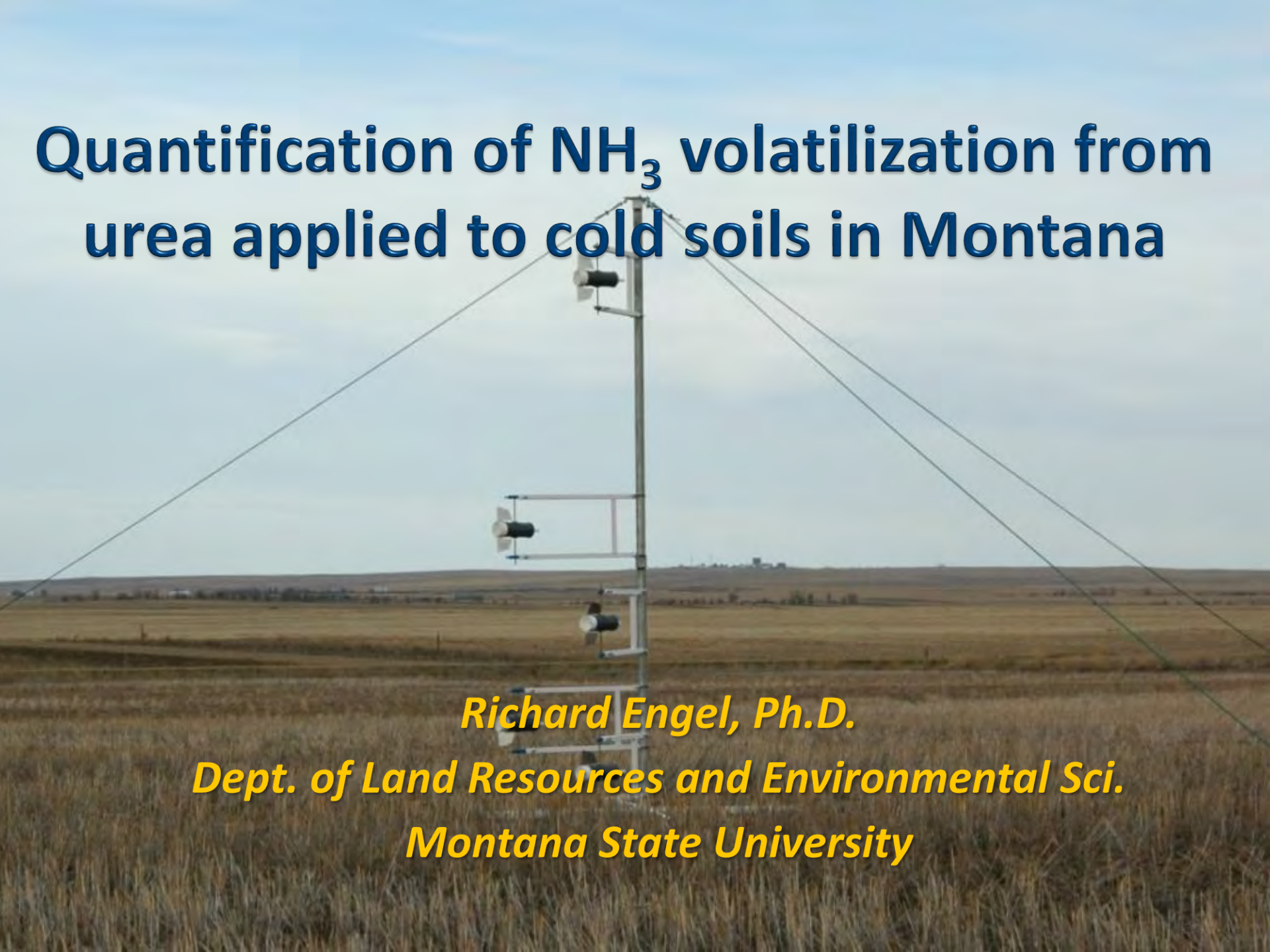
Quantification of NH_3 volatilization from urea applied to cold soils in Montana



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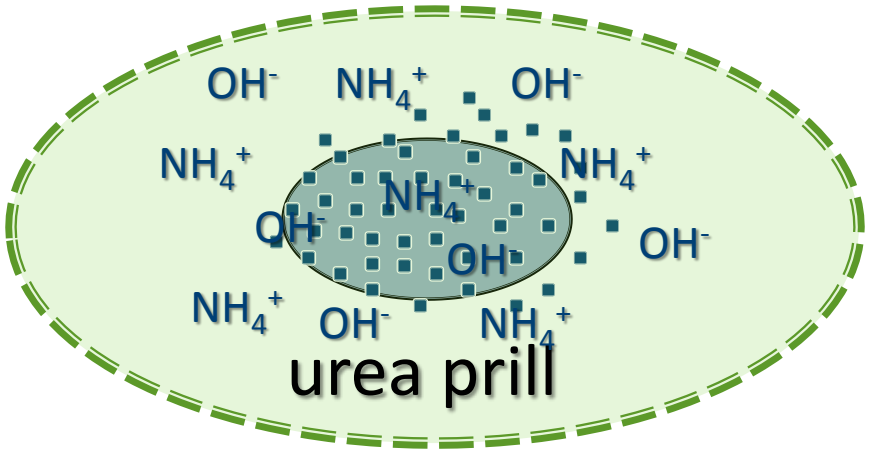
Urea reactions in the soil

- urea + H_2O —*urease*→ $(NH_4)_2CO_3$
- $(NH_4)_2CO_3$ rapidly dissociates to form NH_4^+ and CO_3^{-2}

$$CO_3^{-2} + H_2O \longrightarrow HCO^-_3 + OH^-$$



pH ↑ 2.5 to 3.5 units

Urea reactions

- ✓ **hydrolysis can lead to large increases in pH around fertilizer prill**
- ✓ $NH_4^+ + OH^- \longrightarrow NH_{3(g)} + H_2O$

Urea & volatilization – previous work

- ✓ lot of work published
- ✓ factors influencing losses are well-known:
  e.g. soil moisture, CEC, temperature, pH

Big question ….. How much are we losing ?

Background - Montana fertilizer urea use

- Surface broadcast applications are common practice particularly in dryland winter wheat systems
- late-fall, winter, early spring - cold soils
- The potential for ammonia loss has long been acknowledged from this practice, but is this a problem in our State?

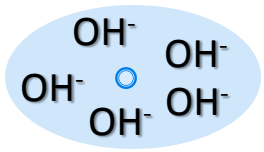
Project objectives

- Quantify ammonia volatilization losses for spring, fall (early,late) and winter applications of urea ?

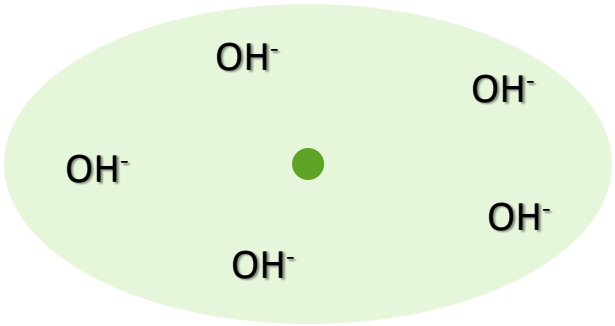
- How do we mitigate losses?
  - e.g. enhanced urea products, NBPT coated urea (Agrotain)
  - e.g. timing & incorporation with air-seeders

NBPT = n-(n-butyl) thiophosphoric triamide

- urease inhibitor
- allows more time for urea to diffuse away from point of application so ⇑ soil pH is moderated



urea



urea +NBPT

…. or rainfall events so urea is leached below the soil surface

Any questions ?

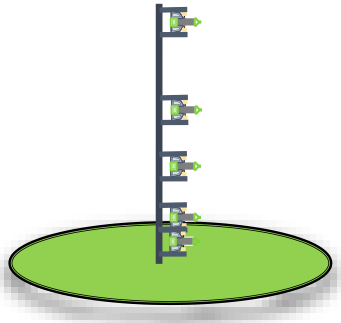
Method – integrated horizontal flux

- micrometeorological - preferred approach for quantifying gas losses
- does not disturb the soil-atmosphere environment
- moderate size plots (~0.3 acre)
- continuous measurement of $NH3_{(g)}$loss over time

mast and shuttles →

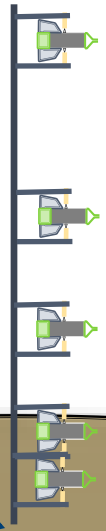
Method – circular plots (20 m)

- urea-N rate - 90 lbs/acre
- Agrotain rate (4 quart/ton)
- large unfertilized buffer areas around plots required !



urea + Agrotain

background

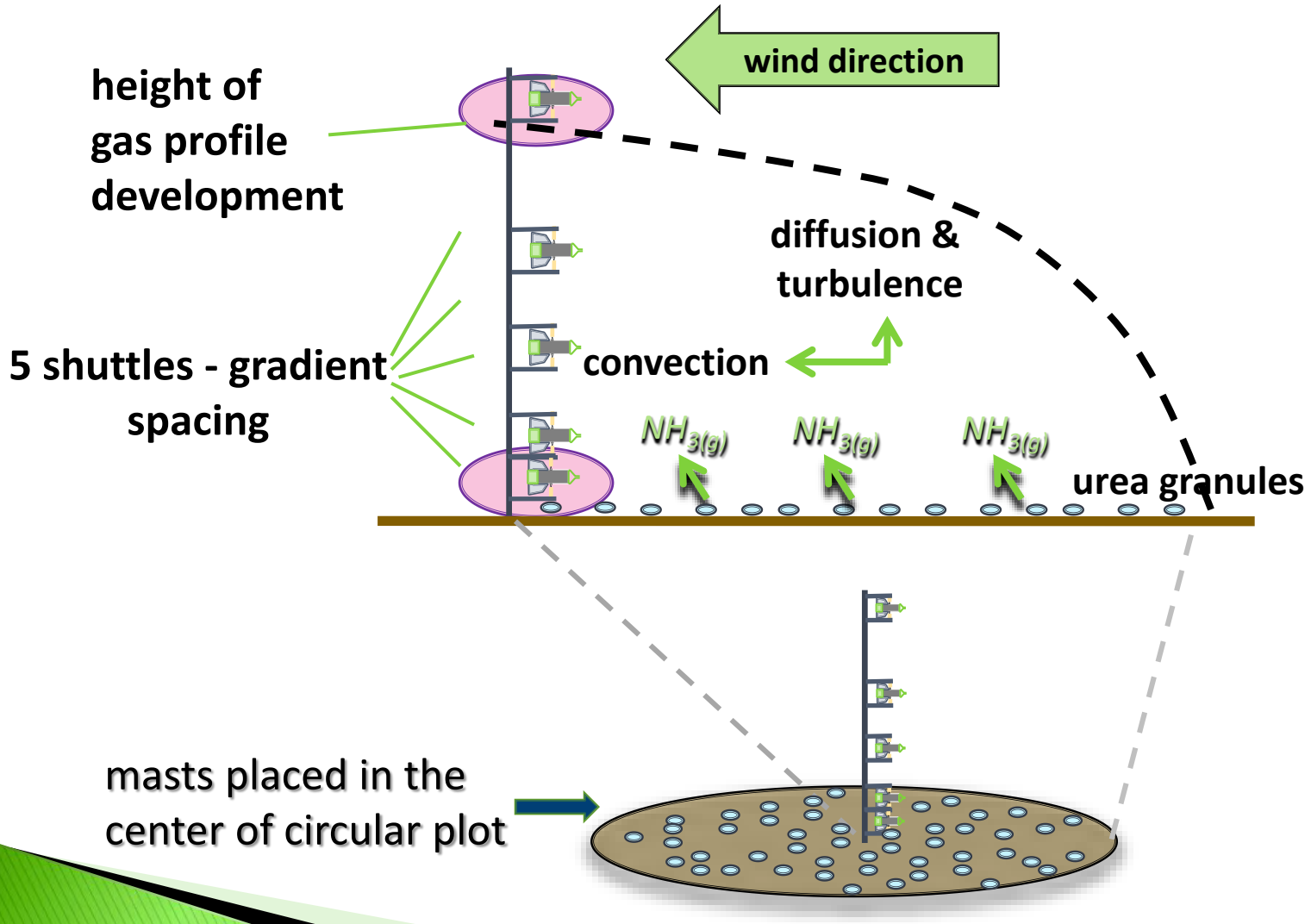


20 m

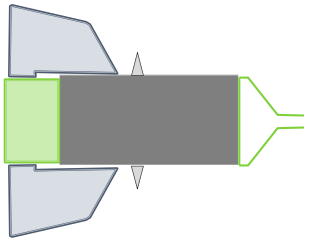
+ urea

200 m

Methods – masts & shuttles (traps for $NH_{3(g)}$)

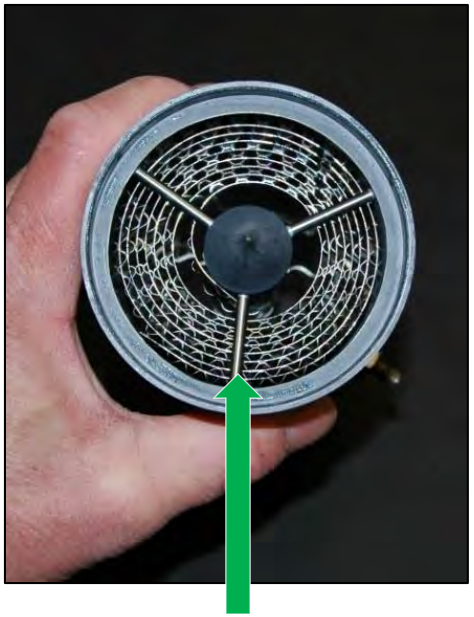


Method - shuttles



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

front

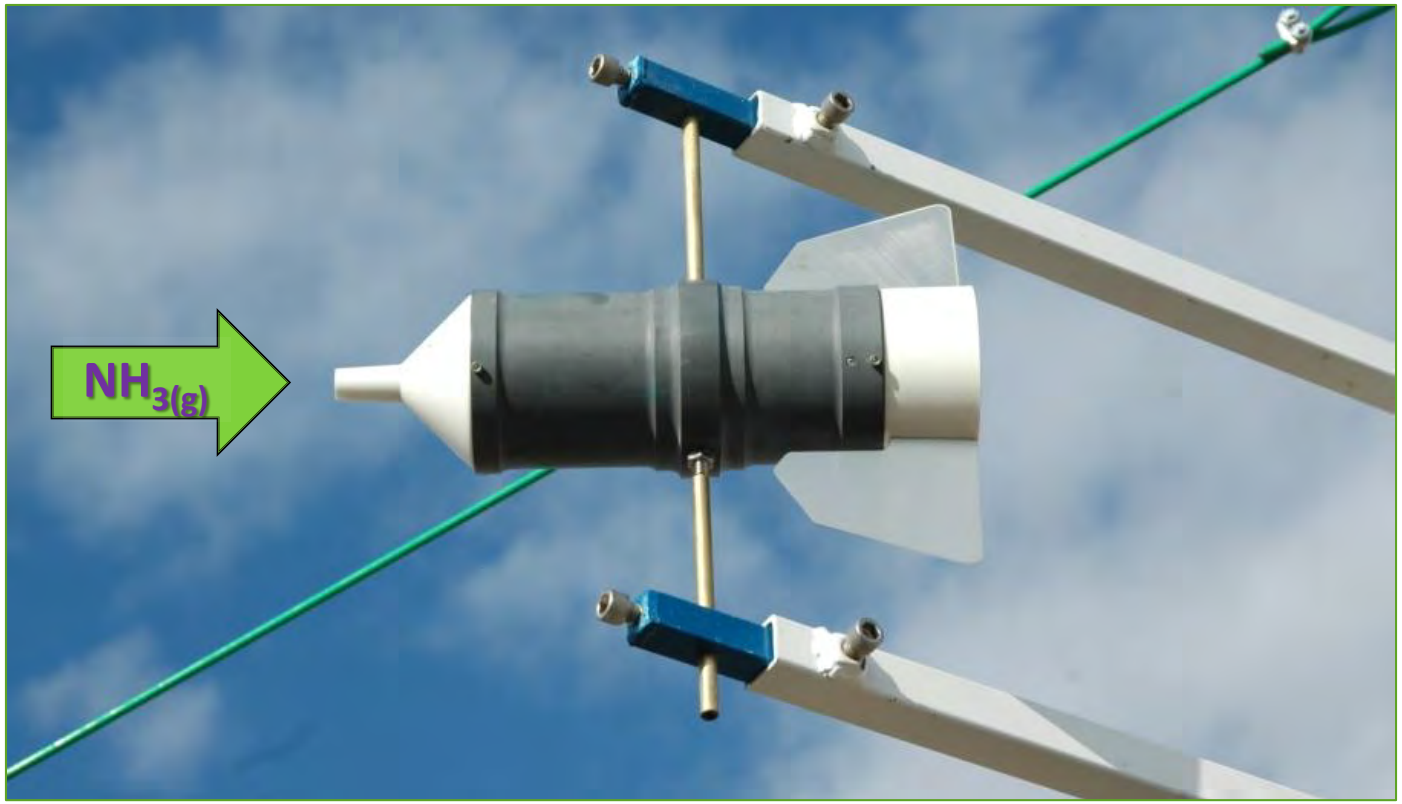


stainless steel spiral coated with oxalic acid

back

Methods - shuttles

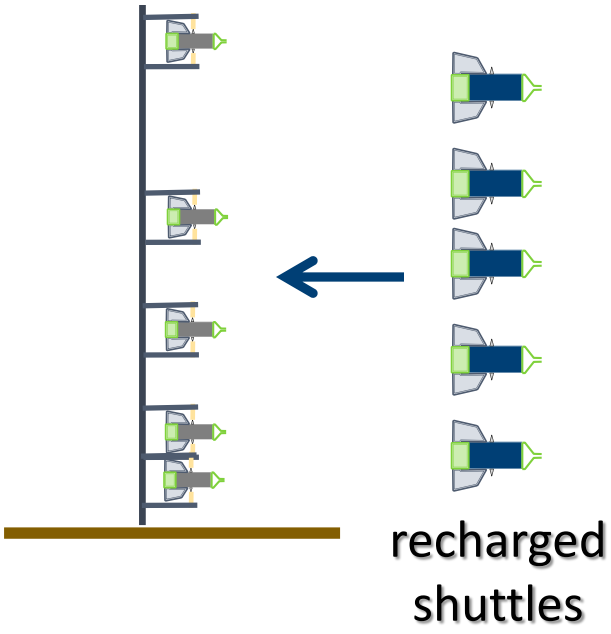
- traps for collecting ammonia, idea & design developed in Australia (Leuning et al., 1985. Atmos. Environ)



rotate on pivot & face into wind

Method-continuous measurement

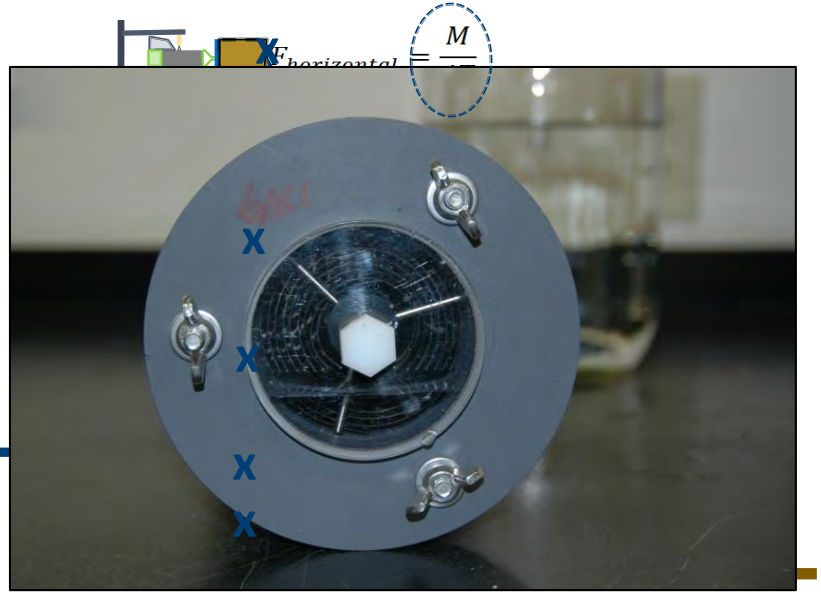
- **Spent shuttles exchanged with recharged shuttles every week**



How are $NH_{3(g)}$ losses quantified?

- Key points
  - $NH_{3(g)}$ trapped in shuttles eluted in lab & quantified
  - horizontal flux calc. - effective shuttle sampling area is known via wind tunnel tests (Leuning et al., 1985)
  - height vs. horizontal flux diagrams (treated area)
  - background NH_3 (mast placed in untreated area)
  - known fetch distance (20 m.)

net area ÷ fetch distance



Horizontal flux measured in five planes

Any questions ?

Kaercher farm site - background

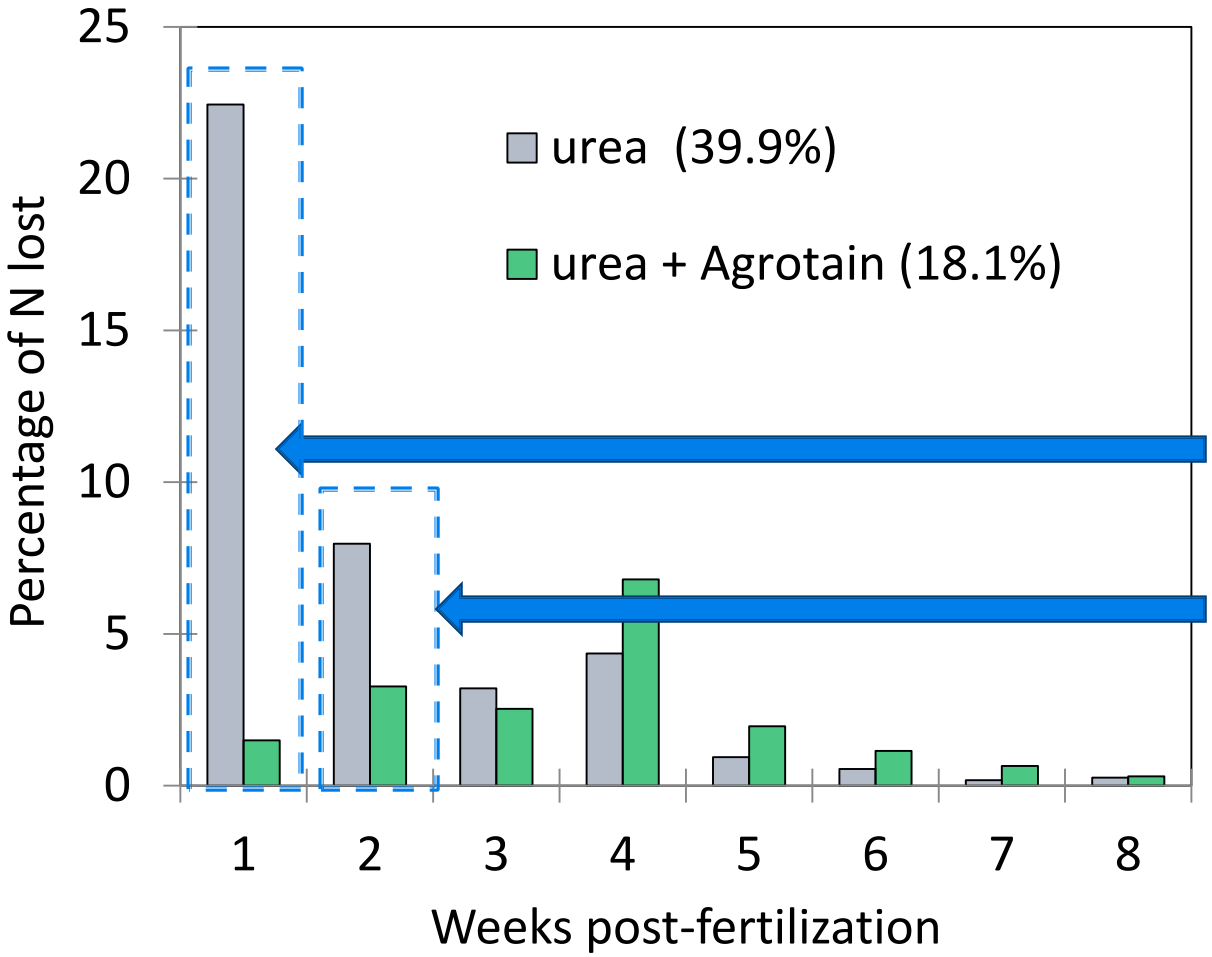
- 10 miles west of Havre, Hill County
- Phillips-Elloam silt loam
- pH 6.0
- 3 gas sampling campaigns – 8 wks
- no till winter wheat

Kaercher site - Spring 2009 – Campaign #5

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

soil surface with fertilizer
prills beginning to dissolve

Kaercher site – Ammonia losses - #5



Precipitation

no rain 0-2 wks

1.54” 2-8 wks

Soil temp (1 cm) = 34.3 F

Air temp. = 33.1 F

Soil temp (1 cm) = 38.5 F

Air temp. = 38.7 F

Peterson farm site - background

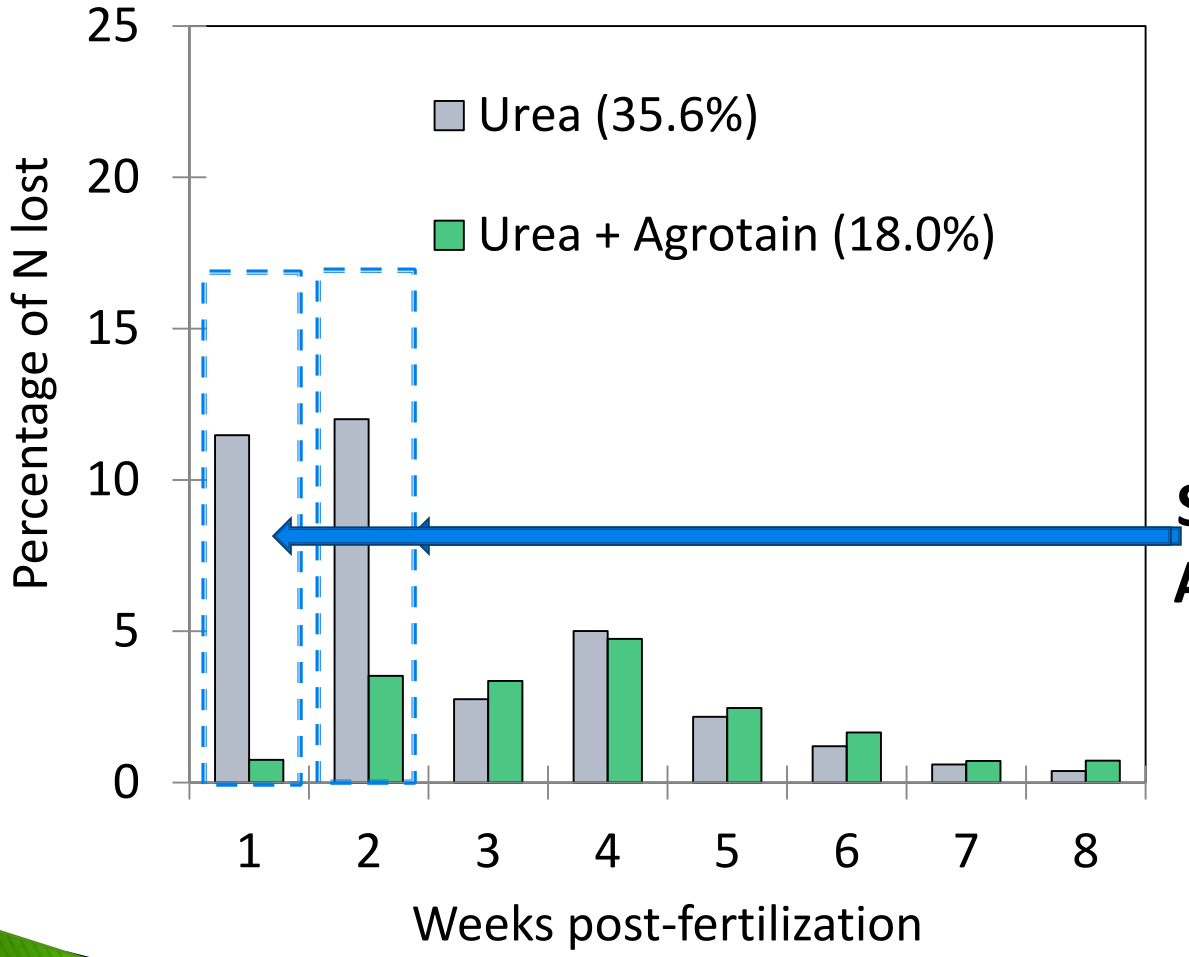
- 28 miles NW of Havre, Hill County
- Telstad-Joplin loam
- pH 5.5
- 2 gas sampling campaigns – 8 wk
- no till winter wheat

Peterson site - Spring 2009 - Campaign #4

Fertilized applied – March 25
"light snow & air-temp. 18 F"

soil surface frozen
30 F

Peterson site - Spring 2009 – Campaign #4



Precipitation

0.01” = 0-2 wks

0.89” = 2-8 wks

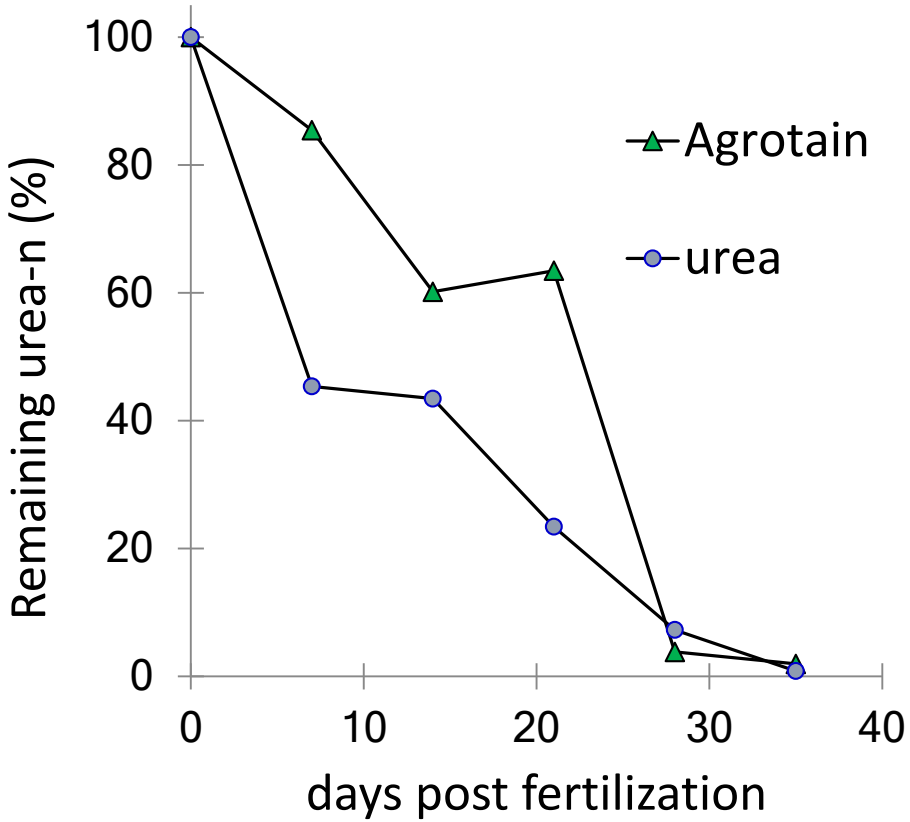
Soil temp (10 cm) = 38.7 F

Air temp. = 43.5 F

Peterson site - Spring 2009 – Campaign #4

Soil urea analysis

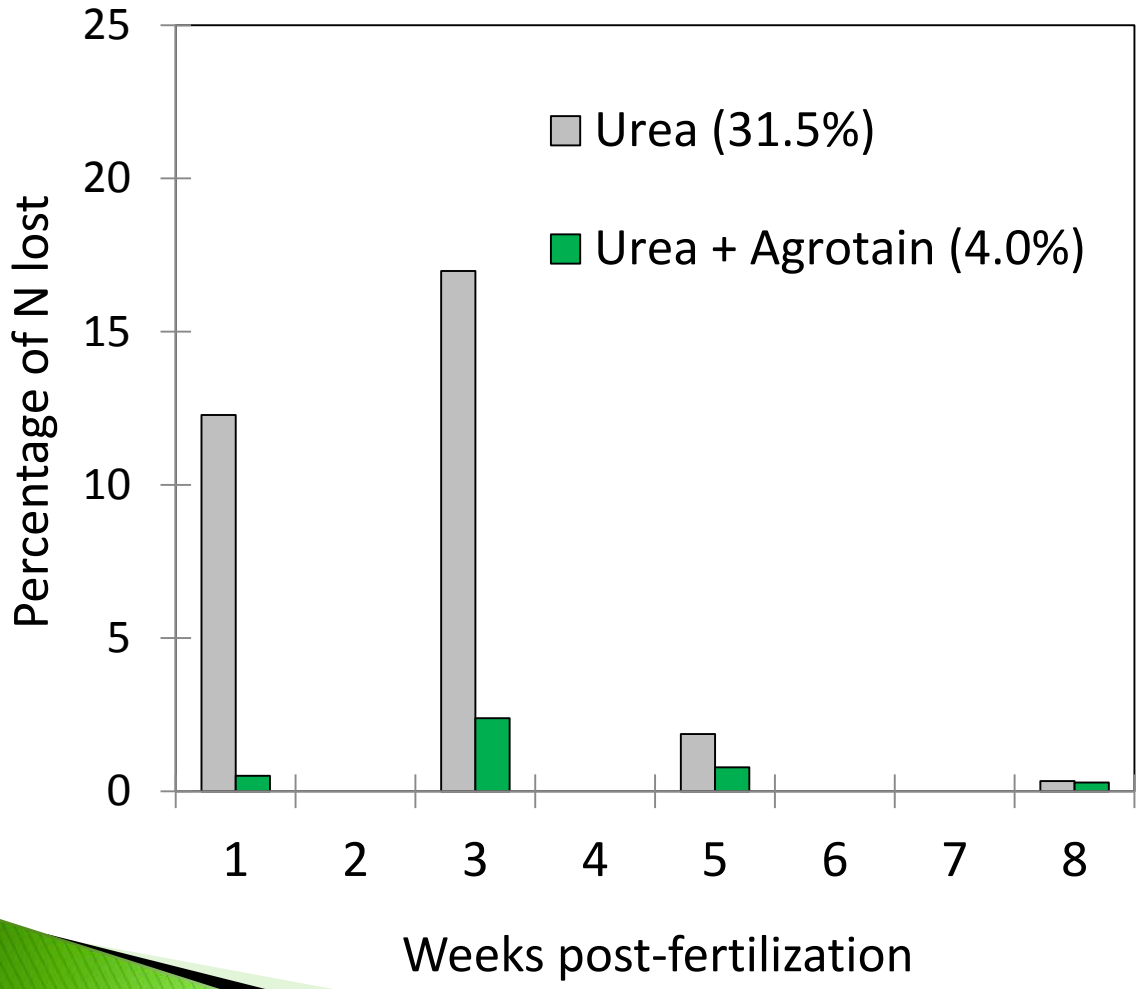
- hydrolysis occurs more slowly in cold soils
- 3 wks before urea is gone



Peterson site - Fall 2008 - Campaign #3

November 14 - fertilization date surface damp from melting snow

Peterson site - Fall 2008 - Campaign #3



Soil-temp. (1 cm)

0-1 wk = 33.8 F

1-3 wk = 28.9 F

Peterson site - Fall 2008 - Campaign #3

- Precipitation – trace amounts over first 3 wks

Dec 4th - 3 wks post-fertilization

December 18th … winter arrived!

Urea-N volatilization loss summary†

Campaign	Cooperator site	Fertilization date		Urea	Agrotain
				---------- % ----------	
1	Kaercher	2008	April 3	8.4	4.4
2	Kaercher	2008	Oct. 9	3.1	1.4
3	Peterson	2008	Nov. 14	31.5	4.0
4	Peterson	2009	March 25	35.6	18.0
5	Kaercher	2009	March 26	39.9	18.1
				23.7	**9.2**

† percentage of applied N lost as $NH_{3(g)}$

Kaercher site (Campaign #2) - low emission

- October 9, 2008 application, air-temp. 45 F
- dry soil & no rain for 24 day
- Nov. 2-5 = 0.98” ppt.

1 wk post-fertilization

Agrotain economics

- assuming urea costs $ 380/ton
- Agrotain adds ~$55/ton urea (4 quart rate) - $435

$$\frac{\$\ 55}{\$\ 380} \times 100 = 14.5\%$$

N losses or differential between urea and Agrotain would need to be ~14.5%

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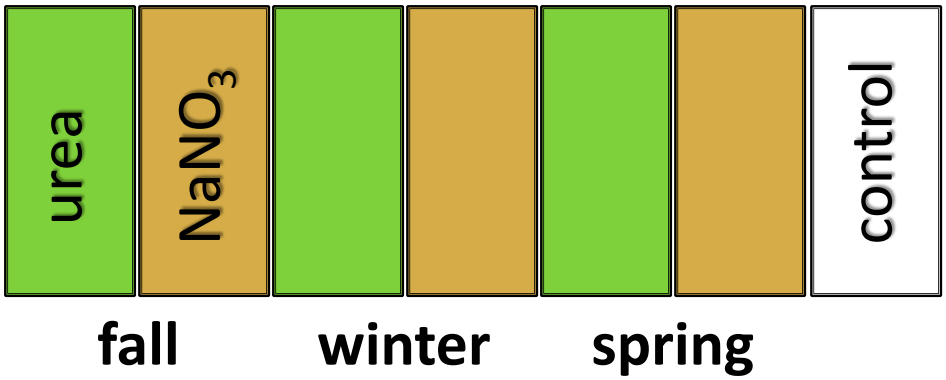
Summary

- ✓ significant $NH_{3(g)}$ losses (up to 40% of applied N) from surface applied urea can occur even though soil temperatures are cold!
- ✓ soil moisture conditions at surface that result in dissolution of urea granules (i.e. prolonged damp) without rain promote high $NH_{3(g)}$ losses.
- ✓ more common to find these conditions in semi-arid Northern Great Plains during the late fall or early spring.
- ✓ Agrotain control = 60% reduction in $NH_{3(g)}$

Future plans

- third site this fall (clay loam)
- additional gas sampling campaigns (fall, winter, early spring)
- complementary study - N source comparisons (urea, sodium nitrate) – paired plots & control



- Where does the volatilized ammonia go?

http://landresources.montana.edu/ureavolatilization/


Thank you