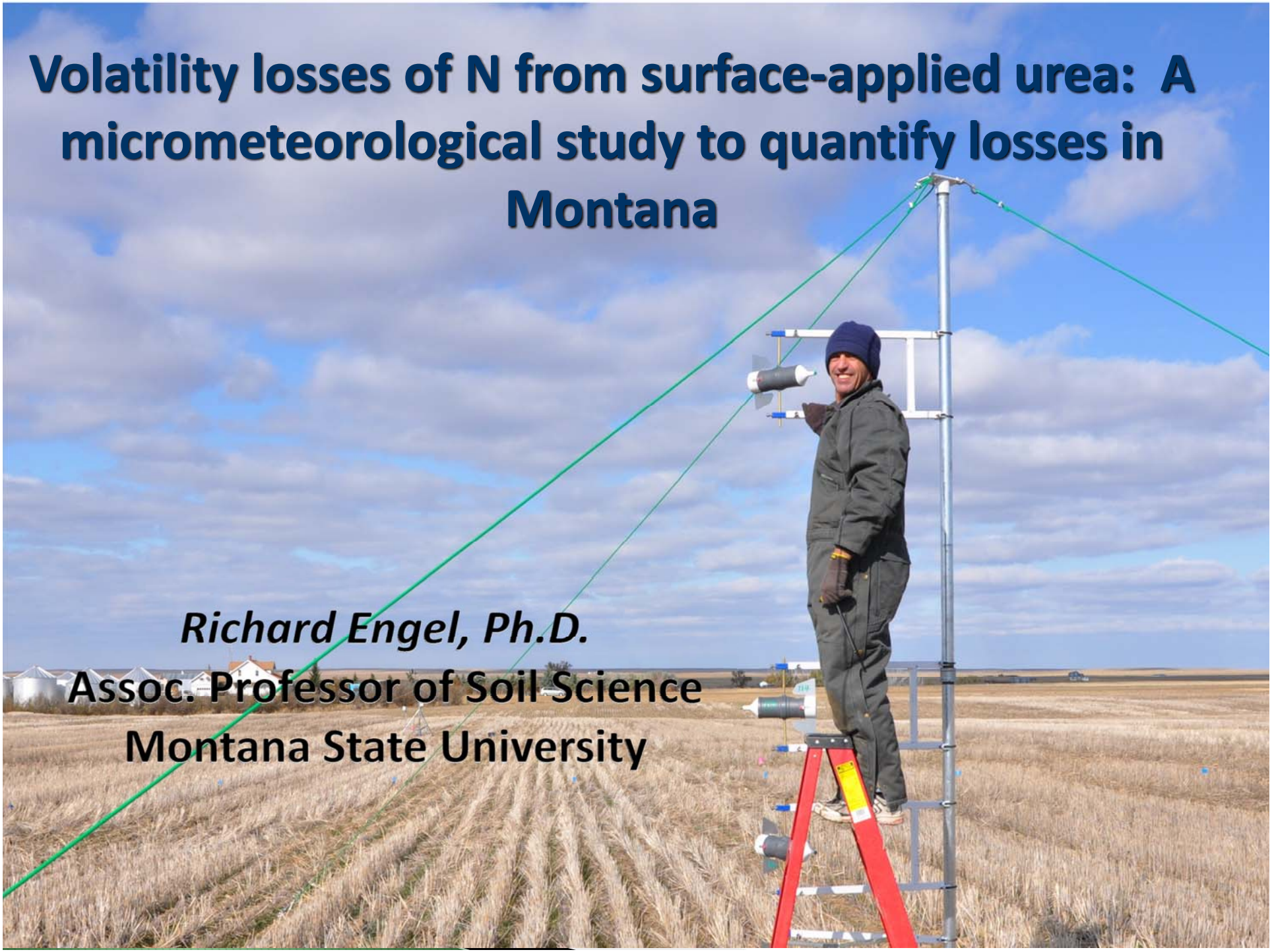
Volatility losses of N from surface-applied urea: A micrometeorological study to quantify losses in Montana

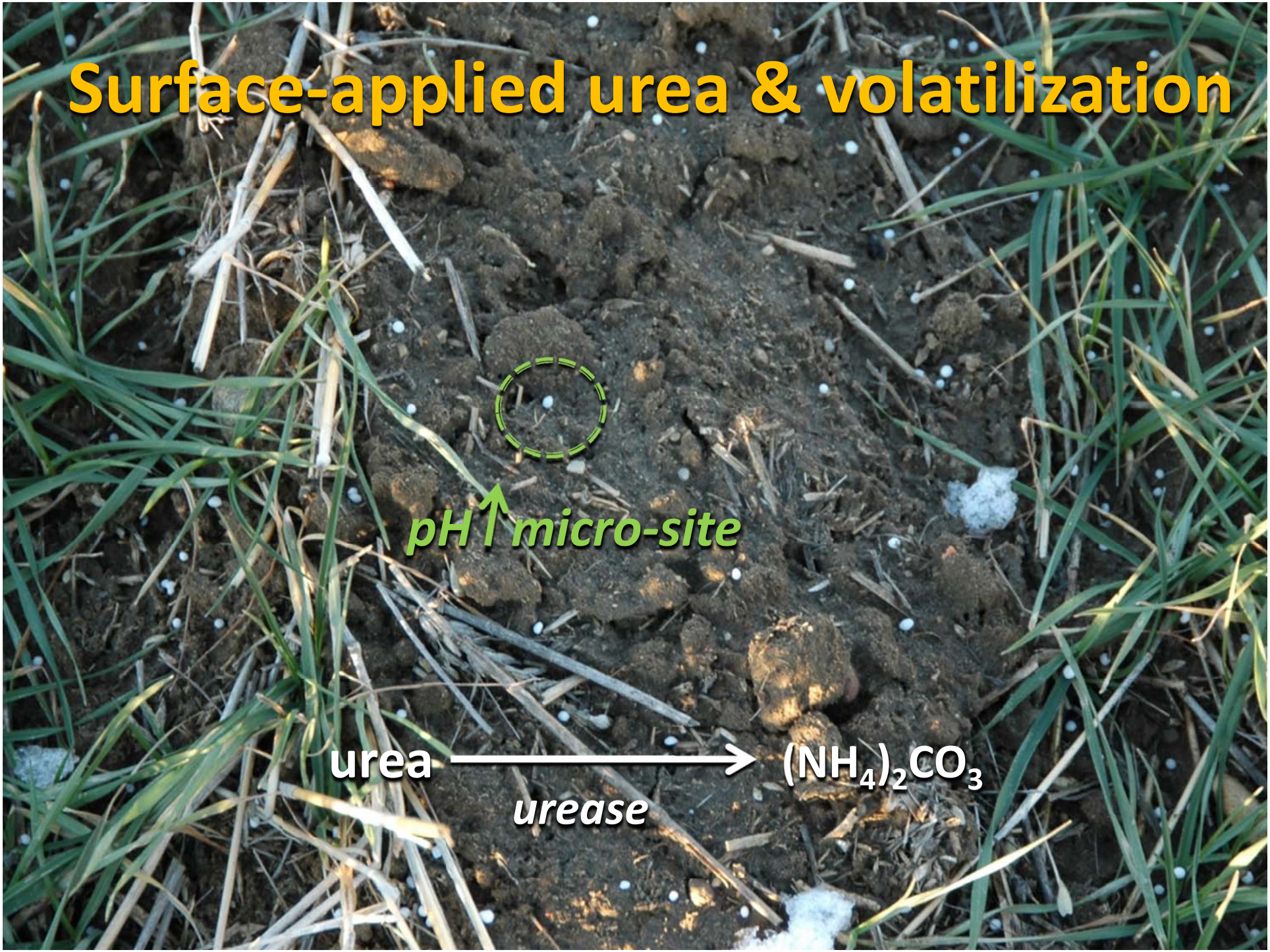


Richard Engel, Ph.D.
Assoc. Professor of Soil Science
Montana State University

Cooperator: Jeff Whitmus, Research Assistant

Winter wheat production in Montana

- large farms, no till has become norm
- seeded in September
- N fertilizer applications deferred to until fall, winter, and early spring (cold weather months)
- surface-applied urea - susceptible to volatility losses
- <u>How much N are we losing?</u>


Surface-applied urea & volatilization
pH↑micro-site
urea
urease
$(NH_4)_2CO_3$

Factors affecting volatilization

1. Soil pH
2. Soil moisture and humidity
3. Wind
4. Precipitation following fertilization
5. Surface residue and vegetation
6. Soil texture (sandy more susceptible than clay soils)
7. Temperature

Bottom line → large number of soil & environmental factors make N losses variable and difficult to predict

Objectives

- **How much N as NH_3 are we losing from surface-applied urea (fall, winter, and early spring)?**

  Do cold temperatures (< 5˚C or 41˚F) provide protection against volatility losses?

- **How do we mitigate losses (particularly when significant) ?**

  - Enhanced efficiency N products (NBPT or Agrotain)
  - Incorporation & subsurface urea applications

NBPT - urease inhibitor

- $CO(NH_2)_2 + H^+ + 2H_2O \xrightarrow{urease} 2NH_4^+ + HCO_3^-$

Flexi coil
4350
surface-applied urea prior to seeding

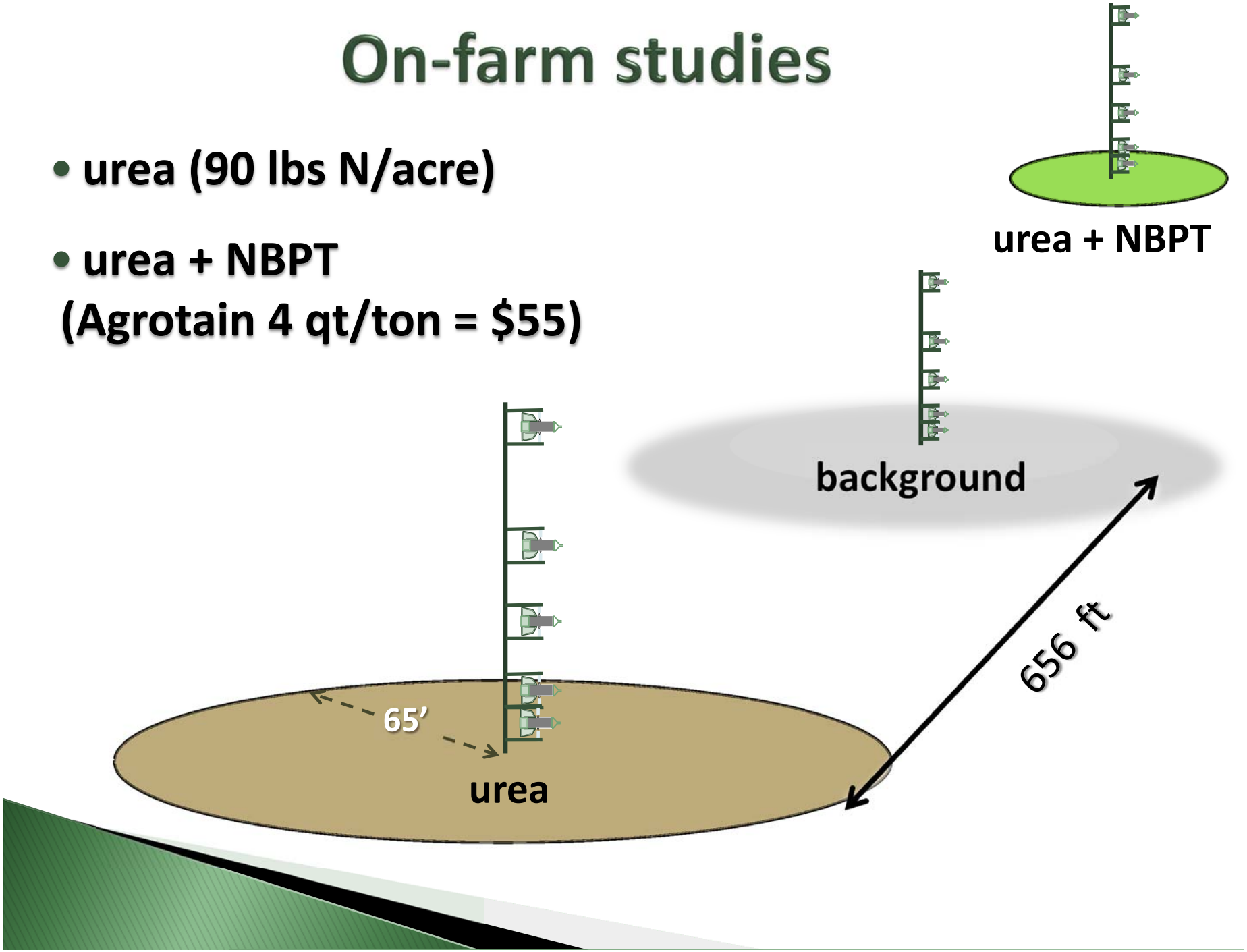
Integrated horizontal flux approach

- micrometeorological - mass balance (Ryden and McNeil, 1984)
- does not disturb the soil-atmosphere environment
- moderate size plots (~0.3 acre) > larger footprint than enclosures
- continuous measurement of gas loss over time

mast and shuttles ➡

On-farm studies

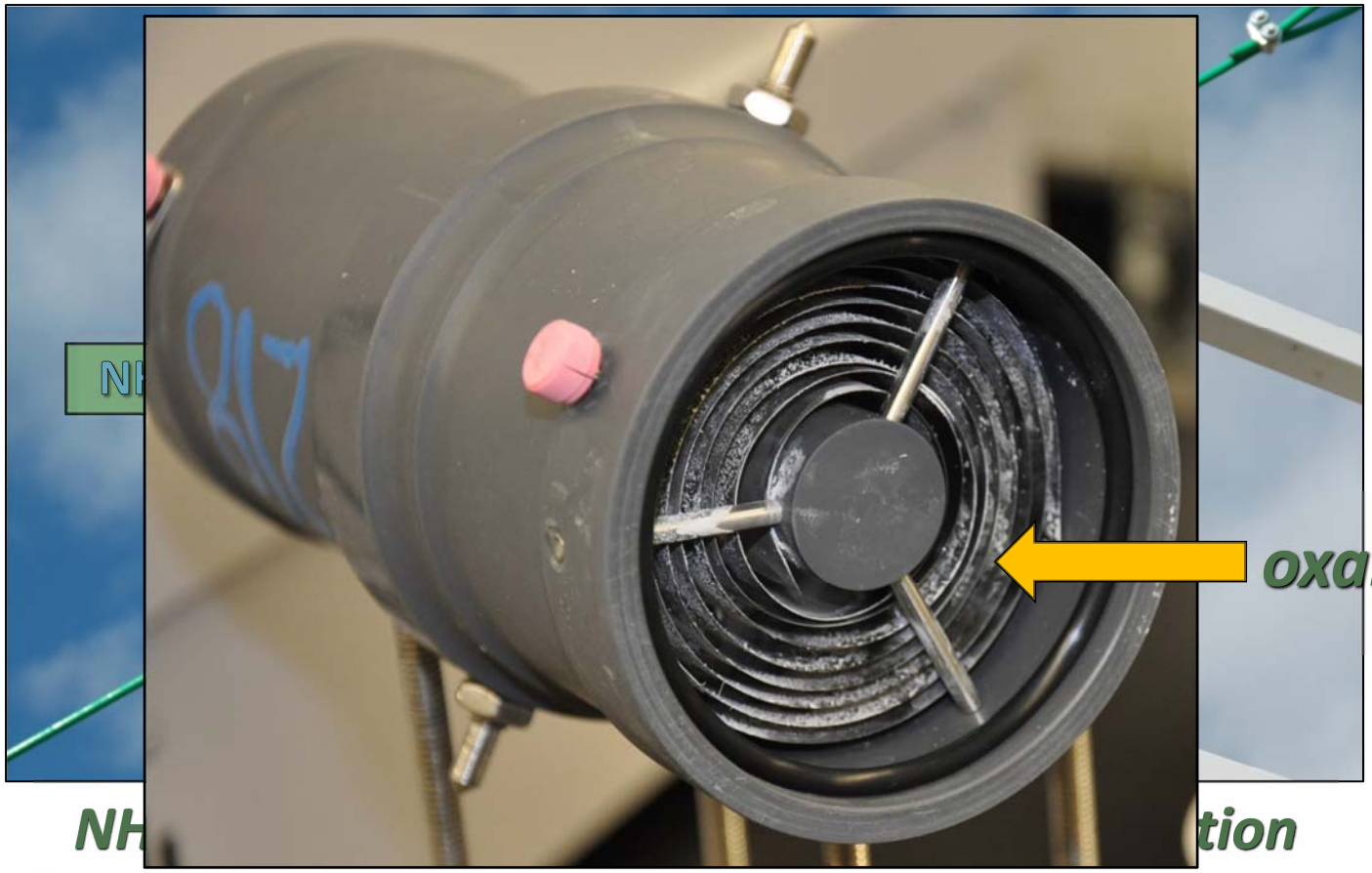
- urea (90 lbs N/acre)
- urea + NBPT
  (Agrotain 4 qt/ton = $55)



≈

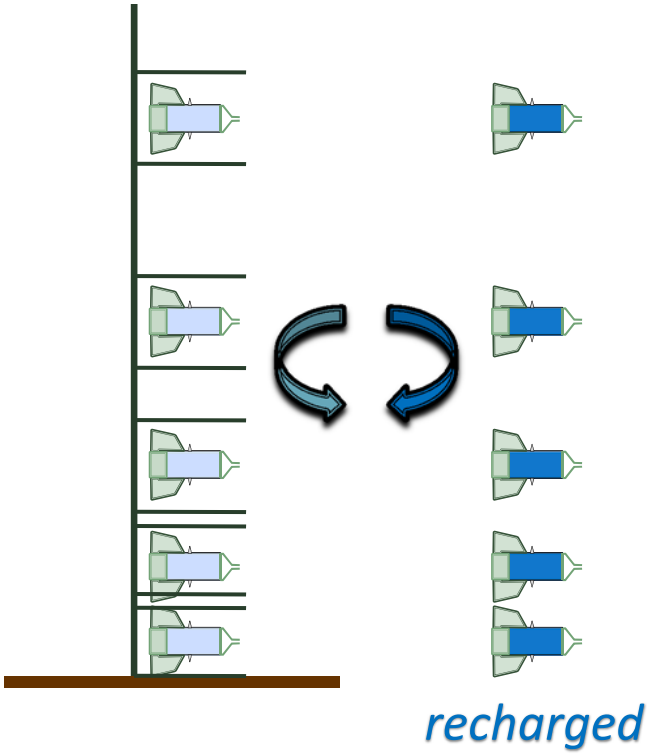
Shuttles

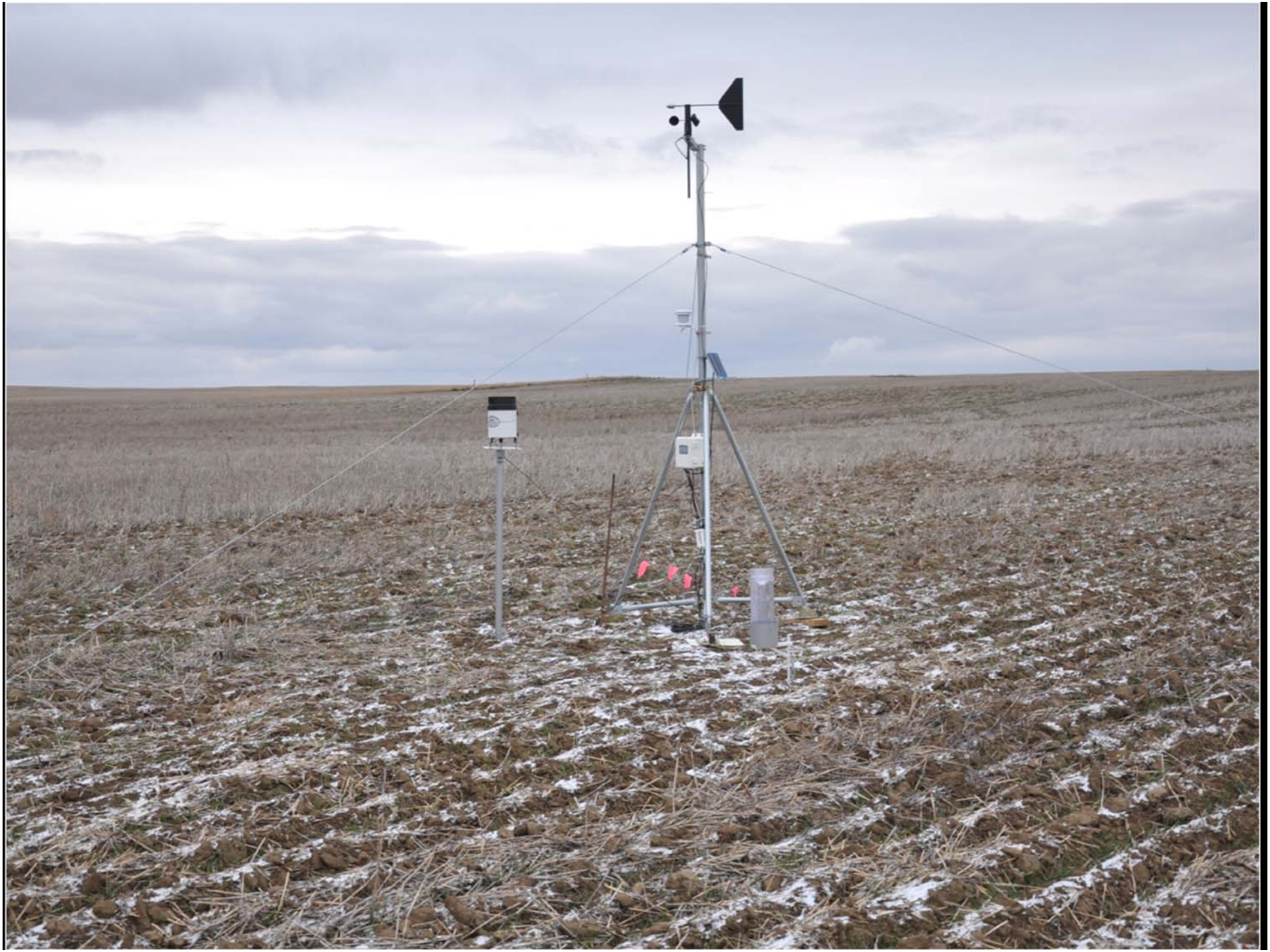
- traps for collecting ammonia, idea & design developed in Australia (Leuning et al., 1985. Atmos. Environ)



Continuous measurements

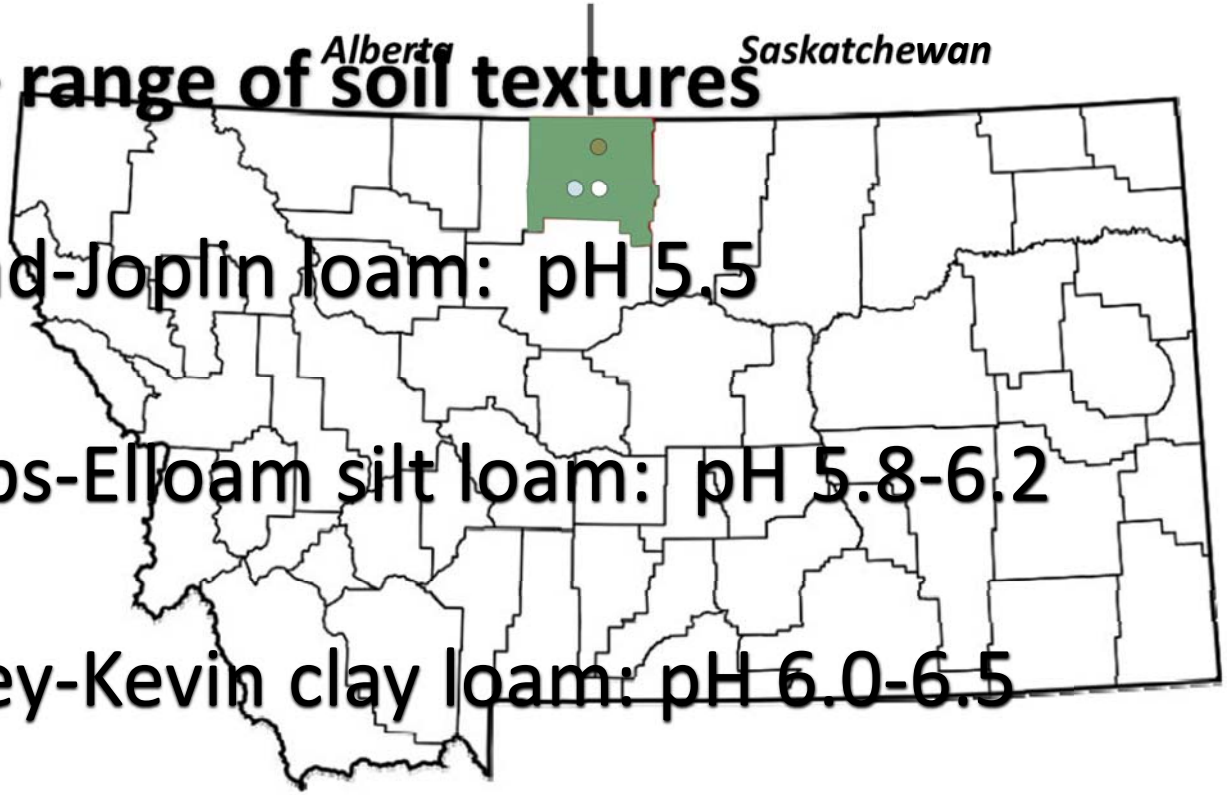
- spent shuttles exchanged with recharged shuttles weekly over 6-10 week campaign following fertilization





Field sites

- 3 dryland farms in northern Montana, no till mgnt
- Soils – range of soil textures



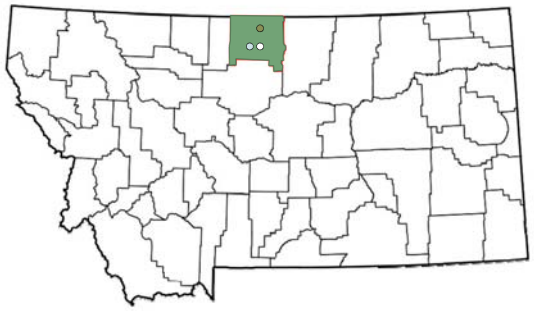
Telstad-Joplin loam: pH 5.5

Phillips-Elloam silt loam: pH 5.8-6.2

Scobey-Kevin clay loam: pH 6.0-6.5

High NH_3 loss campaigns (>30%)

Campaign	Fertilization date	% urea-N volatilized
3 - north Havre	Nov. 14, 2008	31.5
4 - north Havre	March 25, 2009	35.6
5- west Havre	March 26, 2009	39.9

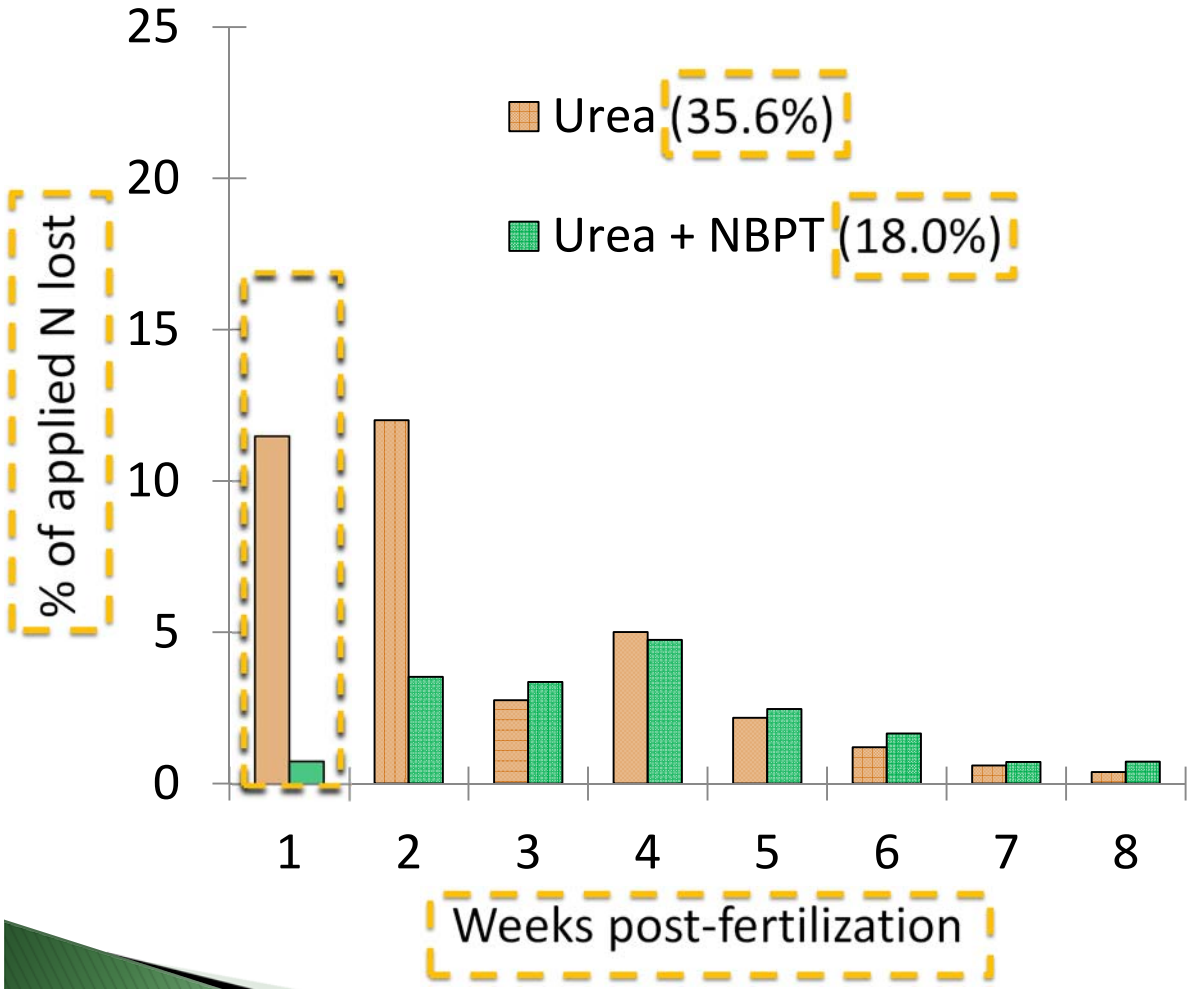


High NH_3 losses – Campaign 4 (TJ loam)

Fertilized applied – March 25, 2009
"light snow & air-temp. 31°F"

soil surface frozen 18 °F
Θ_v = 35%

High NH_3 losses – Campaign 4 (TJ loam)



Precipitation

0.01” = 0-2 wks

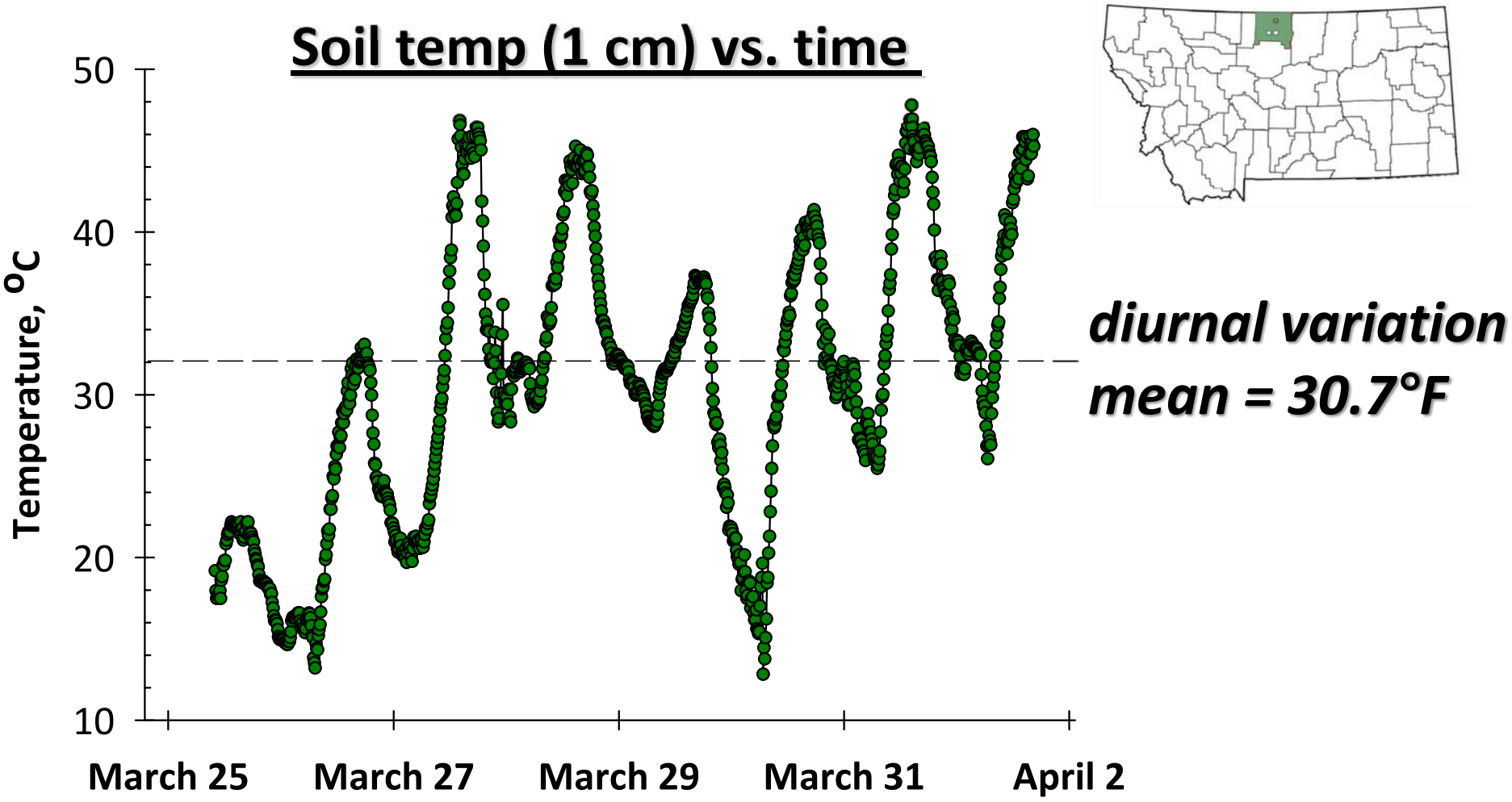
0.89” = 2-8 wks

Temperature

Soil = 30.7 °F

Air = 33.4 °F

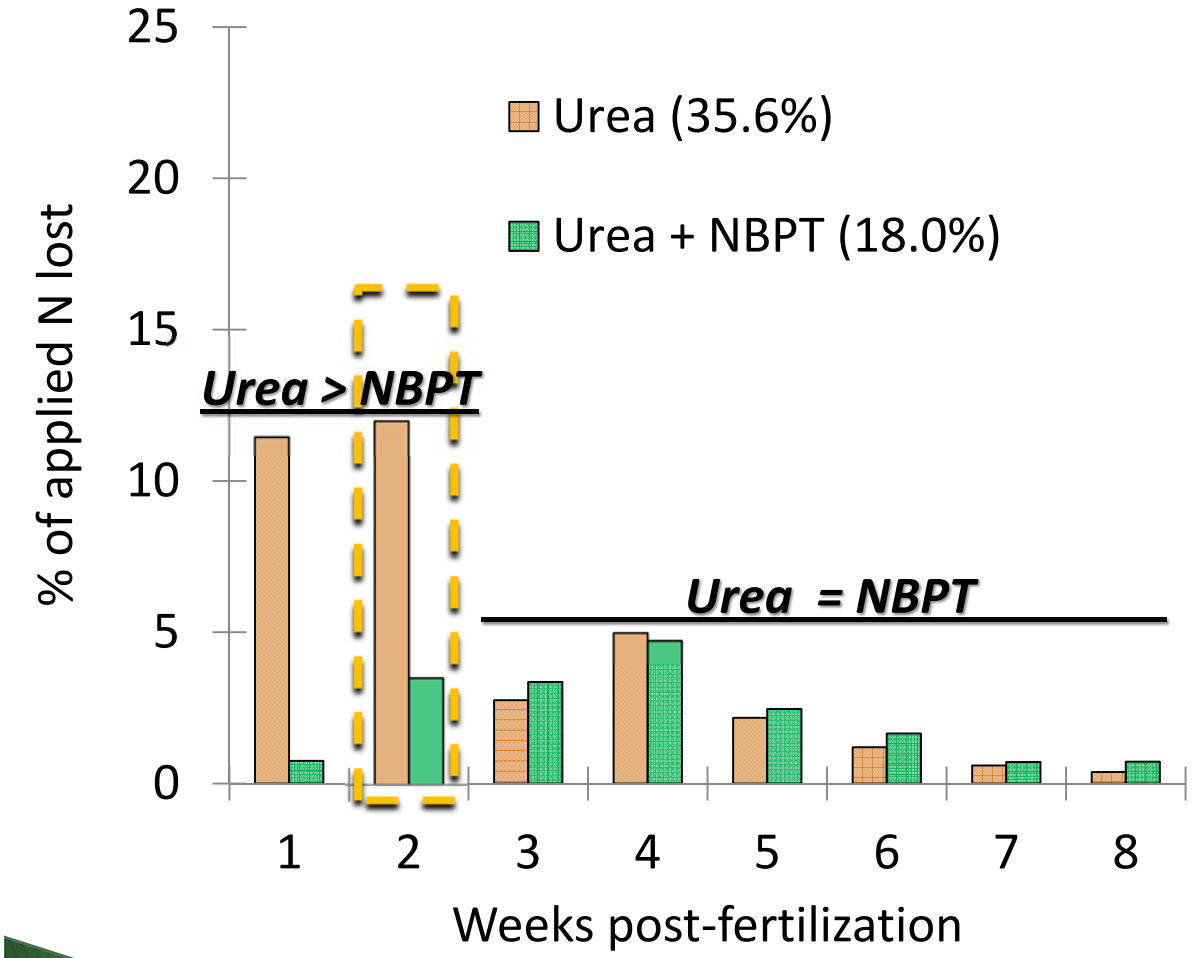
High NH_3 losses – Campaign 4 (TJ loam)



diurnal variation

mean = 30.7°F

High NH_3 losses – Campaign 4 (TJ loam)



Precipitation

0.25” = 0-2 wks

0.89” = 2-8 wks

Temperature

Soil = 38.0 °F

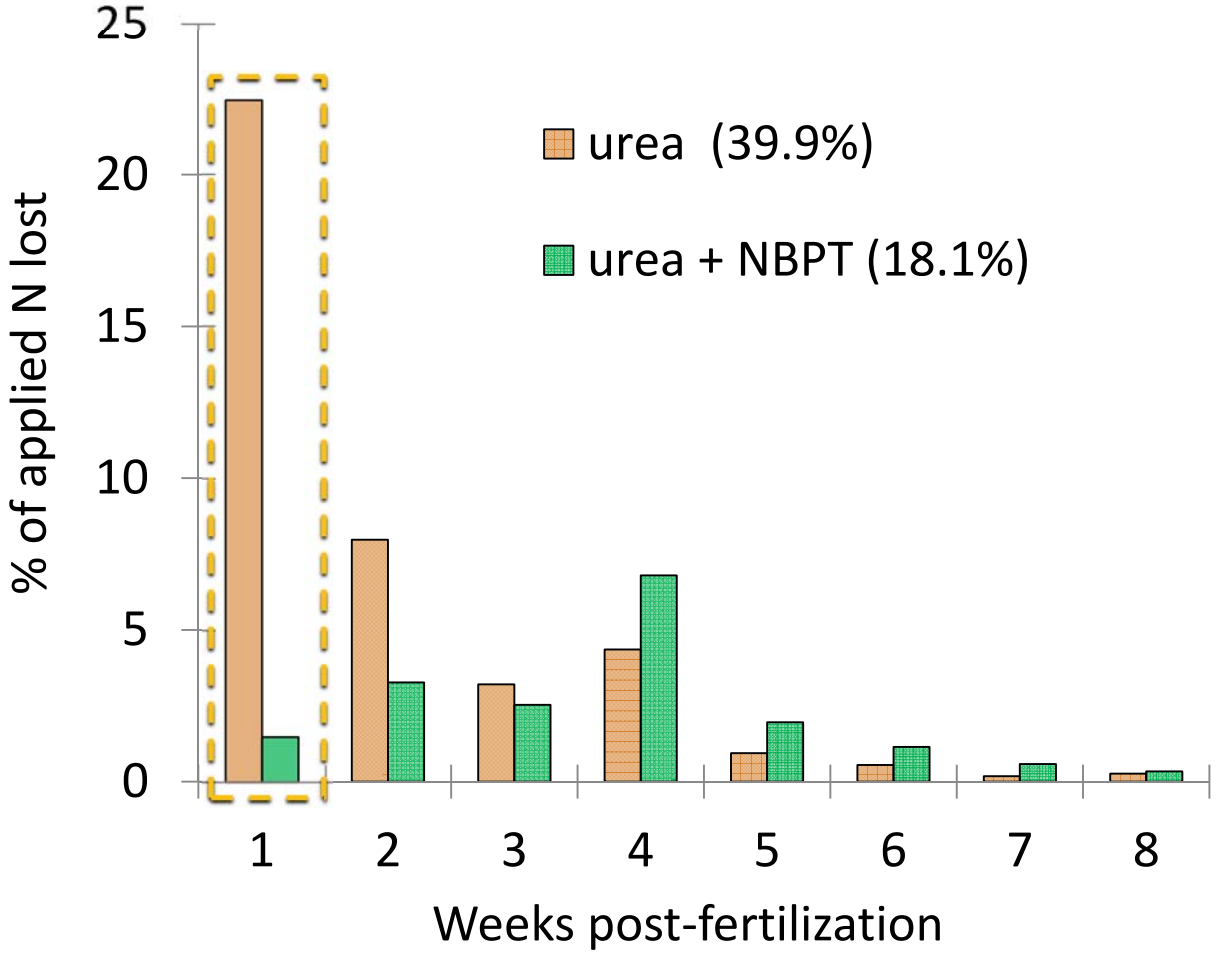
Air = 41.5 °F

High NH_3 losses - Campaign 5(PE silt loam)

Fertilized applied – March 26
"light snow on soil surface &
air-temp. 21 °F"

soil surface with fertilizer
prills beginning to dissolve
32 °F

High NH_3 losses - Campaign 5(PE silt loam)



Precipitation

no rain 0-2 wks

1.54" 2-8 wks

Temperature

Soil = 34.3 °F

Air = 33.1 °F

High NH_3 losses – Campaign 3 (TJ loam)

Surface damp from melting 2” snowfall event
November 14, 2008

High NH_3 losses -Campaign 3 - Summary

- **0-6 days post-fertilization**
  - **N loss 12.3%**
  - **Soil temperature (1 cm) - 33.4 ˚F ***
- **6-21 days post-fertilization**
  - **N loss 17.0%**
  - **Soil temperature (1 cm) - 28.9 ˚F**
- **precipitation – scattered events – often as snow**

High NH_3 losses – Campaign 3 (TJ loam)

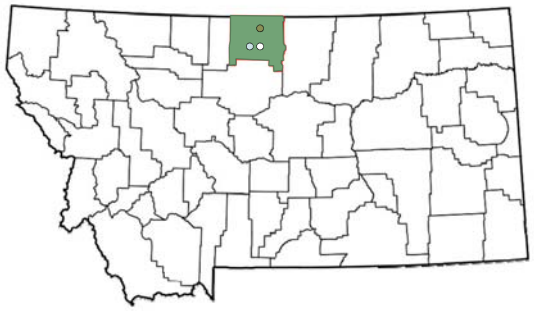
December 4, 2008

High NH_3 losses – Campaign 3 (TJ loam)

winter arrived December 7

High NH_3 loss campaigns (>30%)

Campaign	Fertilization date	% urea-N volatilized
3 - north Havre	Nov. 14, 2008	31.5
4 - north Havre	March 25, 2009	35.6
5- west Havre	March 26, 2009	39.9



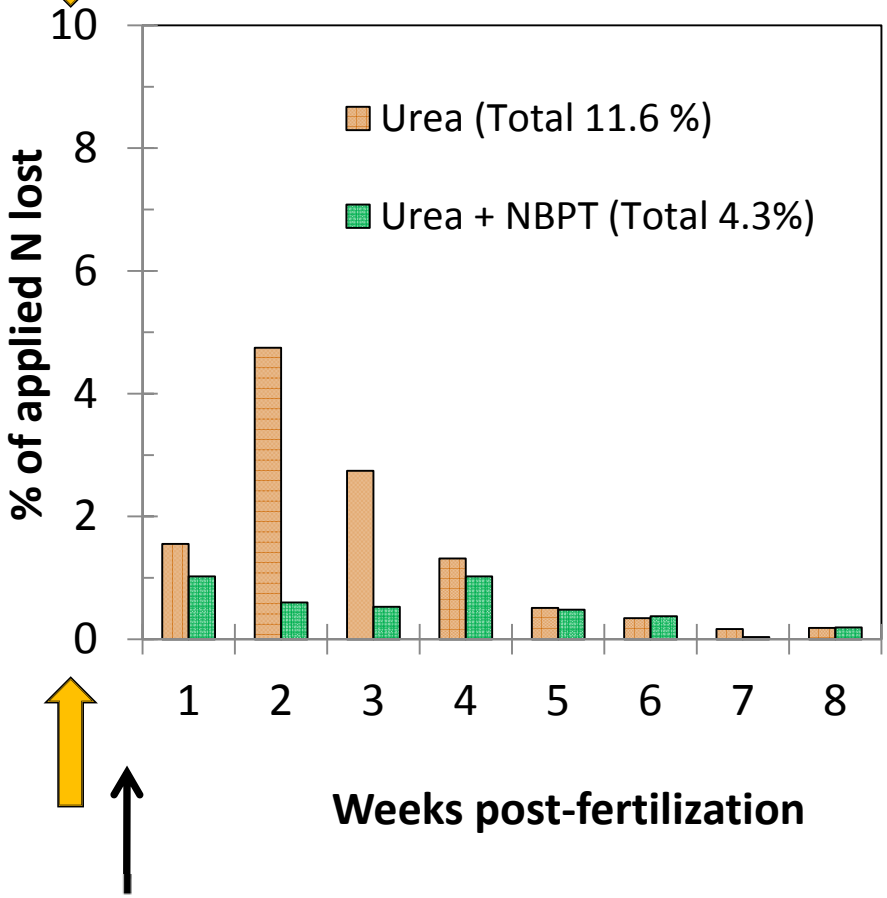
Moderate NH_3 loss campaigns (10-20%)

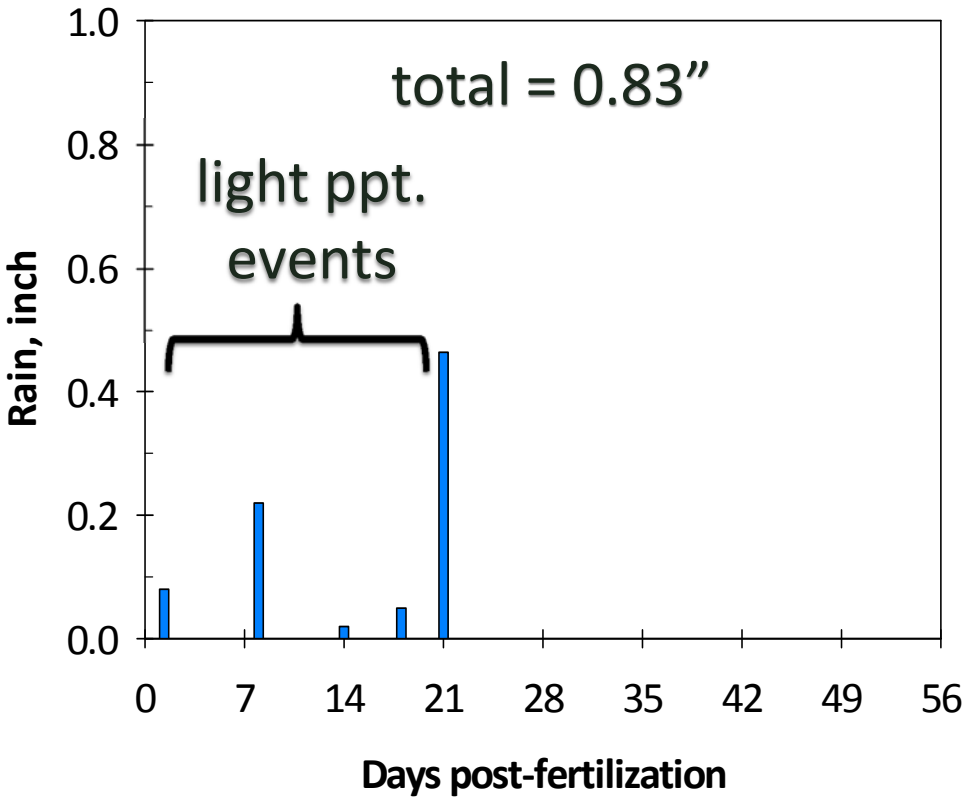
- **urea applied to dry soil surface**

Campaign 6
Oct. 6, 2009

Campaign 7
Oct. 13, 2009

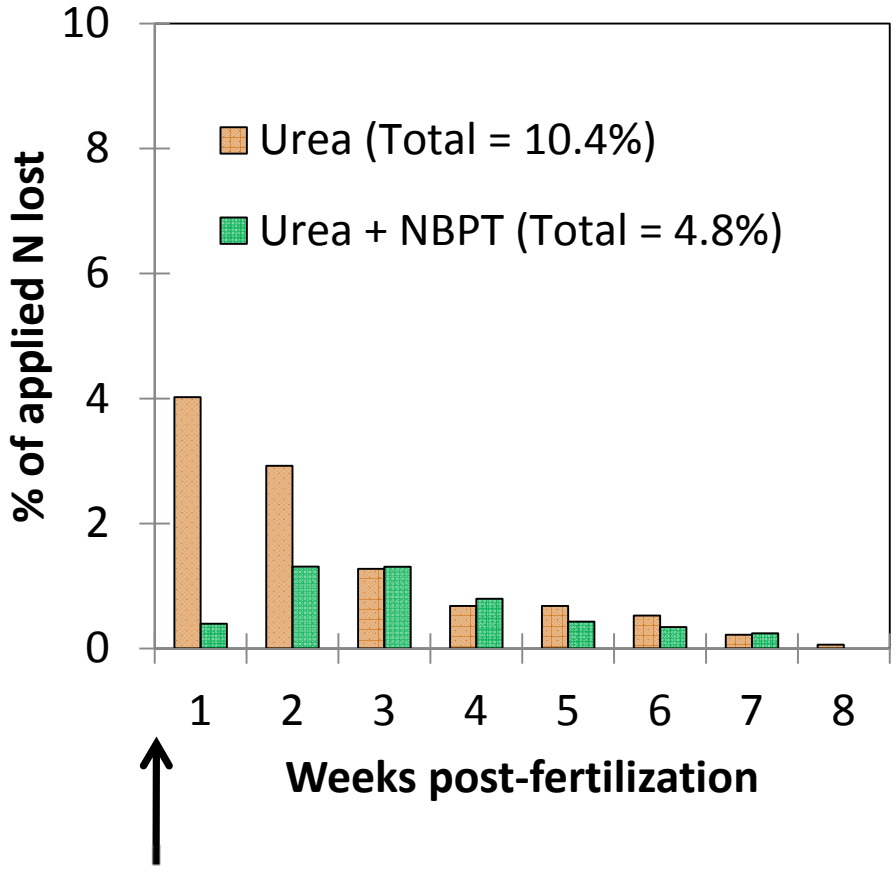
Moderate NH_3 loss - Campaign 6 (clay loam)

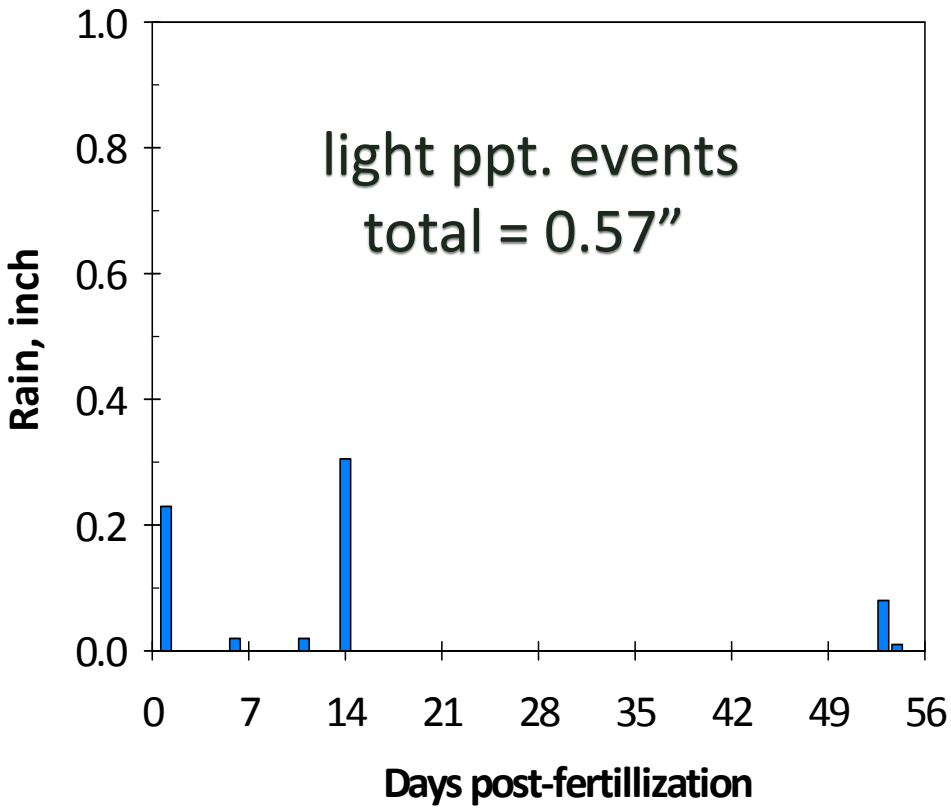




October 6

Moderate NH_3 loss – Campaign 7 (PE silt loam)





October 13

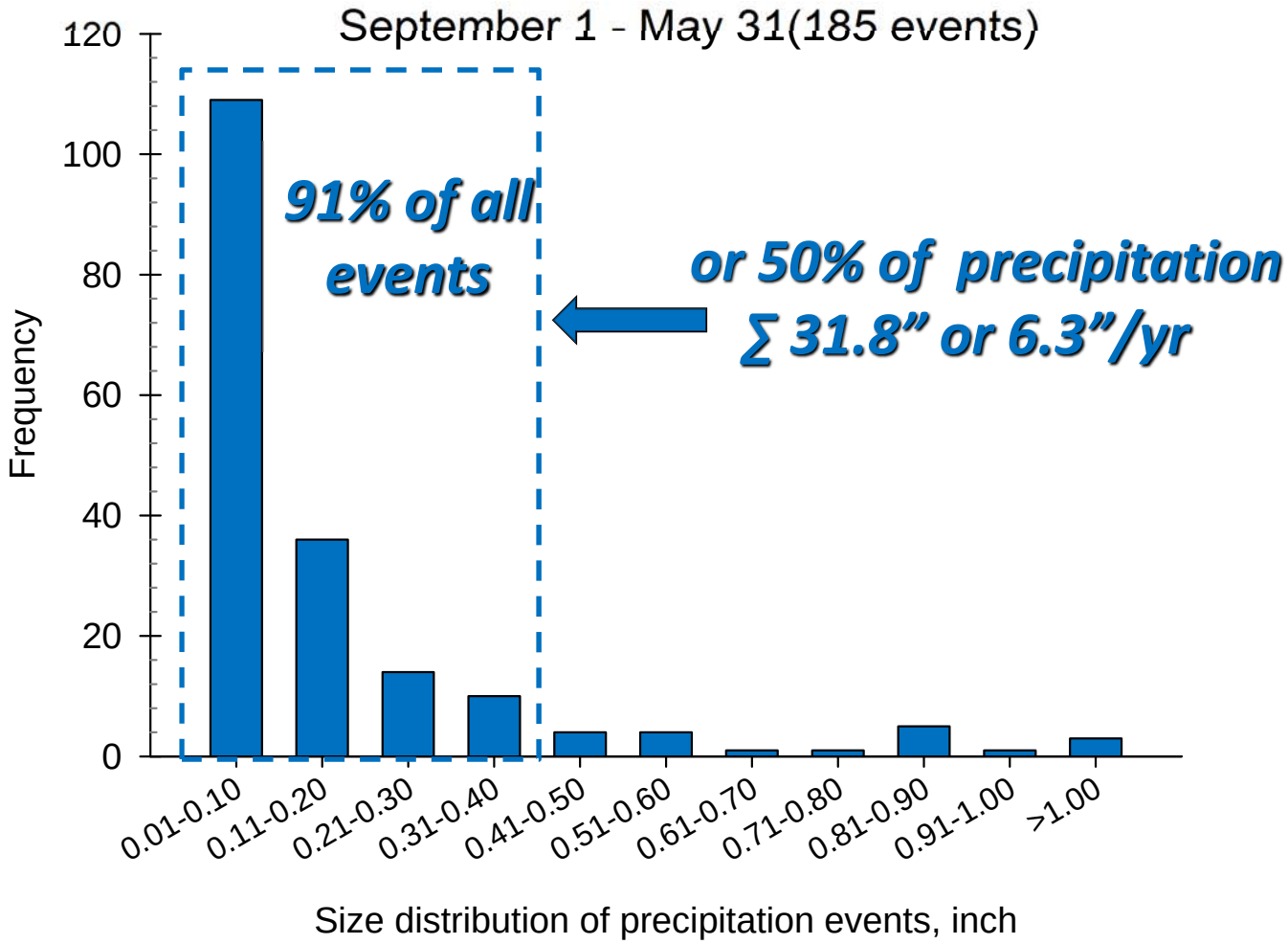
Light ppt events (≤ 0.4“) are common

along the Highline

What is meant by a precipitation event ?

Day	November 2010	
.		
7	.	
8	0.14	
9	.	
10	.	
11	.	
12	.	
13	.	
14	0.02	***0.32”***
15	0.01	
16	0.29	
17	.	
18	0.04	
19	.	
20	0.22	***0.63”***
21	0.02	
22	0.16	
23	0.19	
24	0.01	
25	0.03	
26	.	
27	.	
28	0.08	
29	.	
30	.	

Size and frequency of precipitation events Havre Airport (last 5 years)

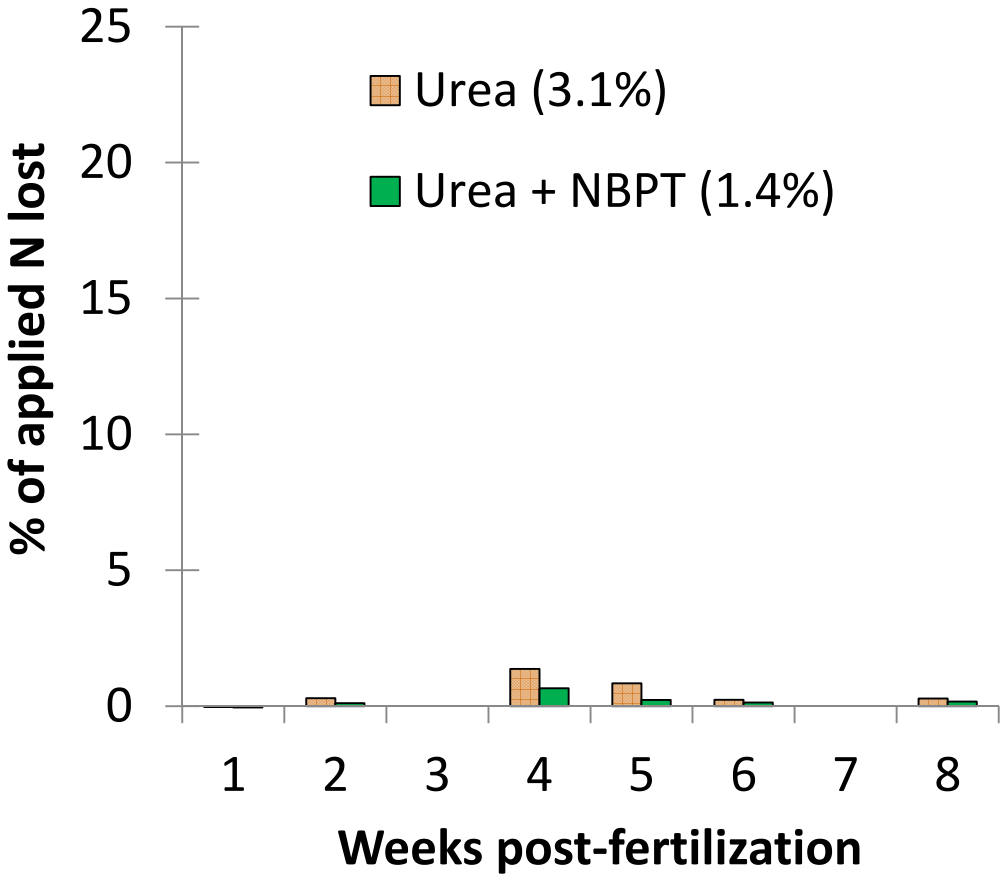


Campaign 2 – low NH_3 losses (<10%)

- October 9, 2008 application, air-temp. 45 °F, dry soil surface
- no rain for 24 days & then Nov 2-5 received 1.0" ppt.
- same field site as Campaign 5

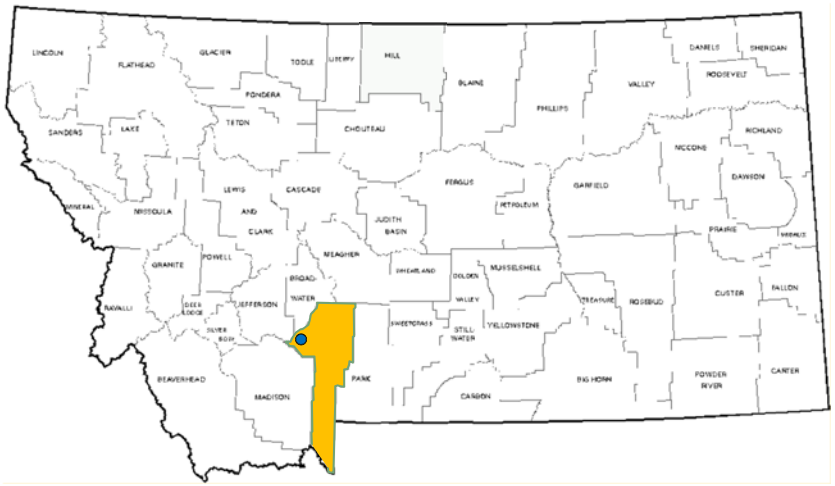
1 wk post-fertilization
prills not dissolved

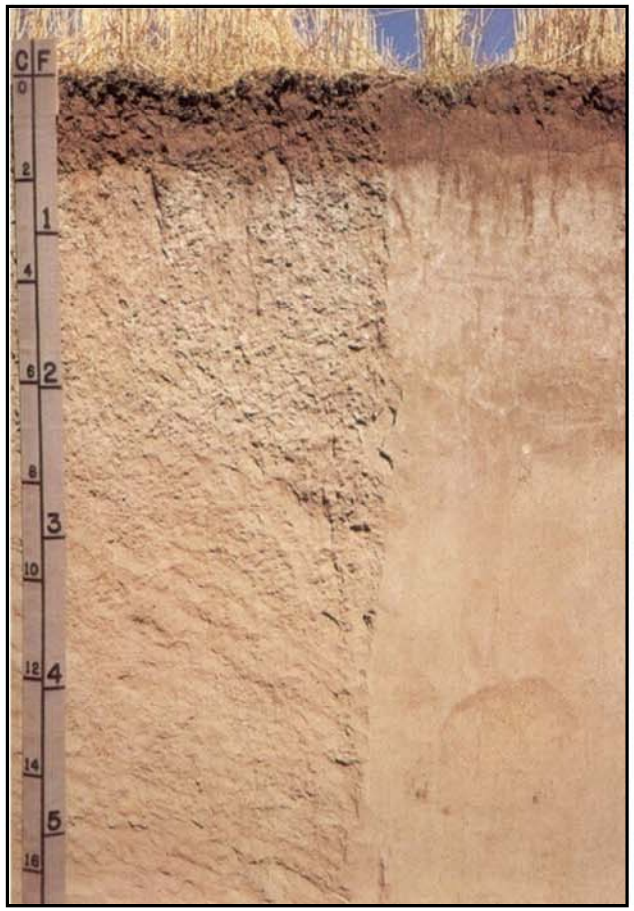
Campaign 2 – low NH_3 losses



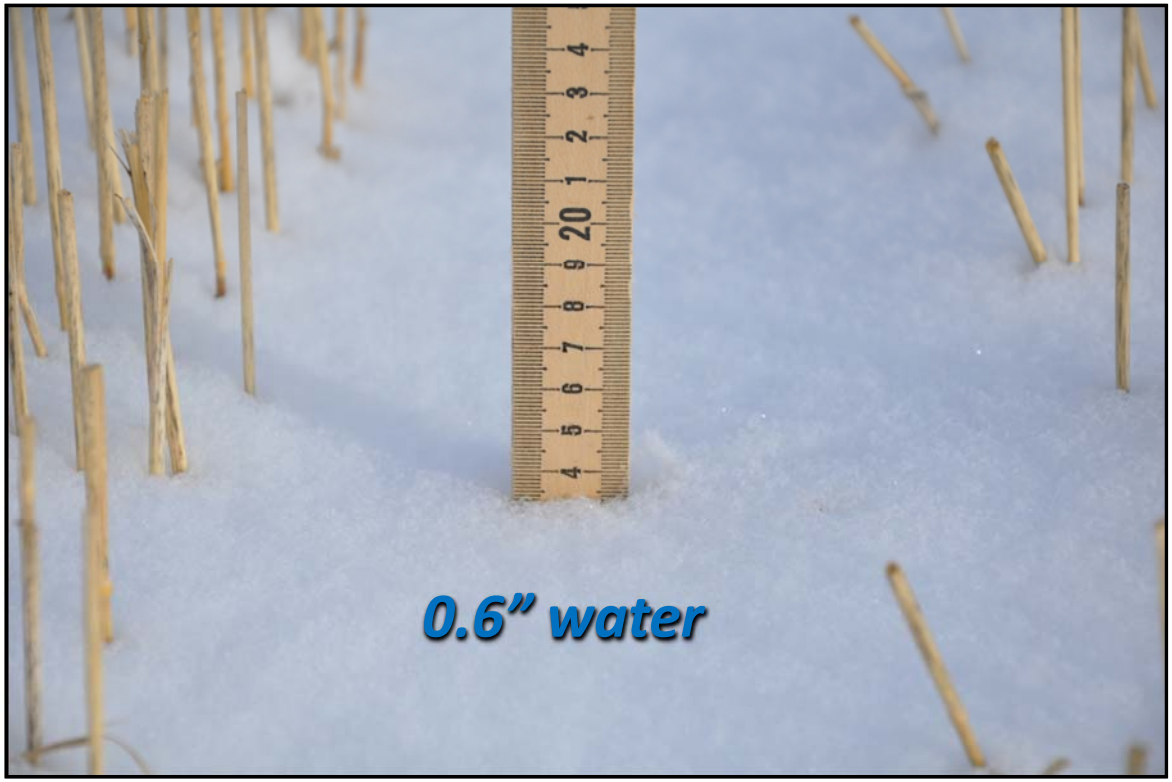
Campaign 9 - Willow Creek - Brocko silt loam

- **calcareous soils, pH 8.3**

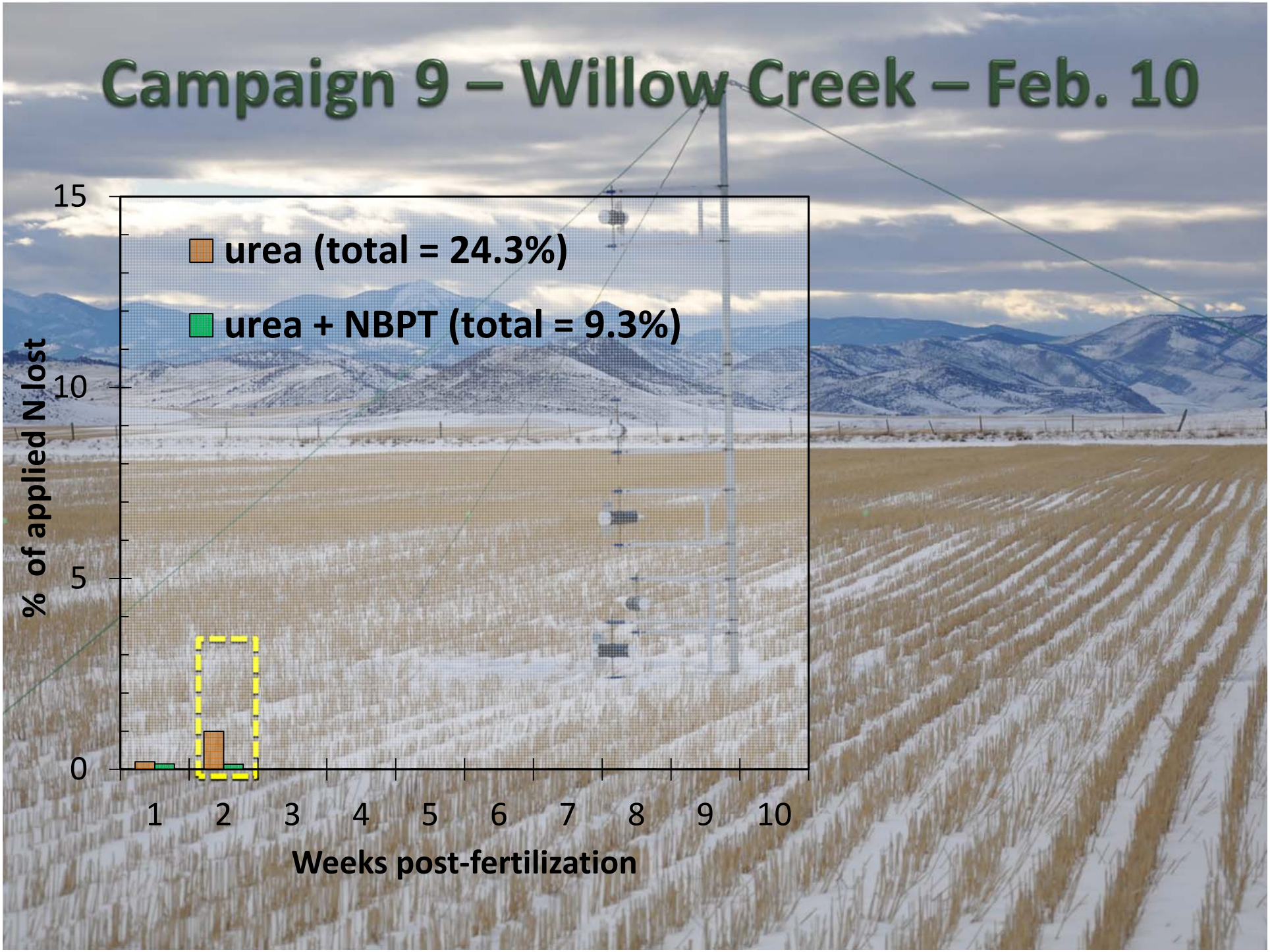




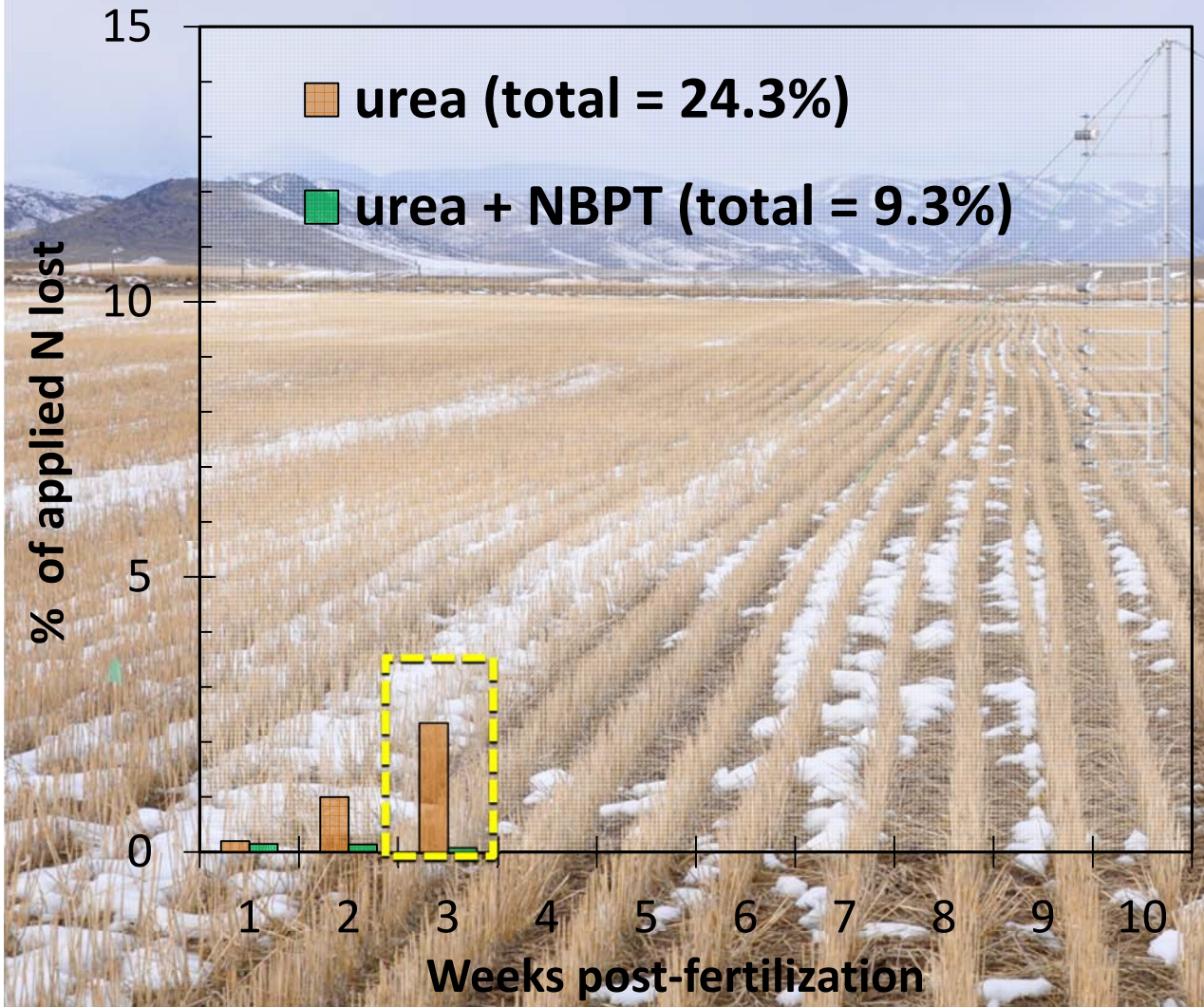
What about urea on snow ?
Campaign 9 – Willow Creek – Jan 27, 2010



Campaign 9 – Willow Creek – Feb. 10

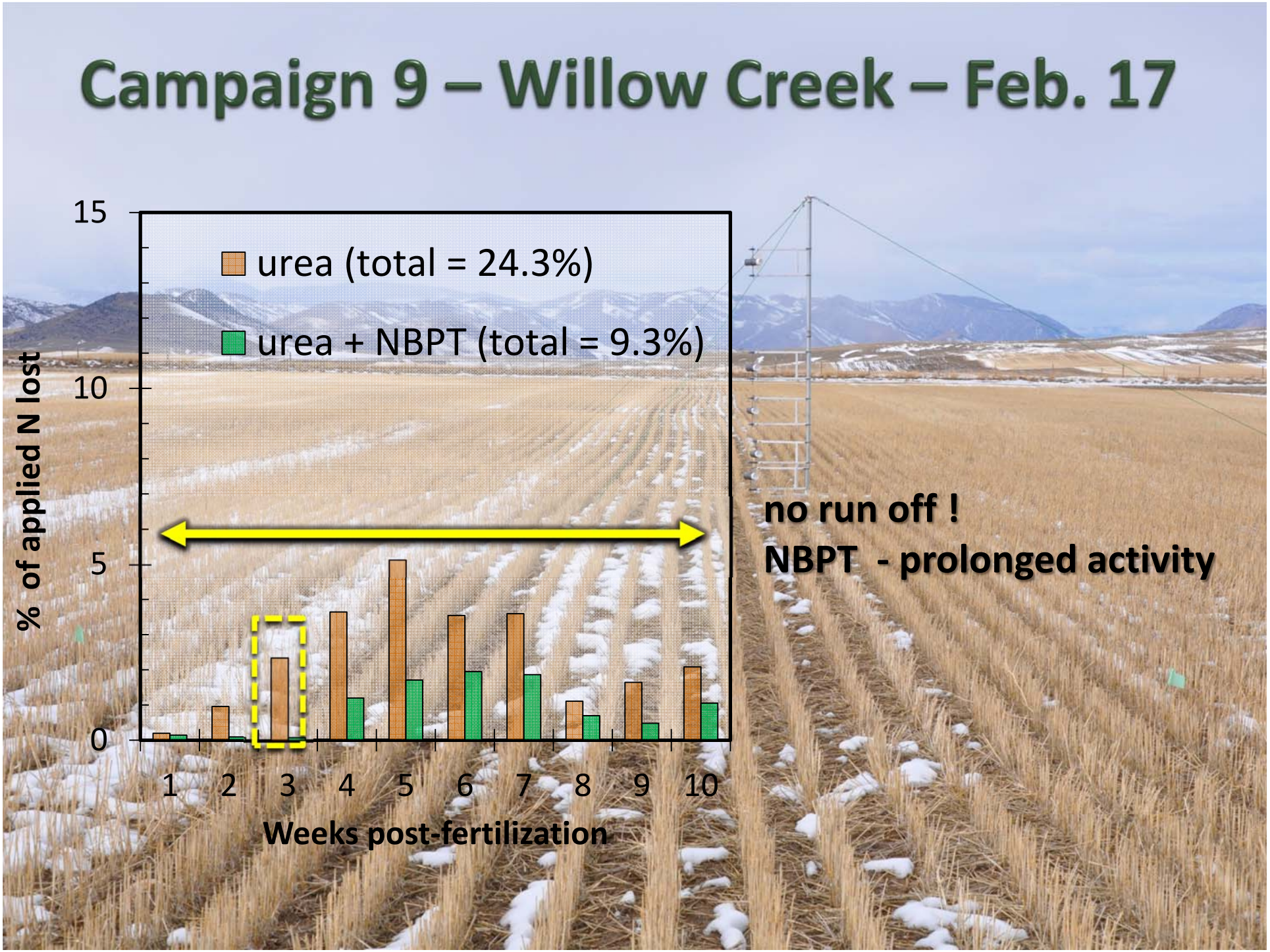


Campaign 9 – Willow Creek – Feb. 17

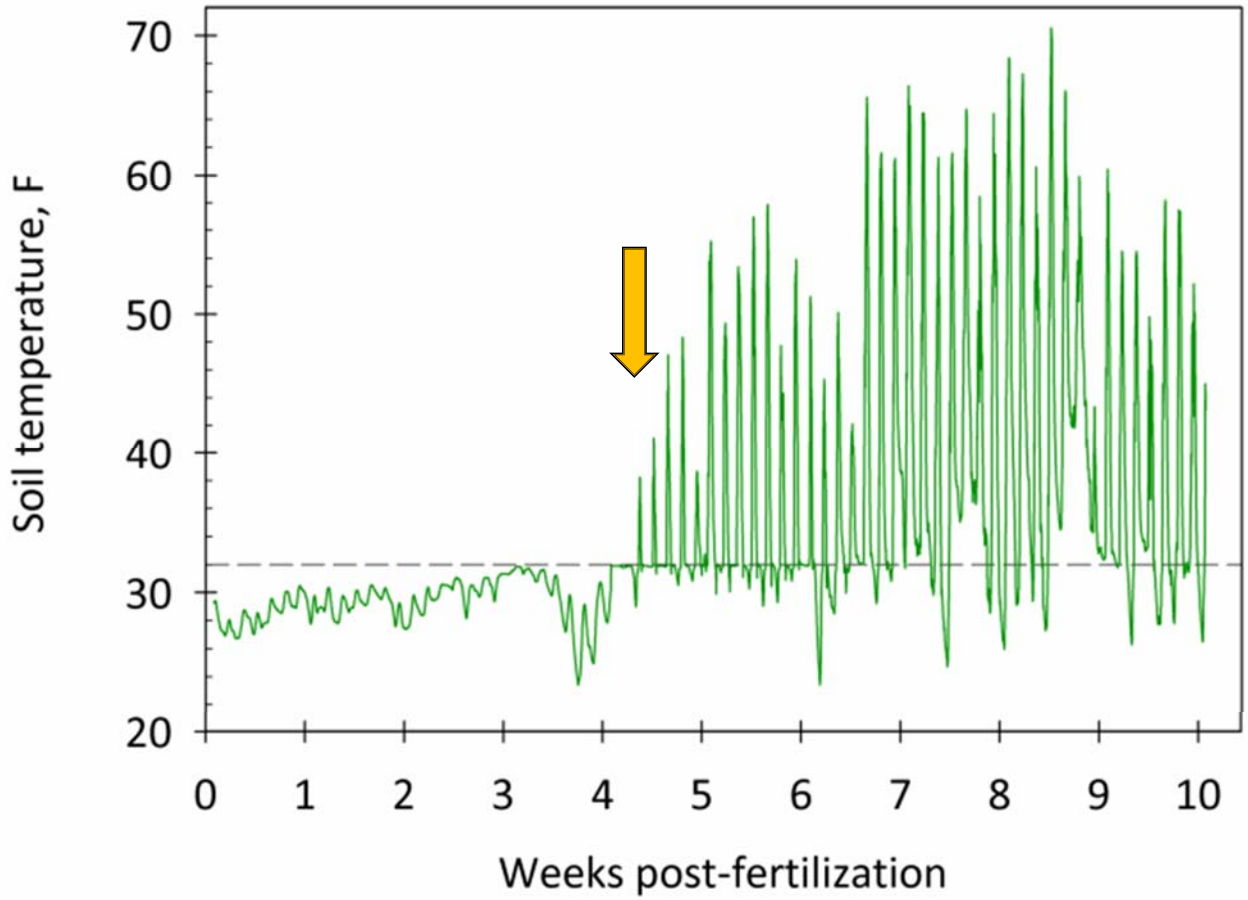


- no run off

Campaign 9 – Willow Creek – Feb. 17



Campaign 9 – Soil temperature (1 cm)



- 12.3% applied N lost 0-5 wk

- soil temp. 30.0˚F

Campaign Summary (% N loss)

Campaign	Fertilization date	Urea	NBPT-urea
1	April 3, 2008	8.4	4.4
2	Oct 8, 2008	3.1	1.4
3	Nov 14, 2008	31.5	4.0
4	March 25, 2009	35.6	18.0
5	March 26, 2009	39.9	18.1
6	Oct 6, 2009	11.6	4.3
7	Oct 13, 2009	10.4	4.8
8	Oct 19, 2009	15.7	3.4
9	Jan 27, 2010	24.3	9.3
10	Feb 26, 2010	44.1	11.9
11	March 29, 2010	6.3	1.7
12	April 20, 2010	14.7	1.4
Average		**20.4**	**6.8**

wide range in N loss amounts

What about applying urea in front of seeder?

Three Campaigns this Fall

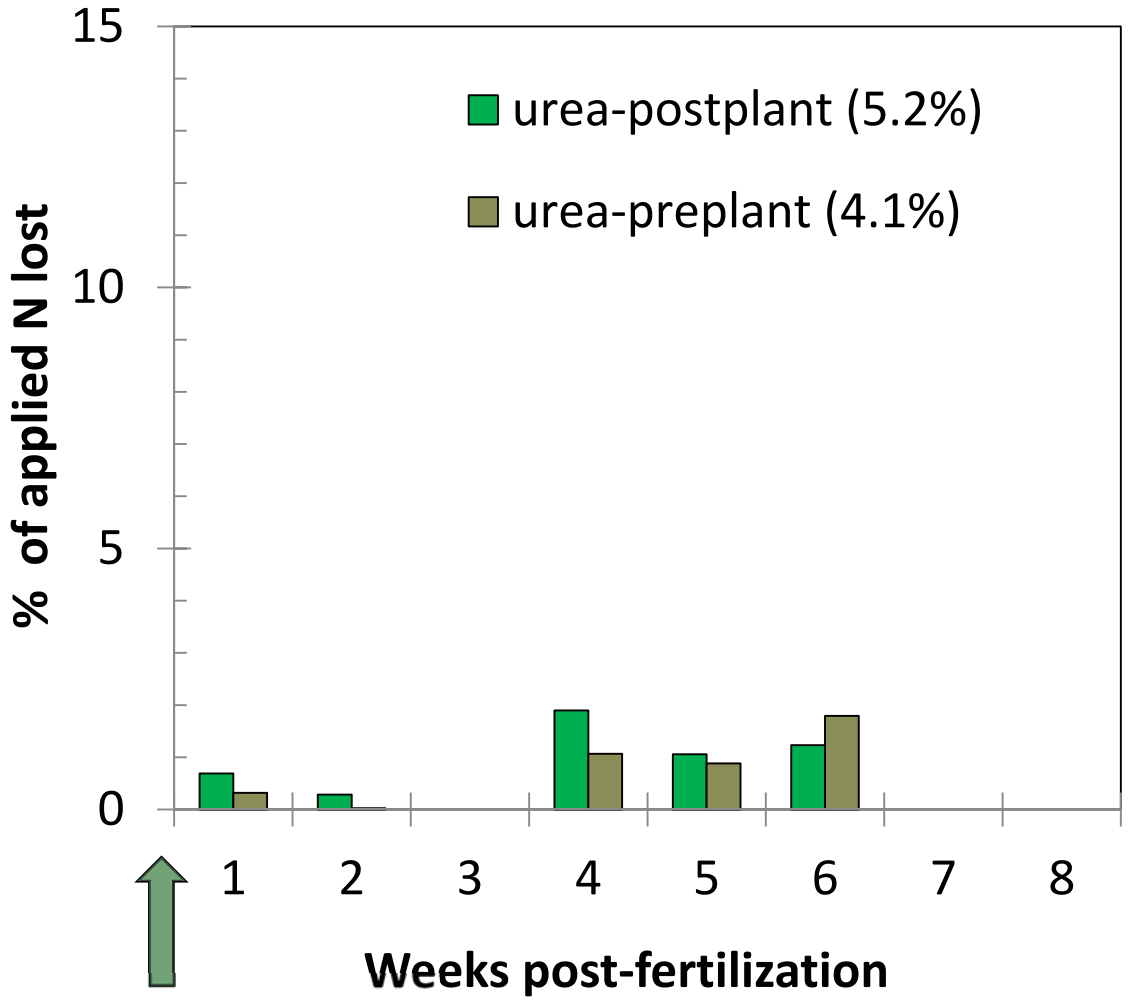
Fertilization date	Cooperator	Pre-seeding	Post-seeding
September 15	McIntosh- north Havre	18.7%	13.8%
September 27	McCormick - Kremlin	20.4%	24.4%
October 7	Peterson – north Havre	4.1%	5.2%

McIntosh site

McCormick site

Peterson site

Campaign 15 (in progress) – low N loss



October 7, 2010

0-4 wks characterized by light precipitation events

214

Summary comments

- significant N losses as NH_3 can happen in Montana when urea is surface-applied

- wet surface soil conditions w/o accompanying ppt → high risk for appreciable NH_3 loss, even if soil temperatures 28 to 41°F
  - ✓ greater potential for these conditions in Montana during late fall, winter (thaw), early spring
  - ✓ throw urea prills on the ground. Do they dissolve ?

- surface-applying urea to a dry soil surface is best, then hope for rain and wet snow that infiltrates into soil; some loss of N (10-20%) appears likely based on results to date

Summary Comments

- mid-winter urea on snow – 1 campaign on soil pH 8.3 (24.3% N loss) - may be problematic from NH_3 loss standpoint but we need to investigate further ??

- NPBT or Agrotain may have a role under the high loss potential conditions - longevity may be greater in calcareous soils

- surface-applying urea in front of air-seeder so far has not shown to be effective in suppressing volatility

Future Plans – evaluation form

- Winter applications
- Preplant N
- Goose Shooter – Kurt Kamberzell (Chester, MT)
- How are wheat yields and protein affected by N loss?

Support

- WSARE
- MT Fertilizer Advisory Committee
- MT Wheat and Barley Committee
- NRCS-CIG program
- International Plant Nutrition Institute
- Agrotain International

Urea volatilization web site

http://landresources.montana.edu/ureavolatilization