground.
4. Think back to the smoke bomb—if that cloud of red was a cloud of dicamba or 2,4-D droplets... ..and it was an entire field that had been sprayed.
5. **We still do not have a great understanding of the relationship between applications made during the day and inversions forming at night.**



# Questions?



[bishm@missouri.edu](mailto:bishm@missouri.edu)

573-882-9878

**Kevin Bradley**

[bradleyke@missouri.edu](mailto:bradleyke@missouri.edu)

573-882-4039



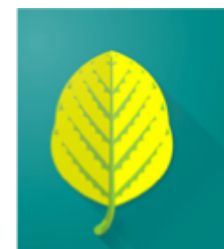
**@ShowMeWeeds**



**Mizzou Weed Science**



**ID Weeds Mobile App**



**Herb Injury Mobile App**

## Acknowledgements

- Larry Steckel, Bryan Young, Karla Gage, Jason Norsworthy  
Dan Reynolds, Shea Farrell, John Travlos
- United Soybean Board
- Missouri Soybean Merchandising Counsel