Ammonia Volatilization from Urea: How large is the issue and losses.

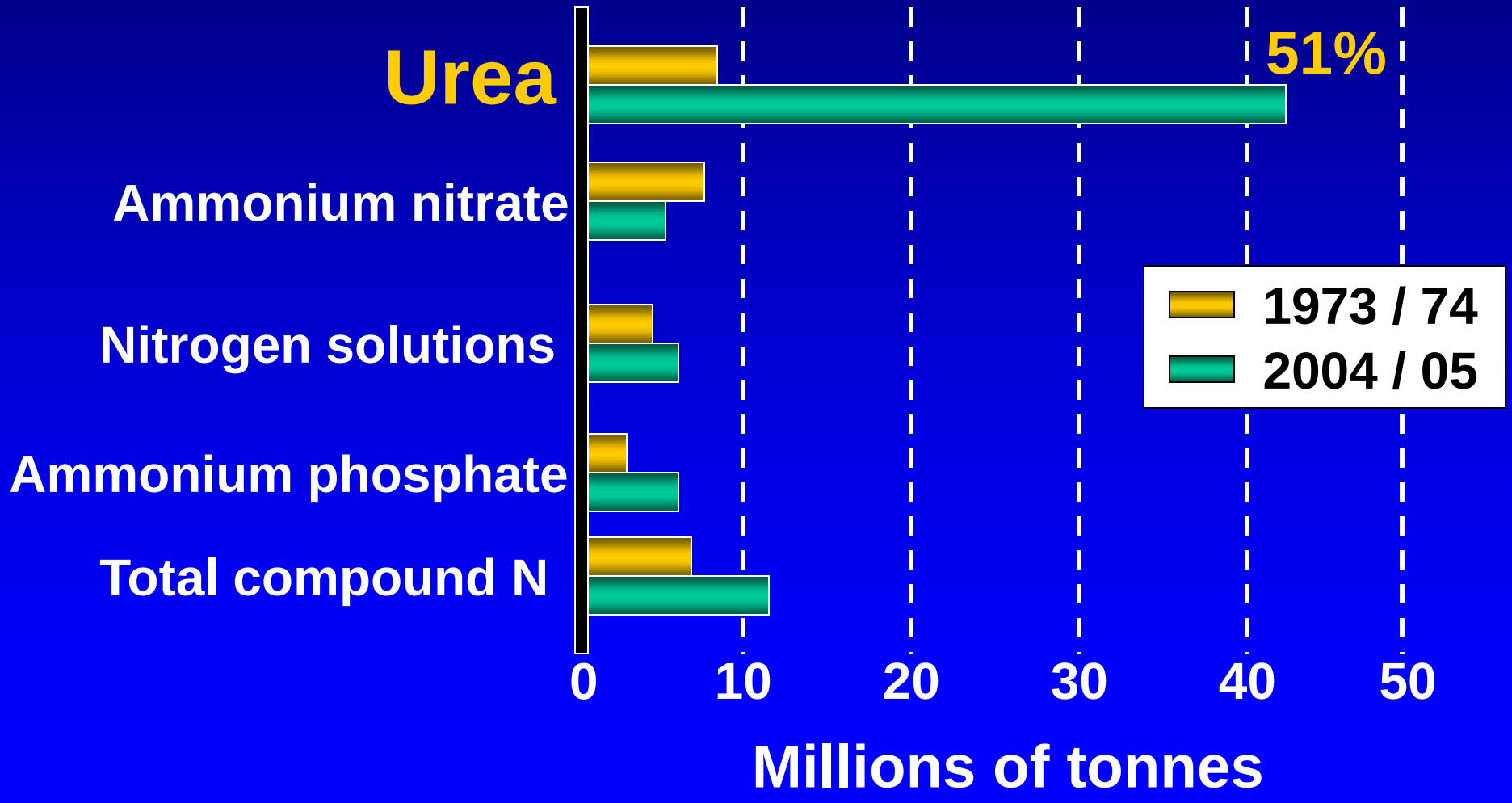
David E. Kissel

University of Georgia

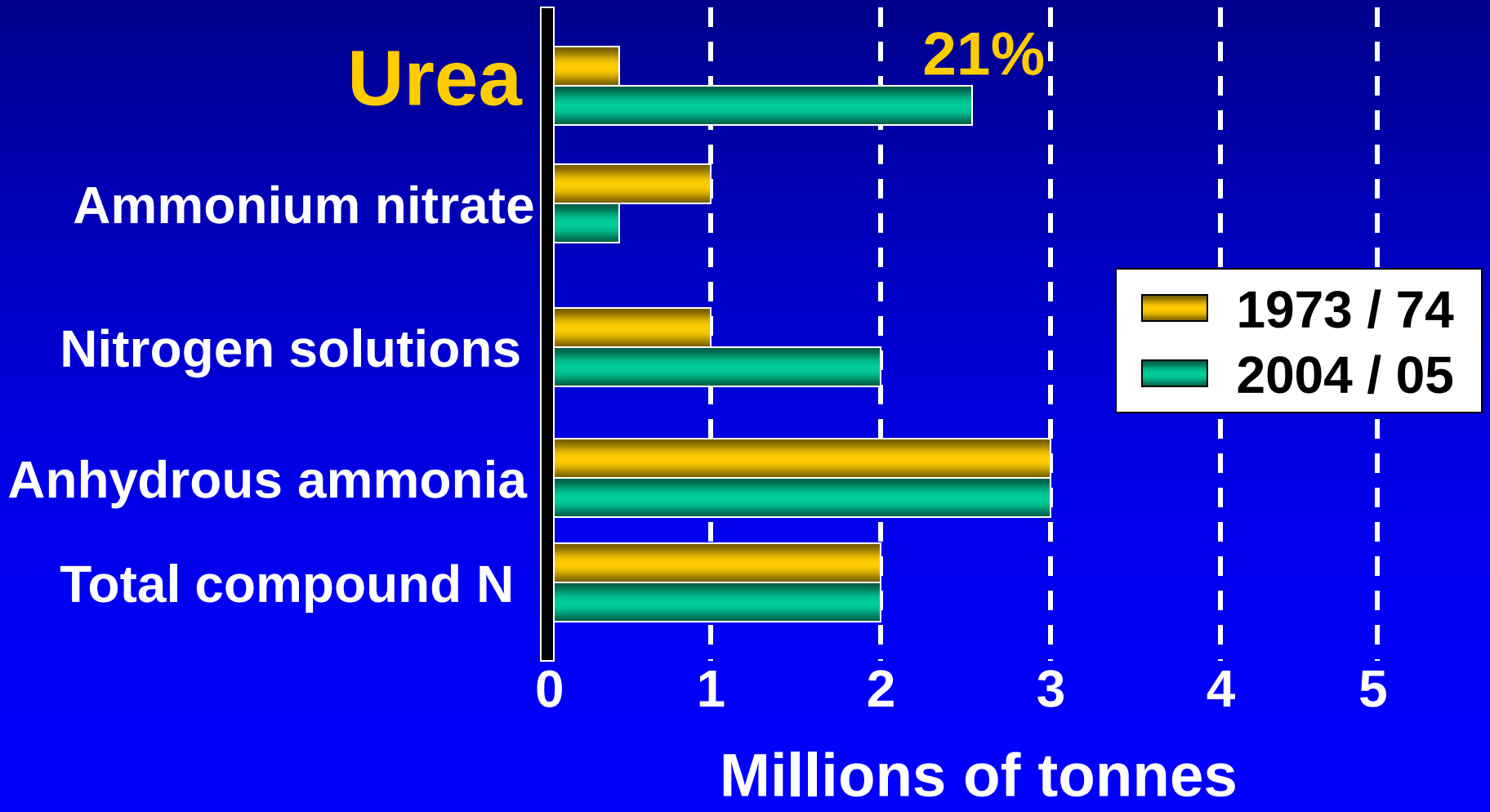
Overview

- Urea Consumption
- Definitions
- UAN Solution Reactions
- Urea Dissolution and Diffusion
- Urea Hydrolysis
- Ammonia Volatilization
- Research Results
- Summary

World Evolution of N Fertilizer Consumption



USA Evolution of N Fertilizer Consumption



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Definitions

- Dissolution: urea absorbs water and converts from solid to liquid
- Hydrolysis: urea converts to ammonium (NH_4^+)
- Diffusion: movement due to motion of molecules
  - Urea has no charge, diffuses easily
  - NH_4^+ has charge, diffuses slowly

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Q. Does any ammonia volatilize from UAN solutions before they are applied or during the application?

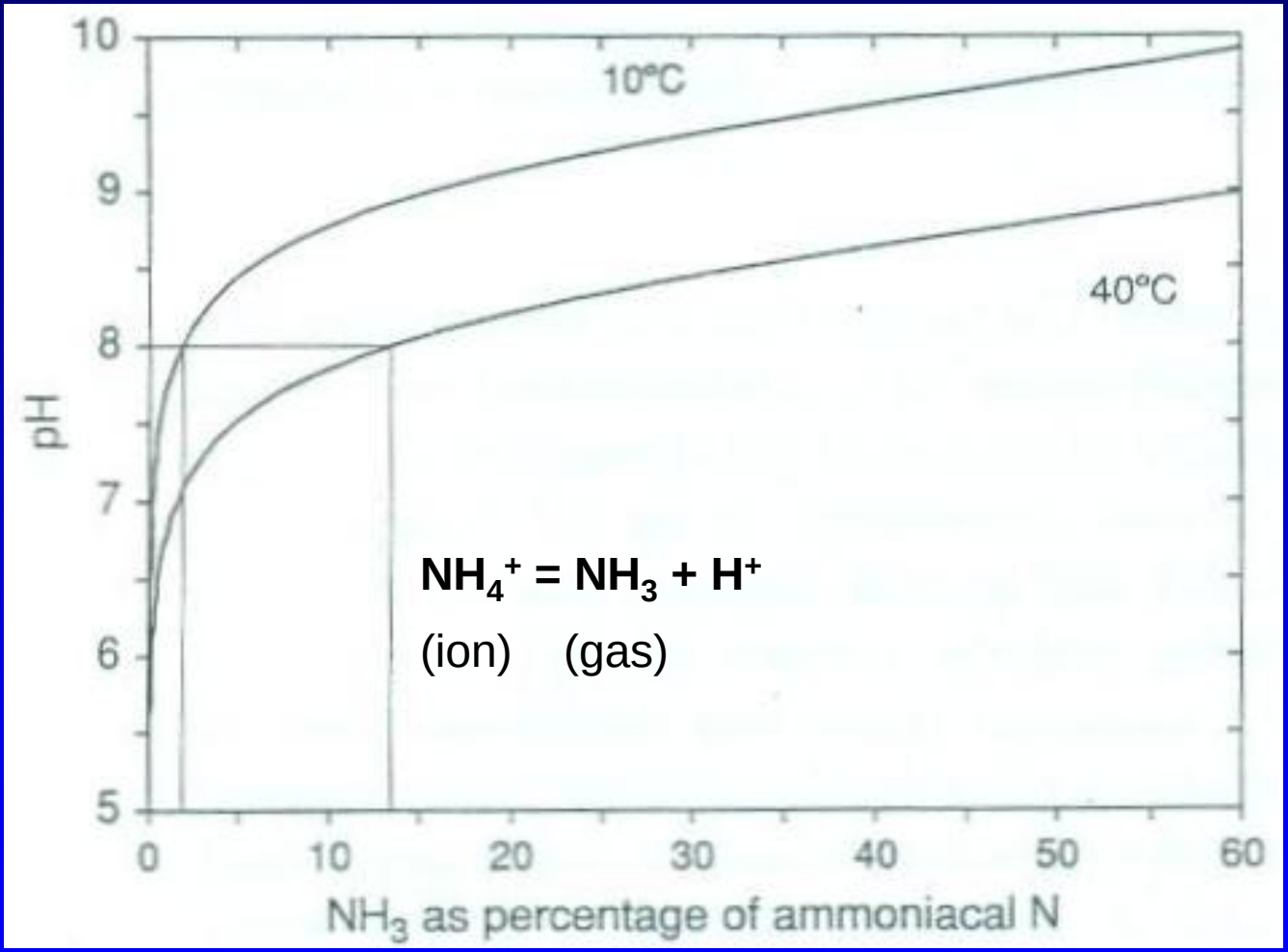
A. None or very little, depending on if a small amount of ammonia is added to protect against corrosion of mild steel.

Composition of UAN 28% N

- 14 % N from Ammonium Nitrate
  - 7% ammonium N
  - 7% nitrate N
- 14% N from Urea
- 30% water
- + small amounts of inhibitors to inhibit corrosion of mild steel

Inhibitors to protect against corrosion of mild steel

- 0.5 % ammonia (raises pH to about 7.5)
- Ammonium phosphates at 0.2 % P_2O_5
- Others


10
9
8
7
6
5
pH
10°C
40°C
0
10
20
30
40
50
60
NH3 as percentage of ammoniacal N
NH4+ = NH3 + H+
(ion) (gas)

Urea Hydrolysis in UAN?

- DOES NOT OCCUR
  - Therefore no ammonia is formed from the urea portion of the UAN solution from this process.
  - Therefore no ammonia loss from the urea portion of UAN solution before soil application.

Summary of ammonia loss from UAN

- Urea in UAN does not hydrolyze in the fertilizer tank.
- The NH_4^+ from the ammonium nitrate portion of the UAN cannot be lost as NH_3.
- The amount of NH_3 added to some UAN to inhibit corrosion is very small, around 10 lb per ton. A small portion of this NH_3 may be lost during application.

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Urea Dissolution

- Urea has to be dissolved before it can be hydrolyzed

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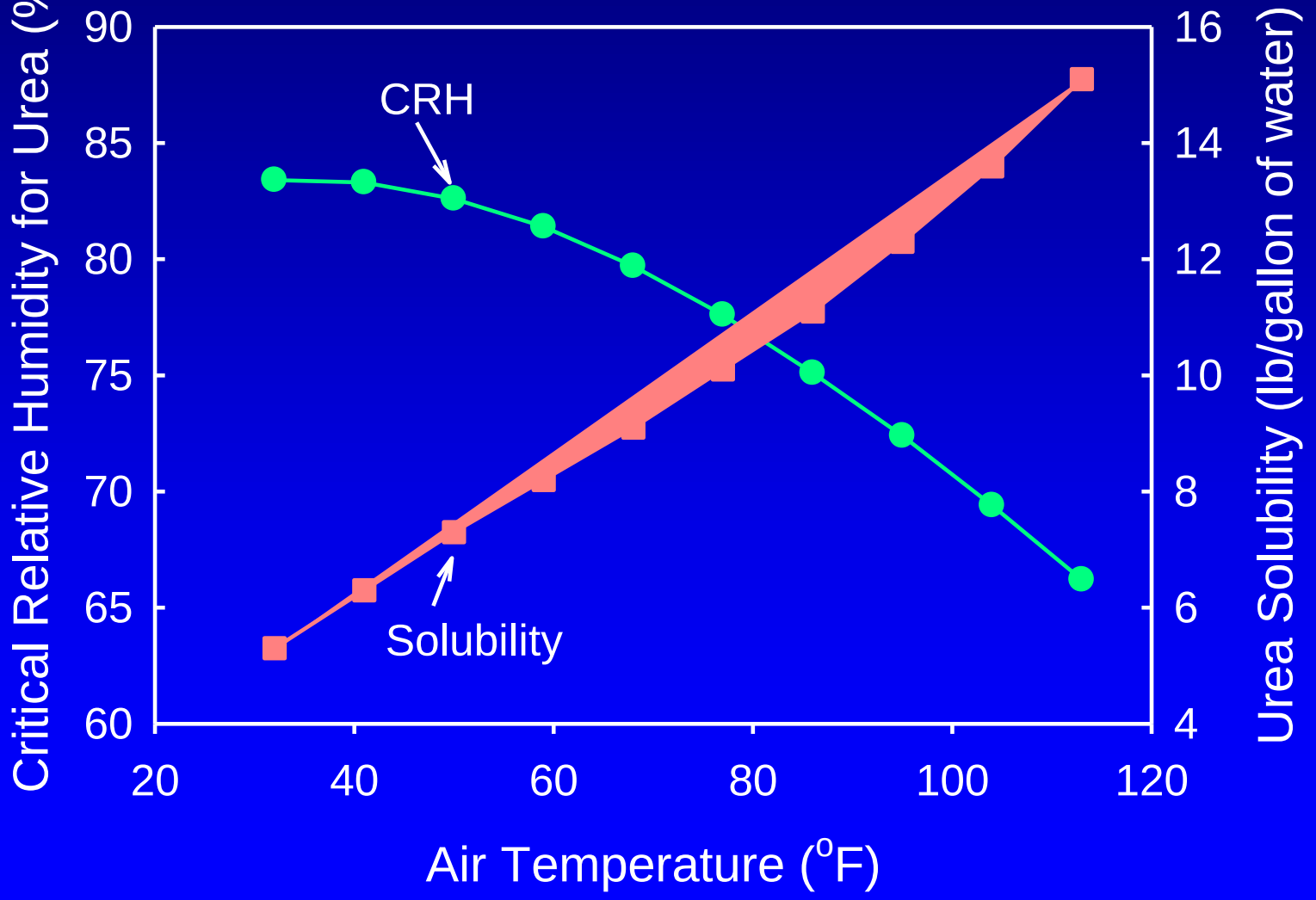
- Urea has to be dissolved before it can be hydrolyzed
- Urea can absorb water from the atmosphere and from the soil/crop residue
- Absorption of water from the atmosphere depends on relative humidity (RH)
- Critical relative humidity (CRH) is the RH at which urea dissolves

Effect of Temperature on CRH and Water Solubility of Urea



Urea dissolution and diffusion

RH > CRH (80%)

www.agrium.com

Urea Urea Urea

Crop residue

Dry Soil

Urea dissolution and diffusion

www.agrium.com

Crop residue

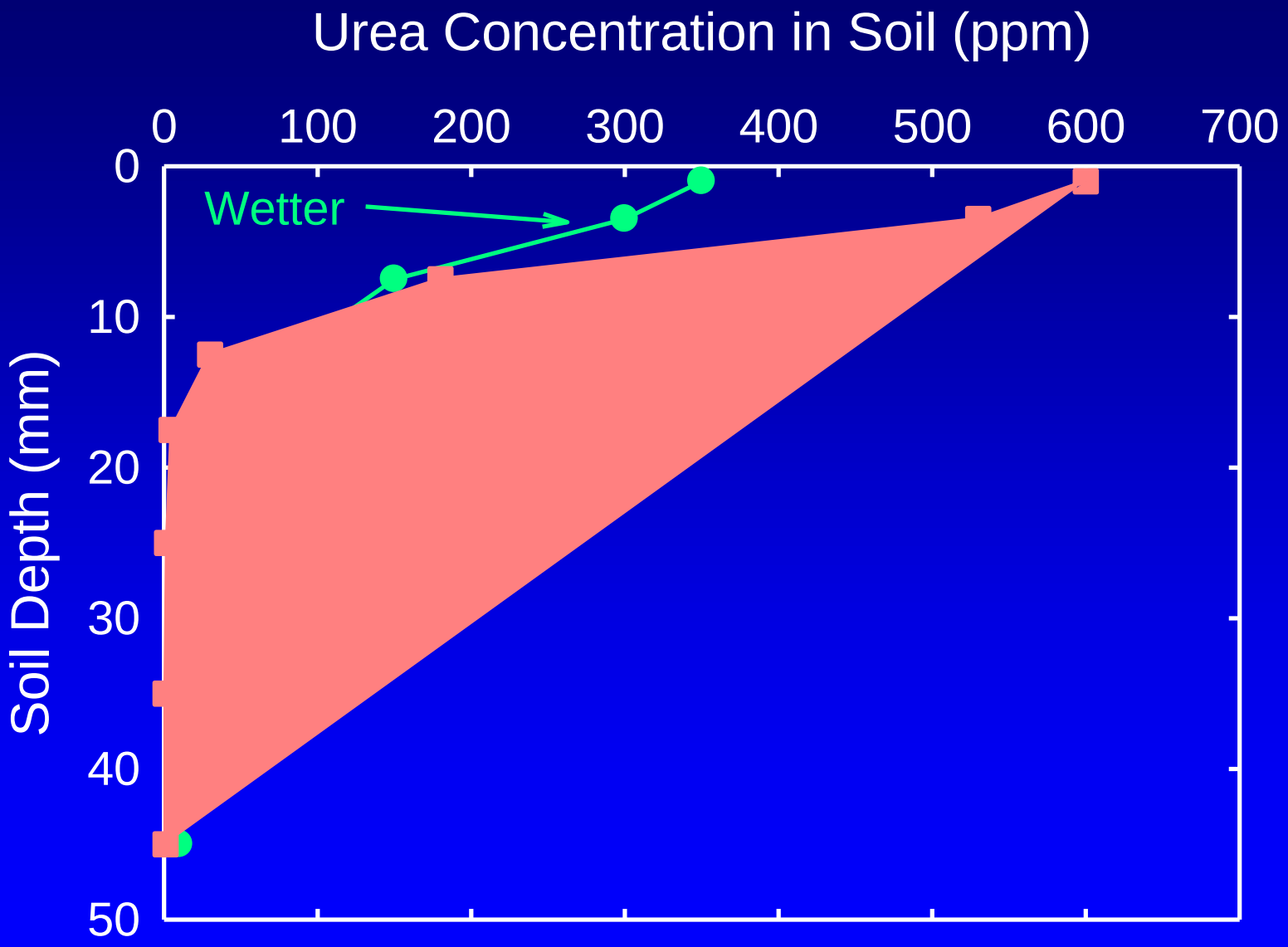
Urea Urea Urea

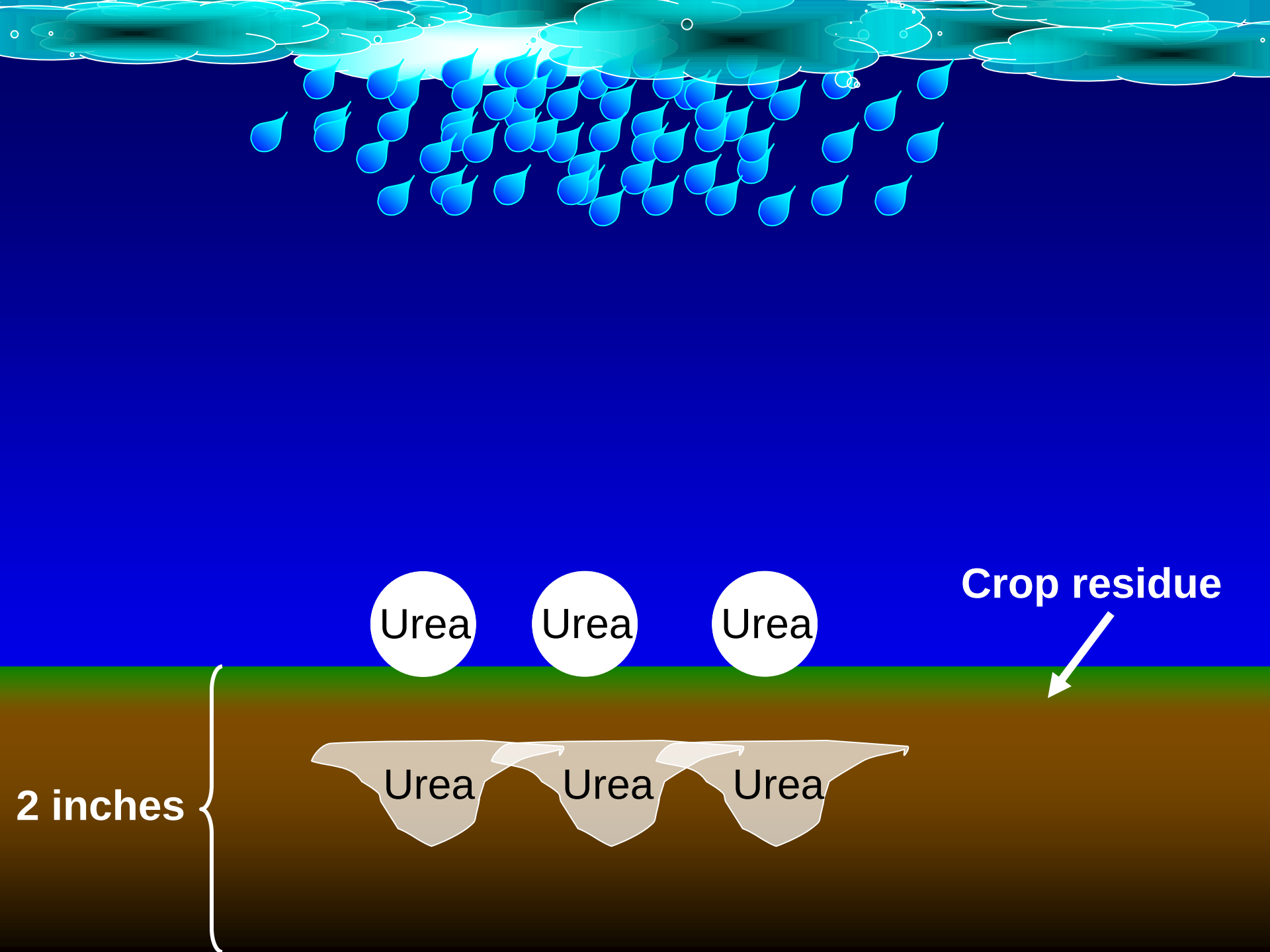
Urea Urea Urea

1/2 **inch**

Wet Soil

Urea Diffusion into Soil (after 10 days)




Crop residue
Urea
Urea
Urea
Urea
Urea
Urea
2 inches

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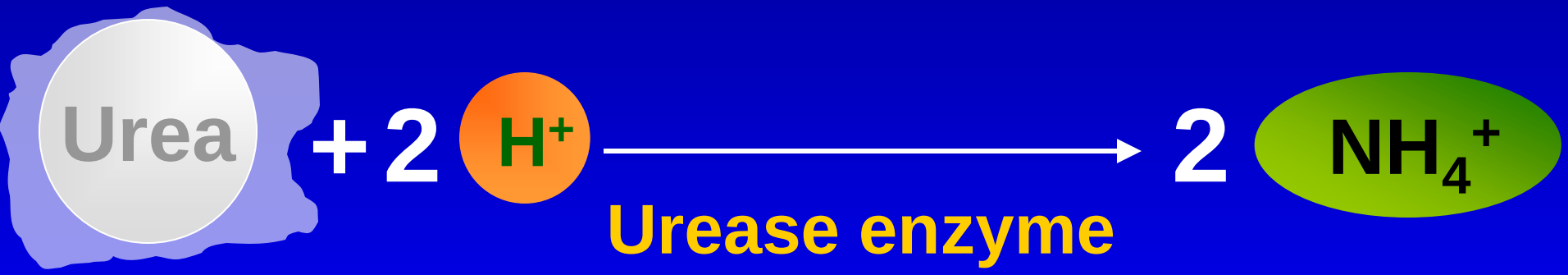
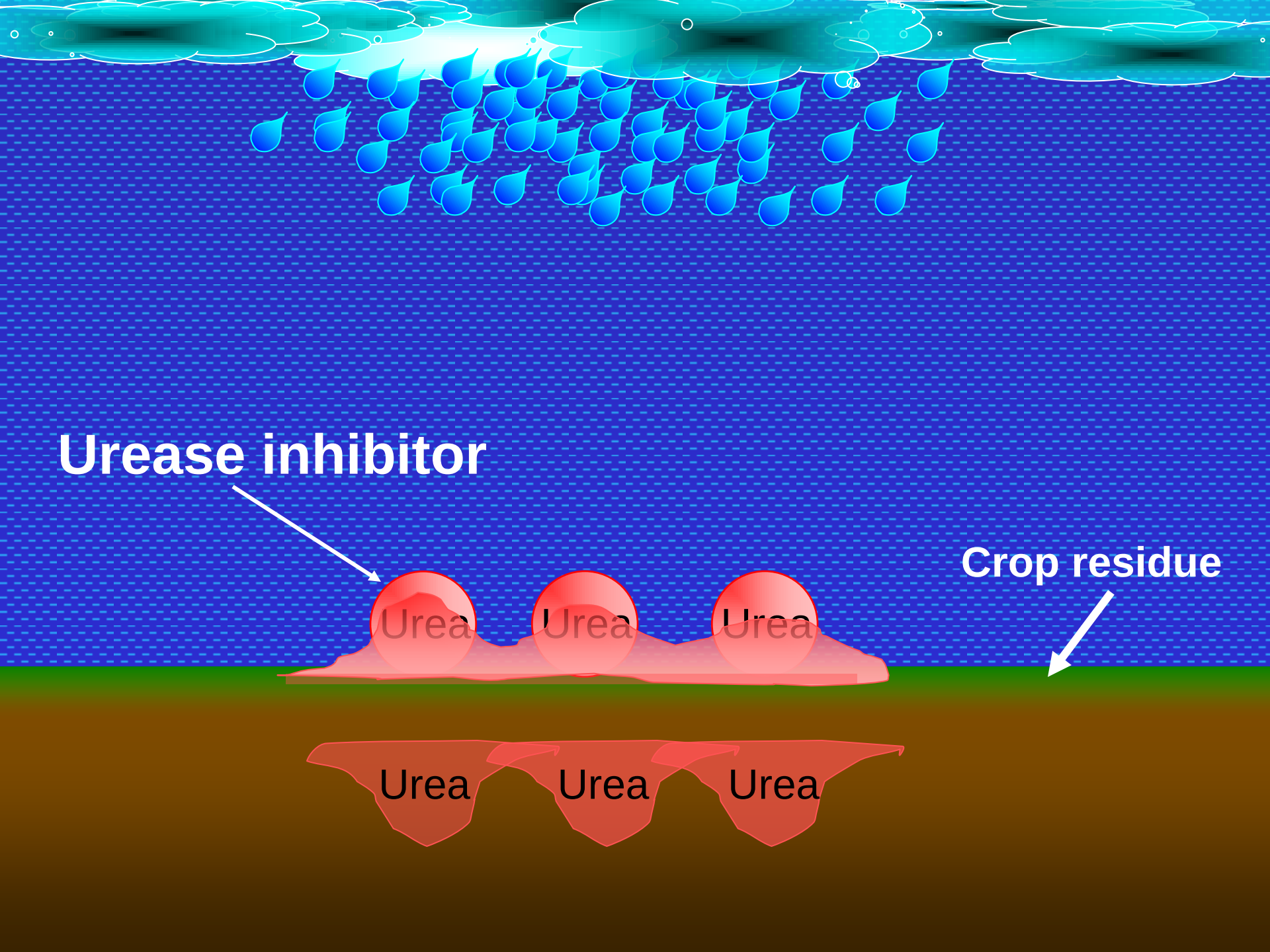
Urea Hydrolysis



- Urease is derived from crop residues and soil microorganisms


Urease inhibitor
Crop residue
Urea
Urea
Urea
Urea
Urea
Urea

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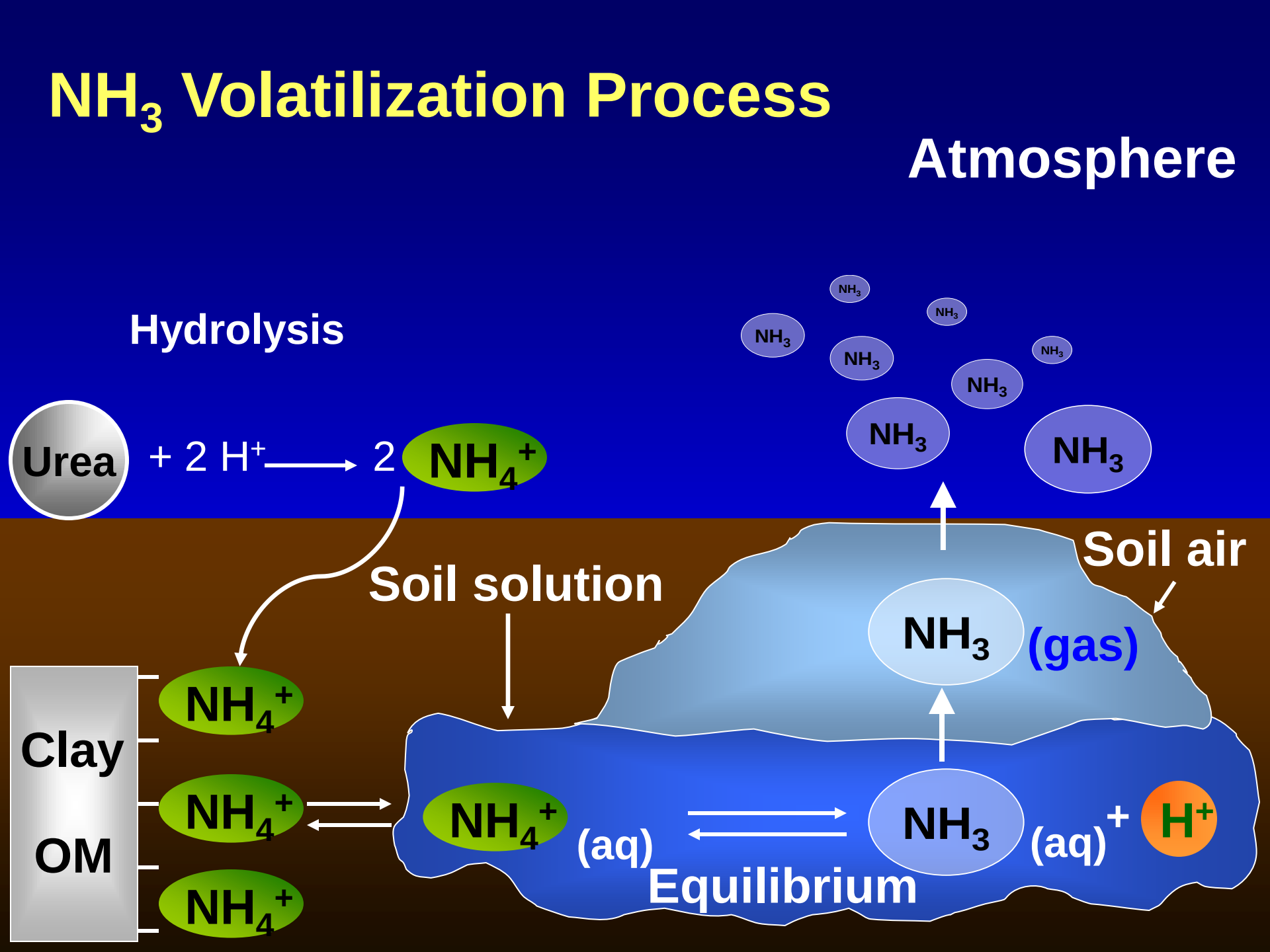
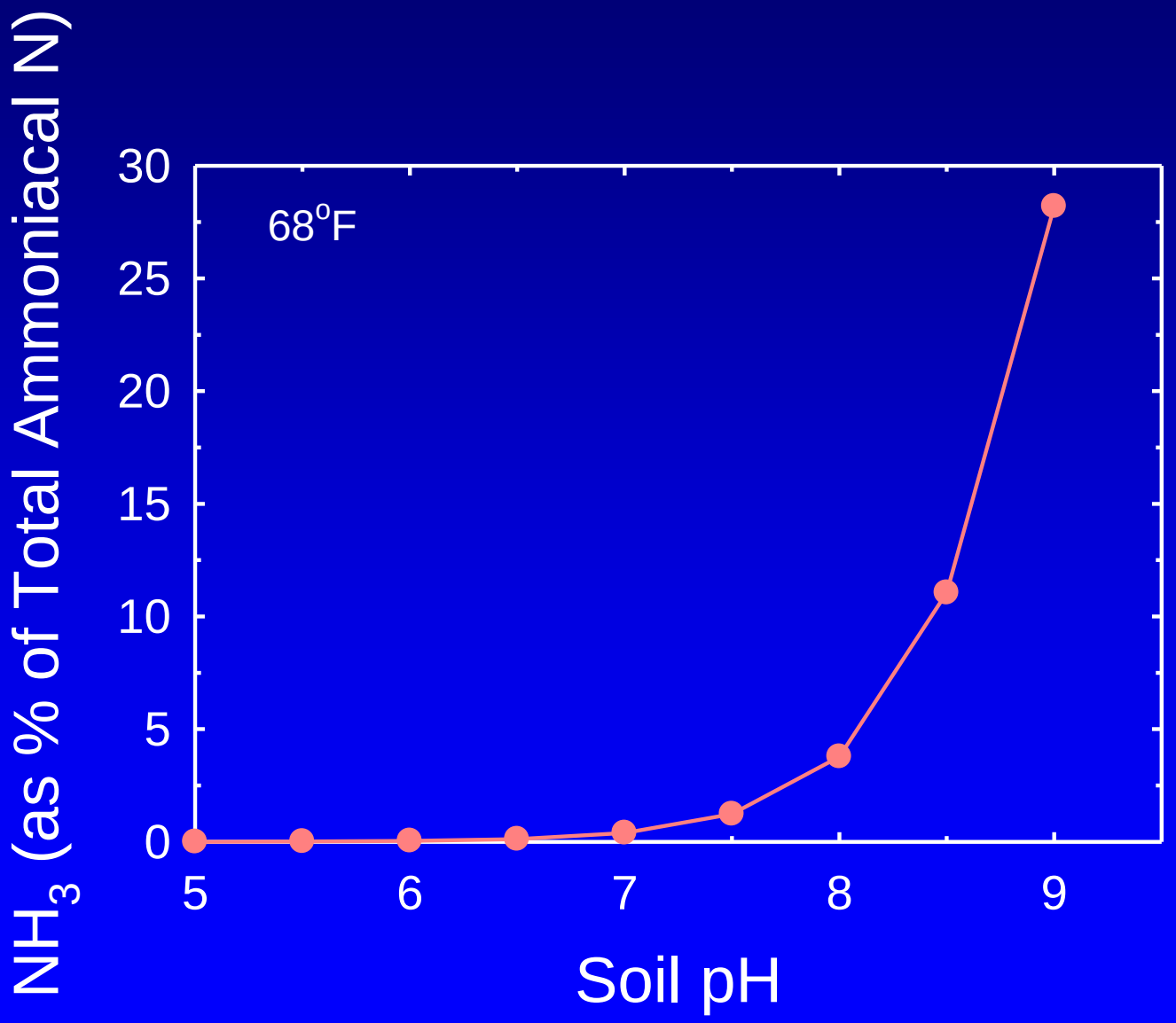
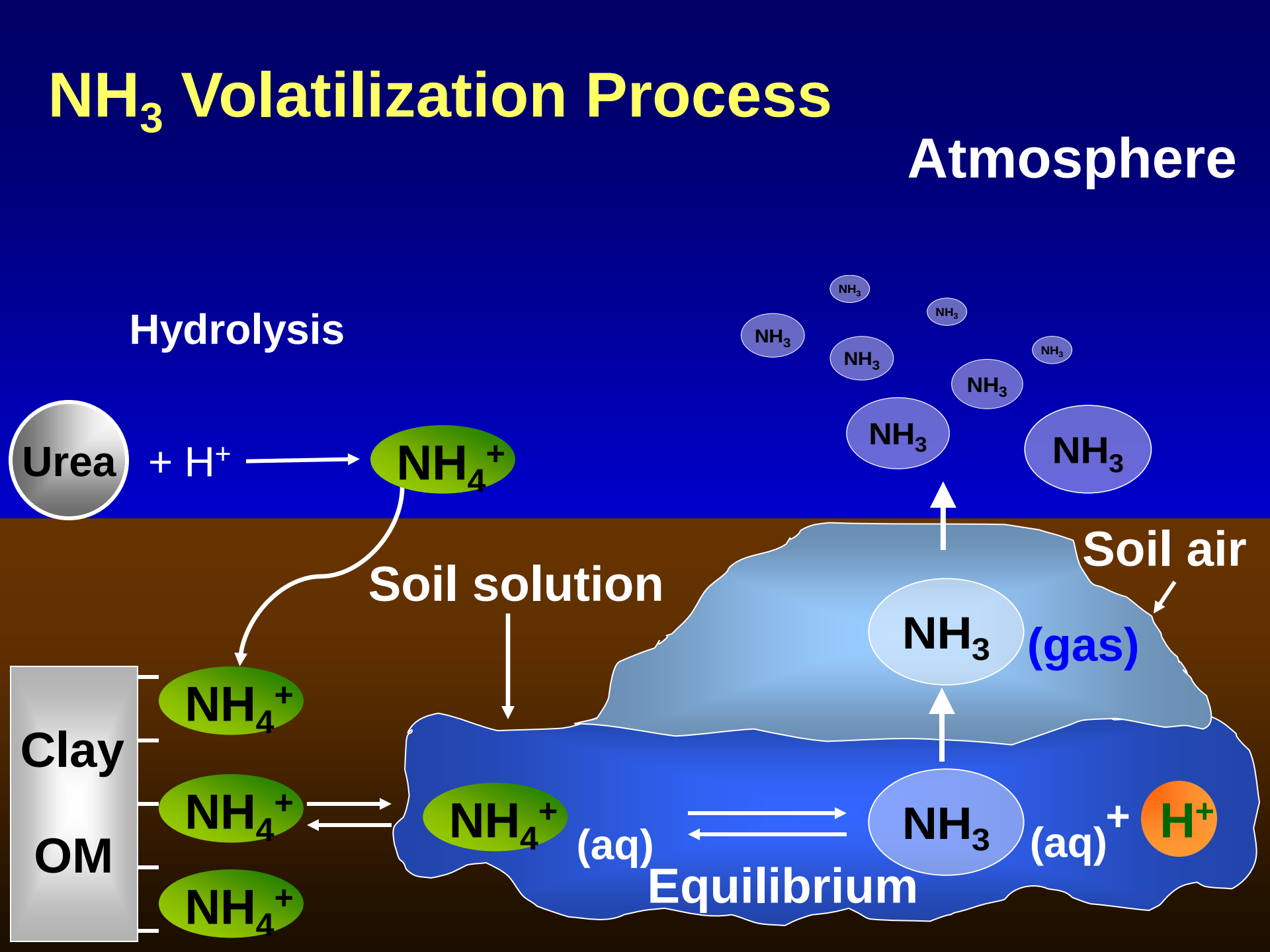
NH_3 Volatilization Process



Effect of soil pH on NH_3 as % of Total N

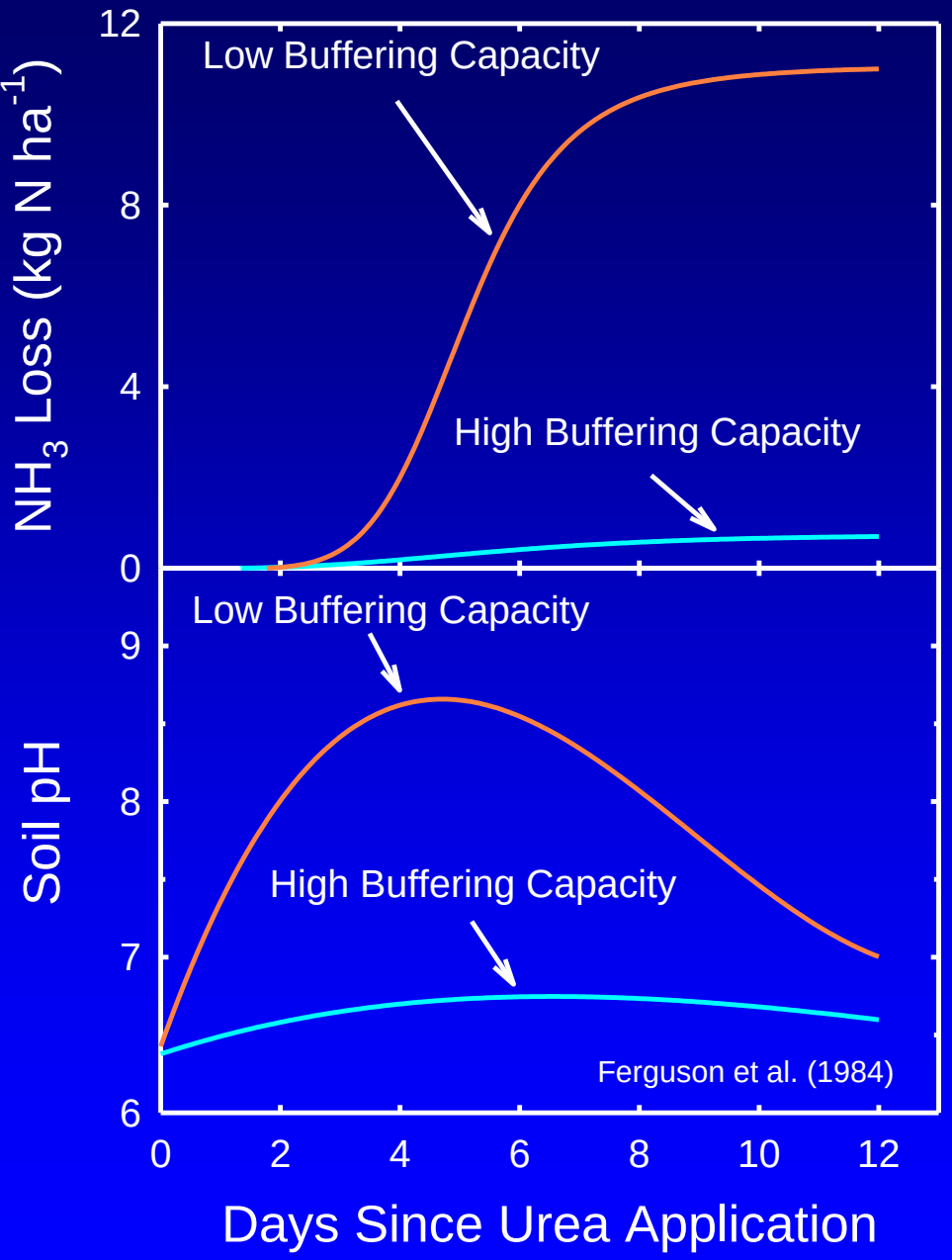


NH_3 Volatilization Process



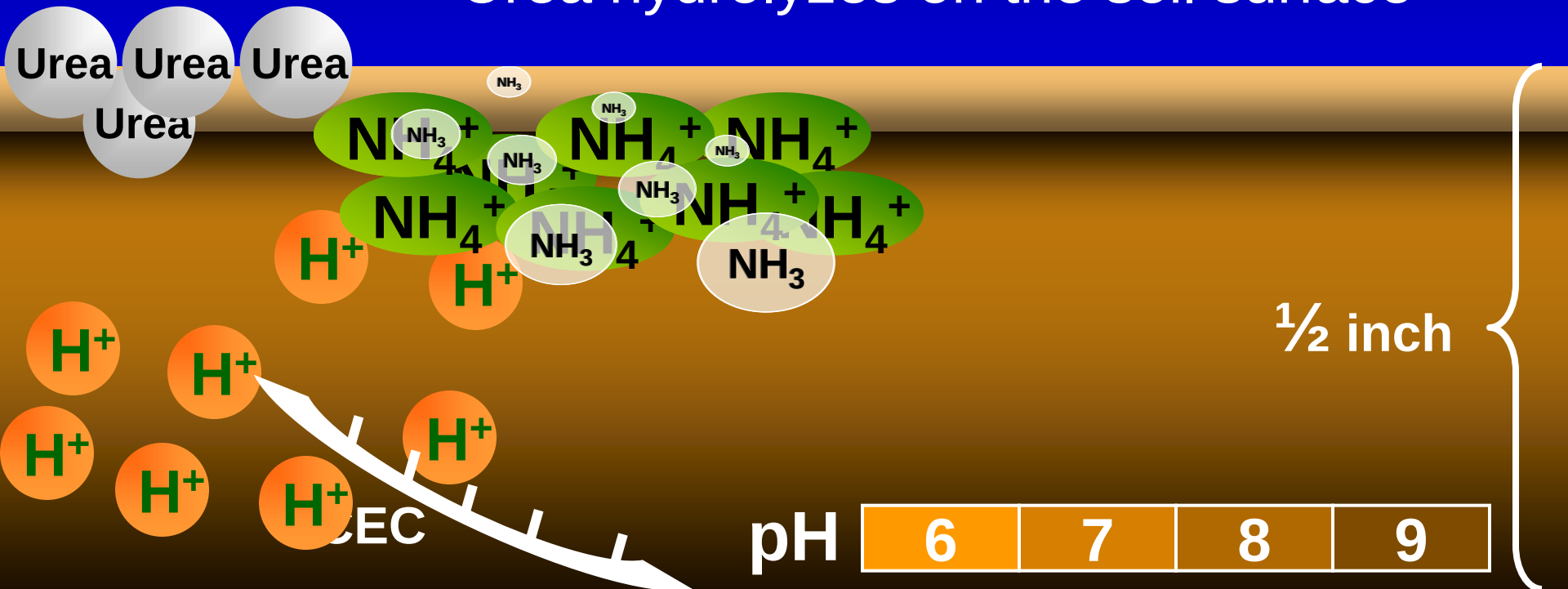
- Increase in soil pH depends on soil H^+ buffering capacity

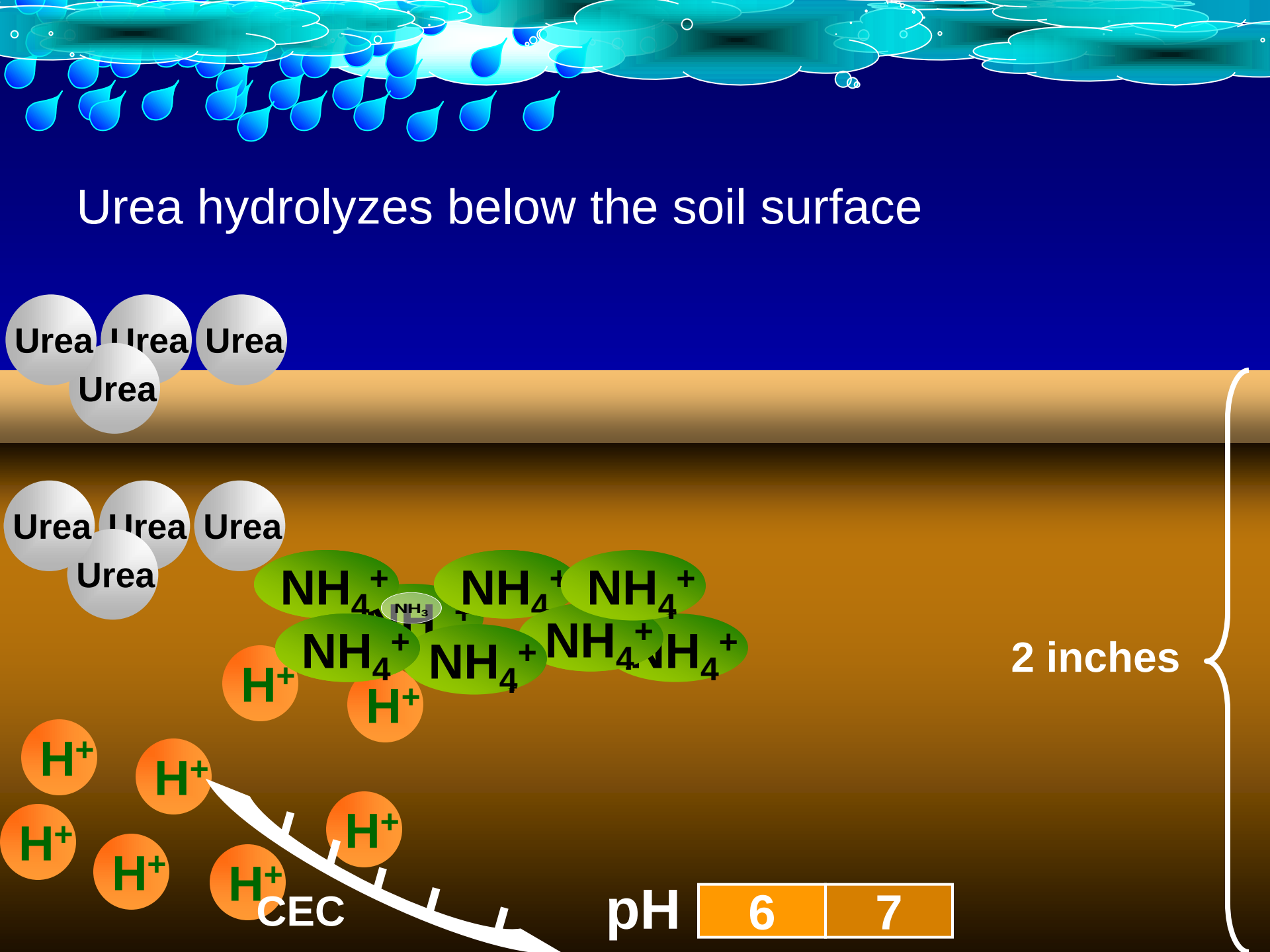
- Higher clay and OM contents lead to higher soil H^+ buffering capacity



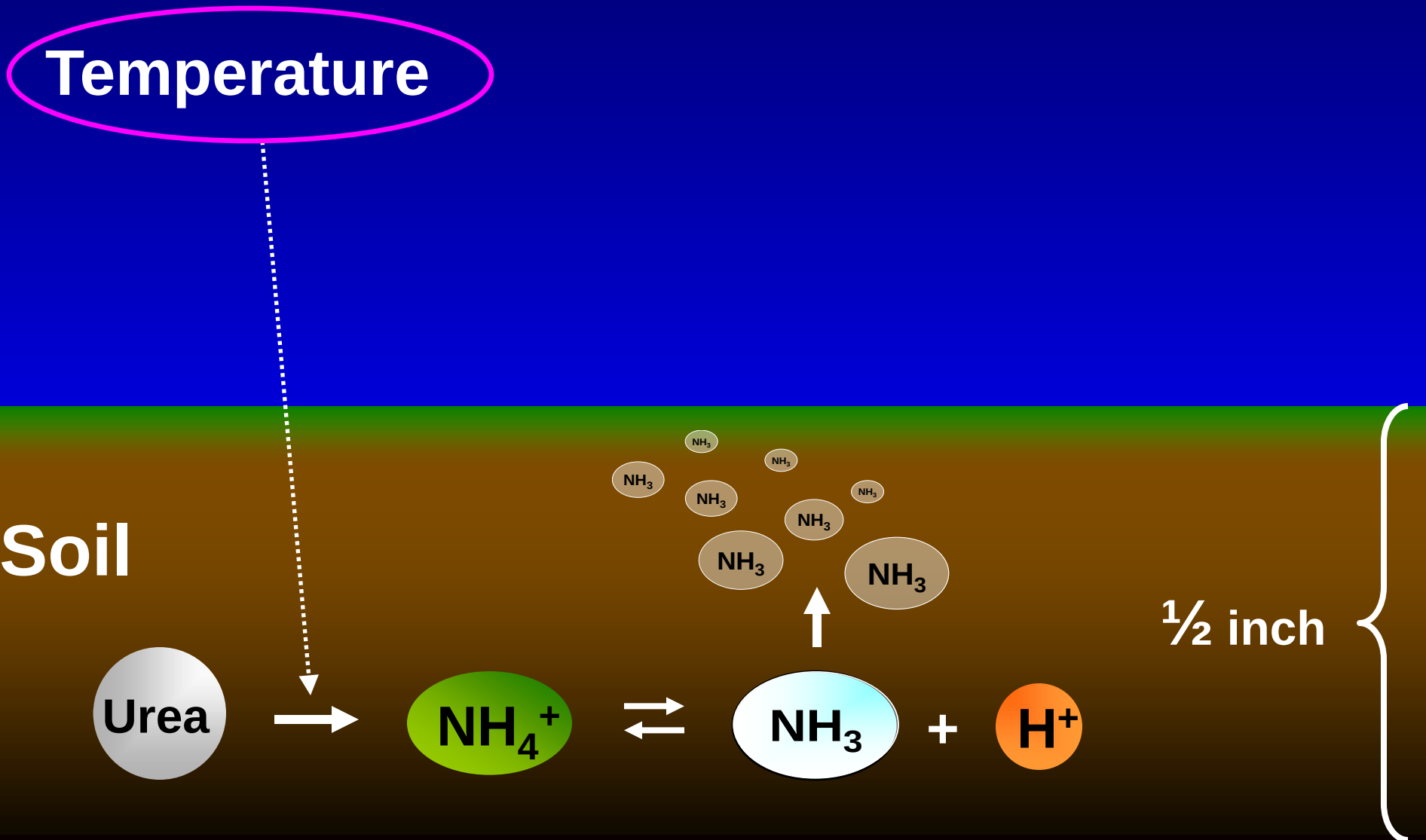
Atmosphere

Urea hydrolyzes on the soil surface

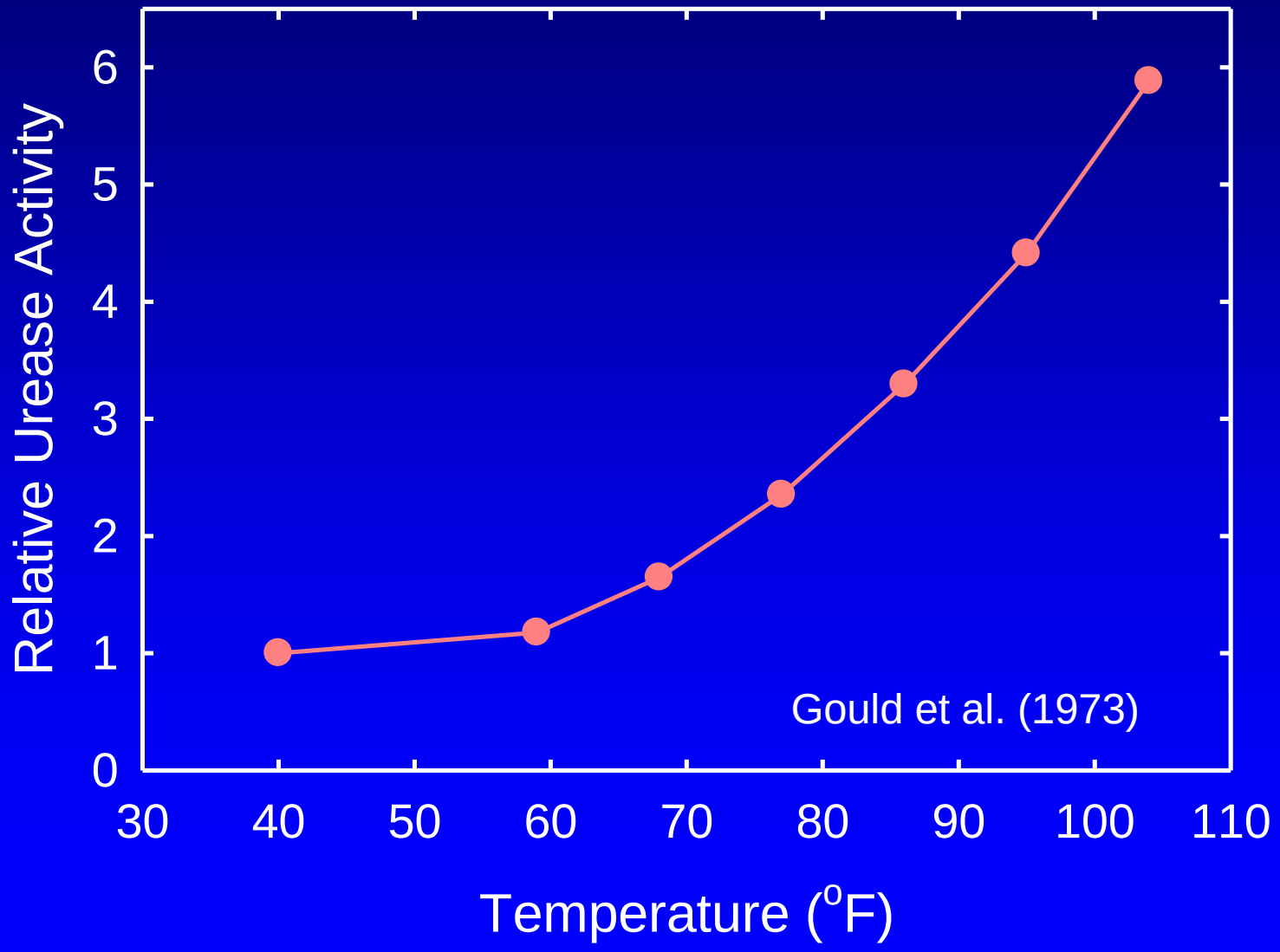



Urea hydrolyzes below the soil surface
Urea
Urea
Urea
Urea
Urea
Urea
Urea
NH_4^+
NH_4^+
NH_4^+
NH_3
NH_4^+
NH_4^+
NH_4^+
NH_4^+
H^+
H^+
H^+
H^+
H^+
H^+
H^+
H^+
2 inches
CEC
pH
6
7

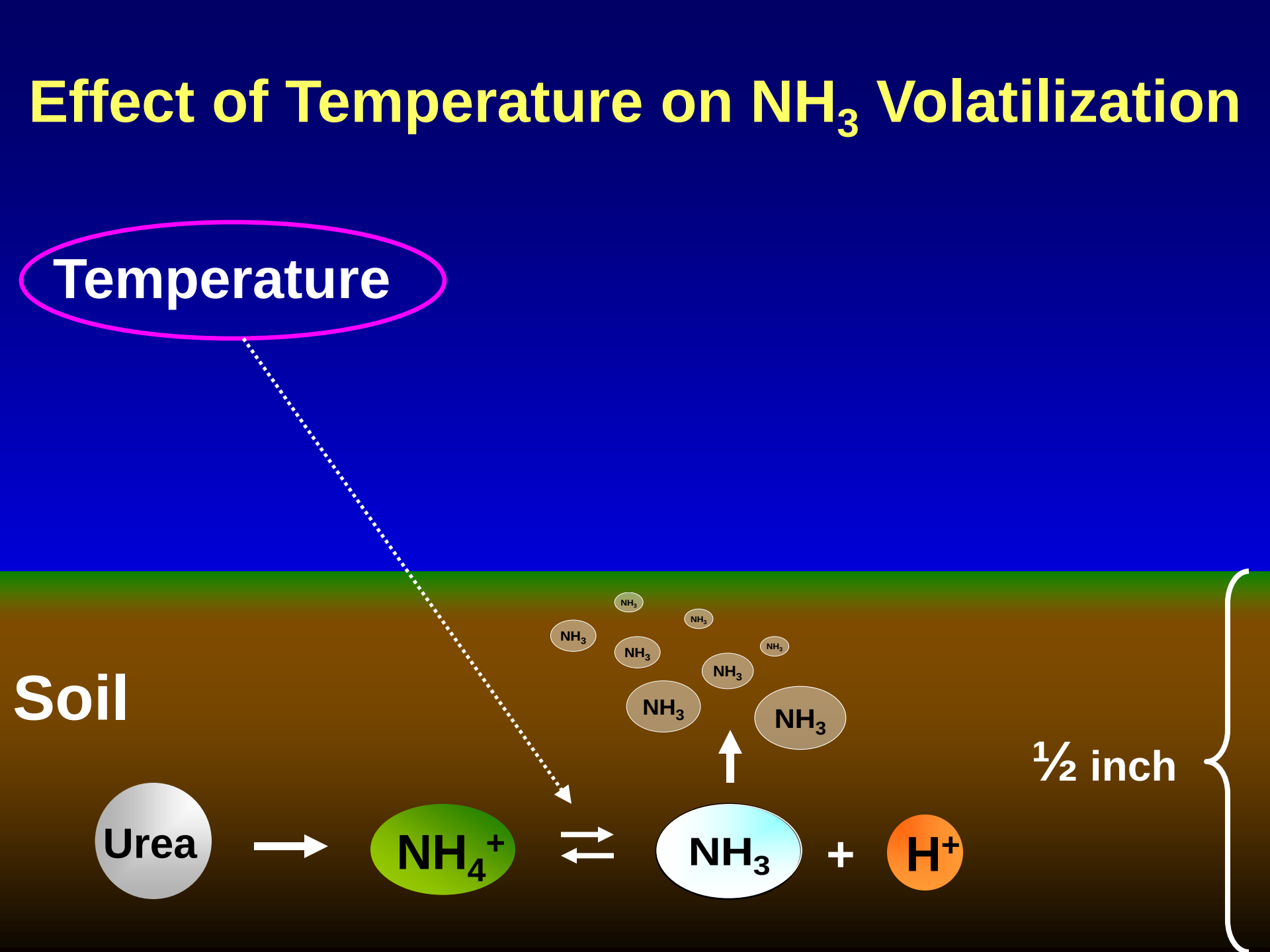
Effect of Temperature on NH_3 Volatilization



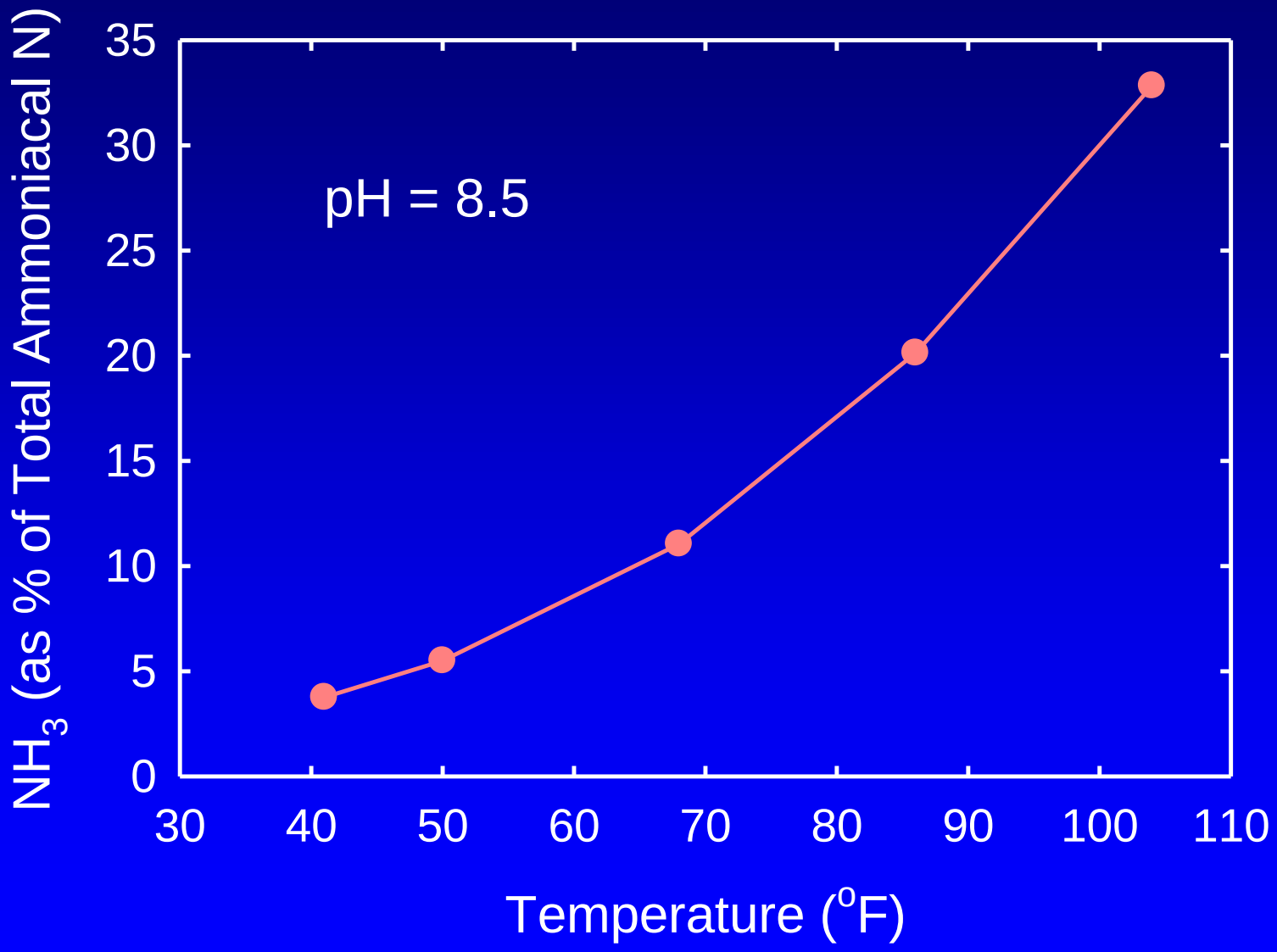
Effect of Temperature on Urea Hydrolysis



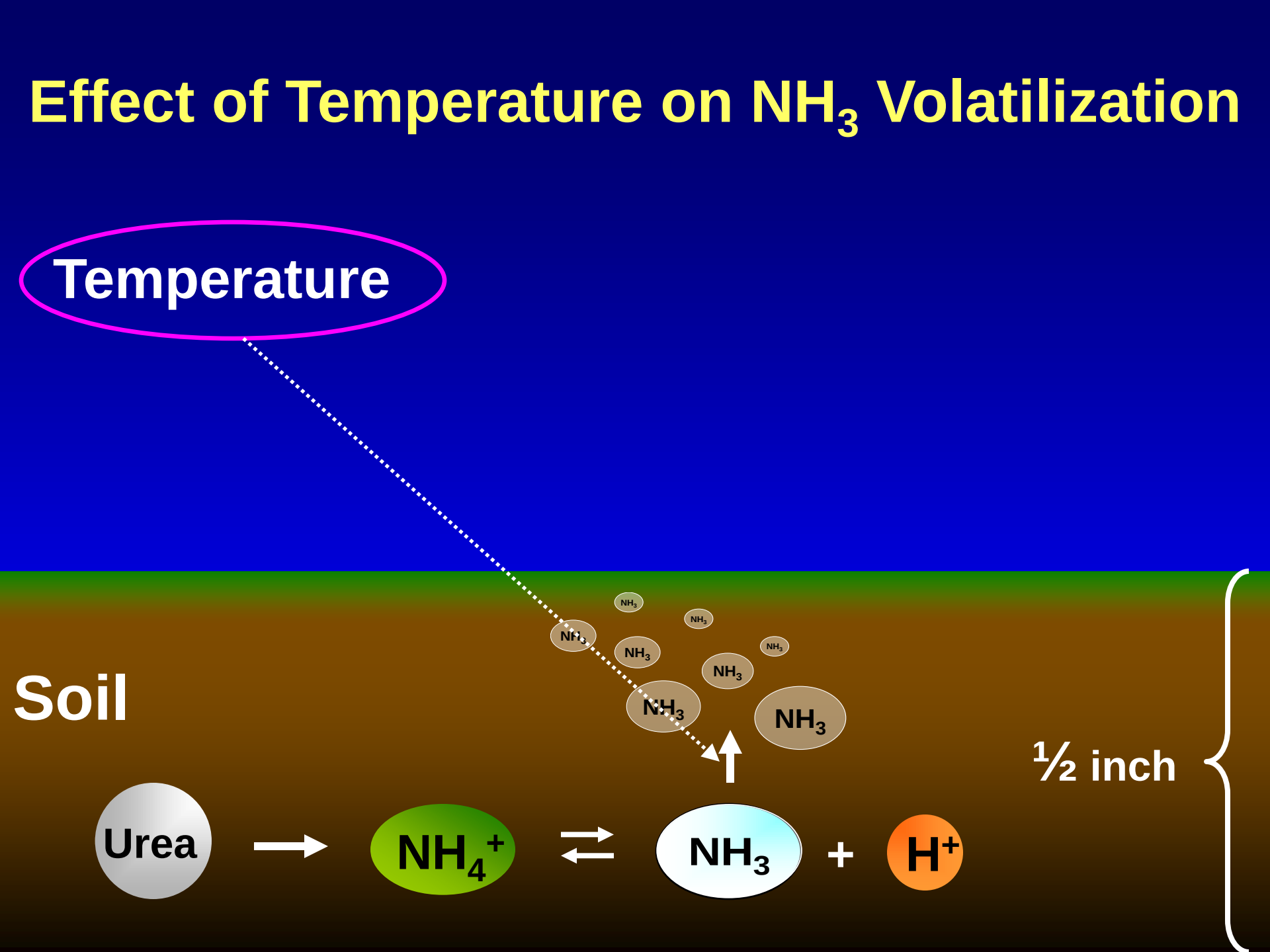
Effect of Temperature on NH_3 Volatilization



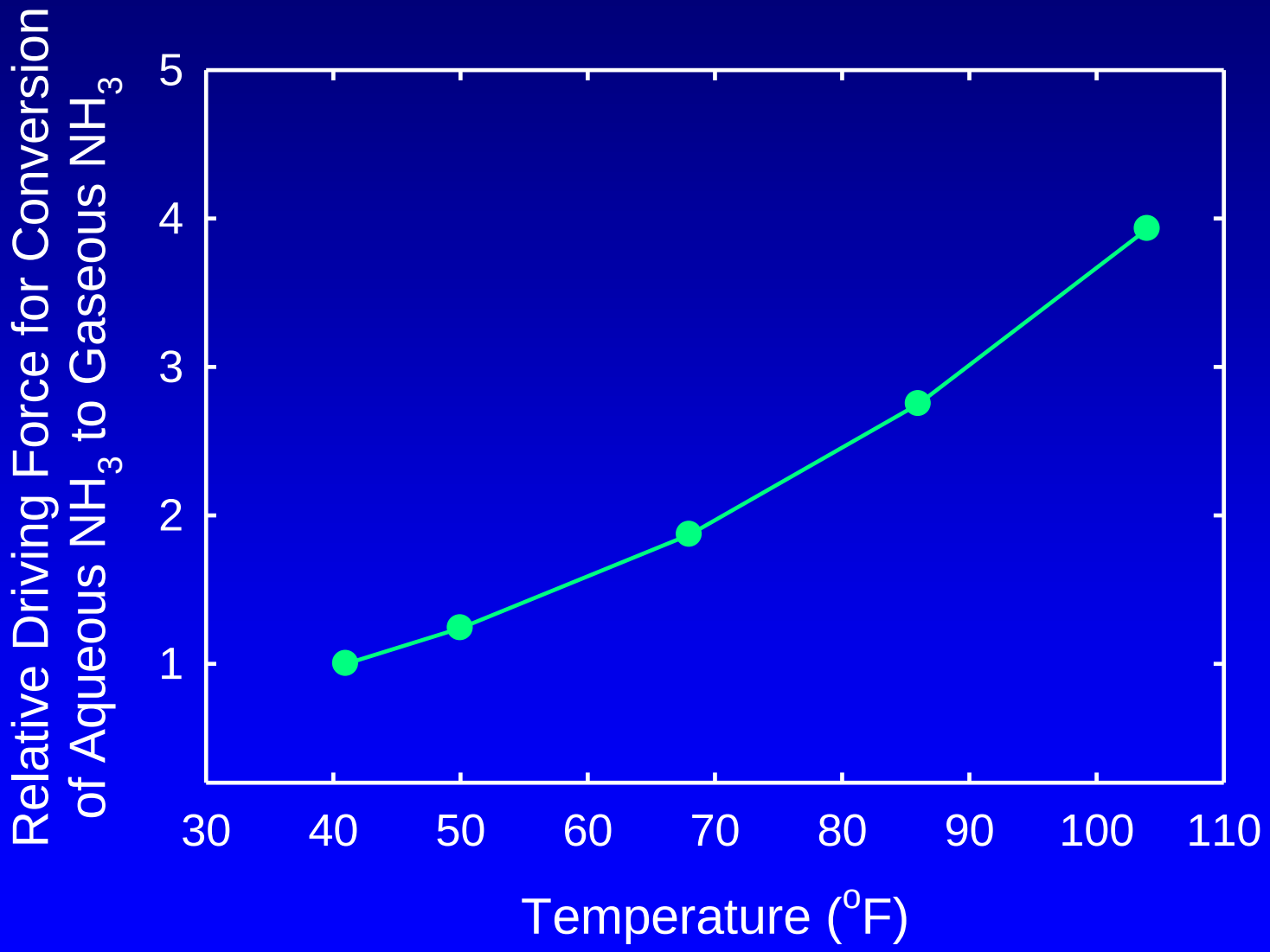
Effect of Temperature on % of NH_3



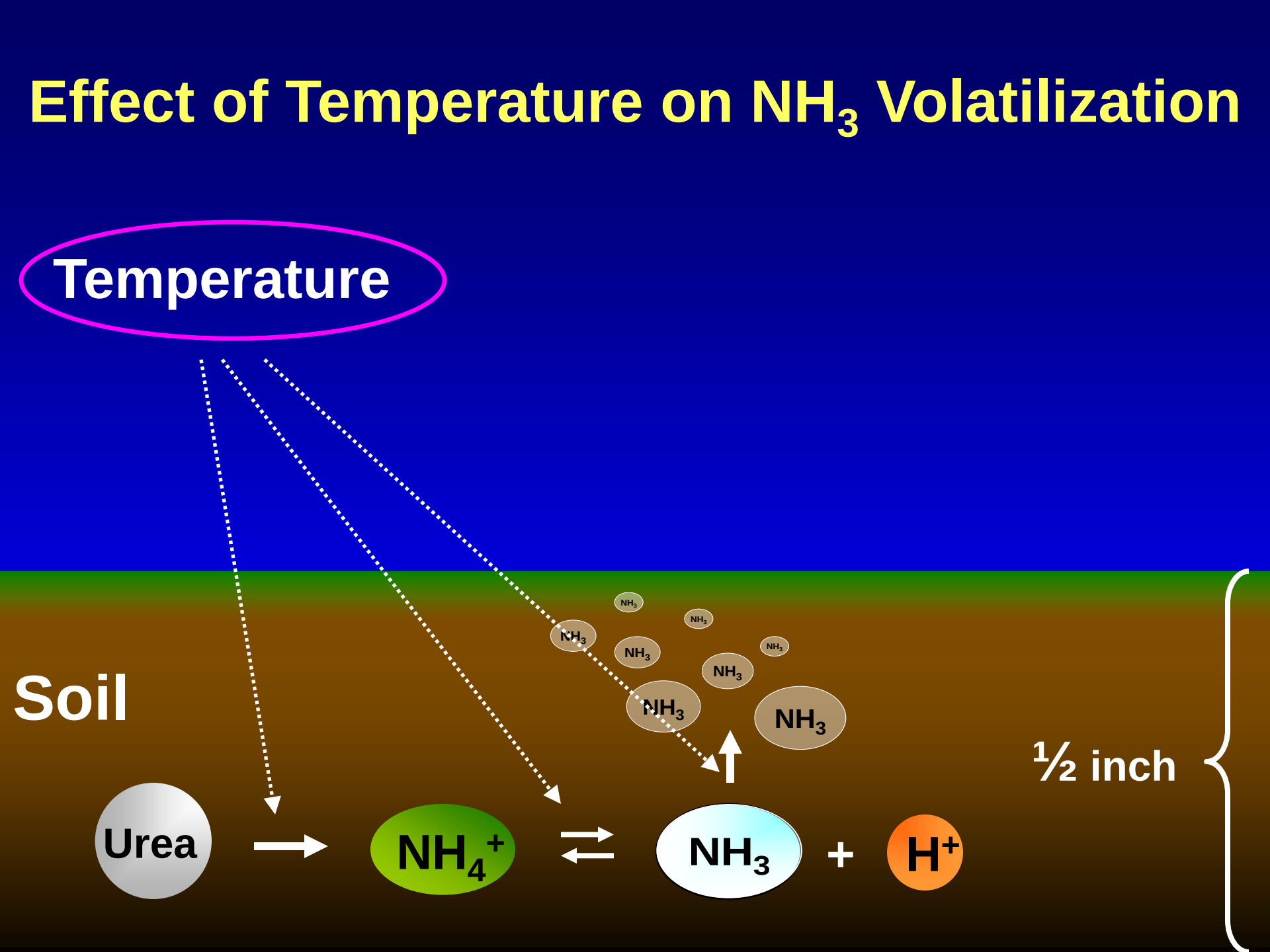
Effect of Temperature on NH_3 Volatilization



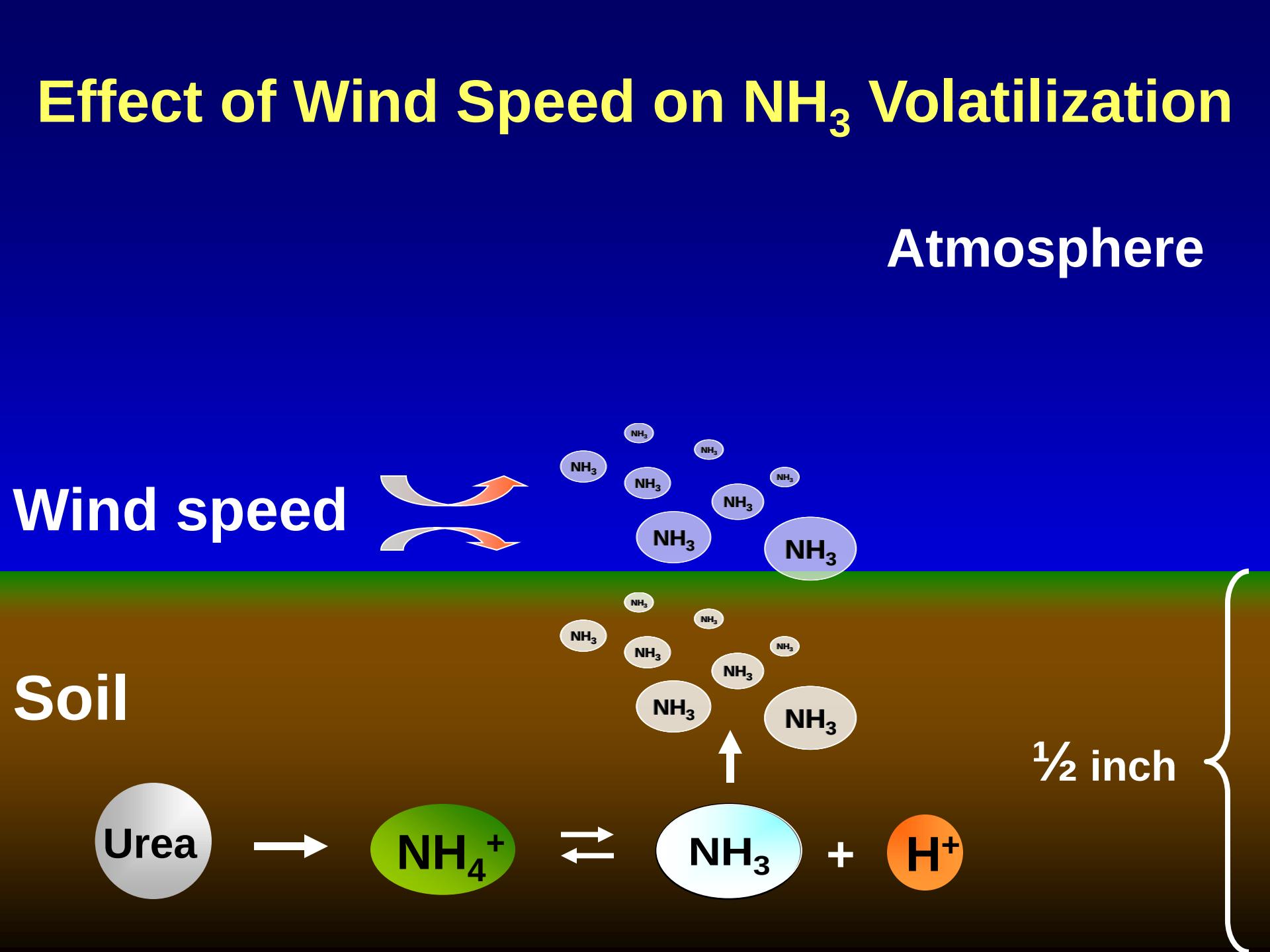
Effect of Temperature on Conversion of Aqueous NH_3 to Gaseous NH_3

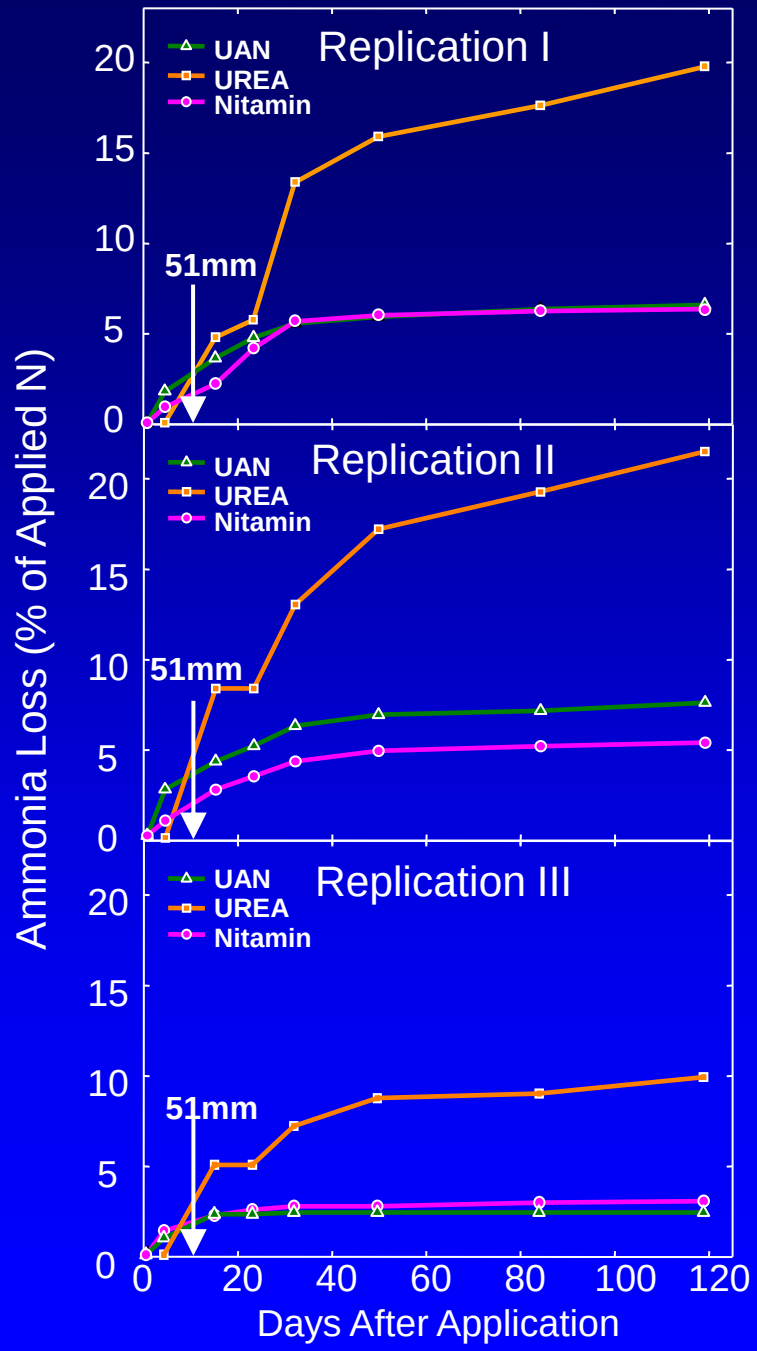


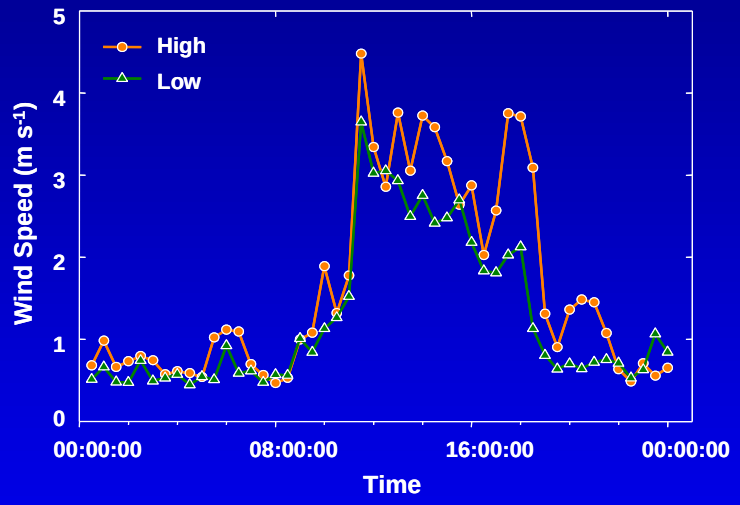
Effect of Temperature on NH_3 Volatilization



Effect of Wind Speed on NH_3 Volatilization




Replication I
Replication II
Replication III
UAN
UREA
Nitamin
51mm
Ammonia Loss (% of Applied N)
Days After Application
0
5
10
15
20
0
20
40
60
80
100
120


High
Low
Wind Speed (m s-1)
Time
0
1
2
3
4
5
00:00:00
08:00:00
16:00:00
00:00:00

Optimum Conditions for Volatilization

- Small diffusion depth into soil
- RH > CRH
- High temperature
- High wind speed
- Low pH buffering capacity

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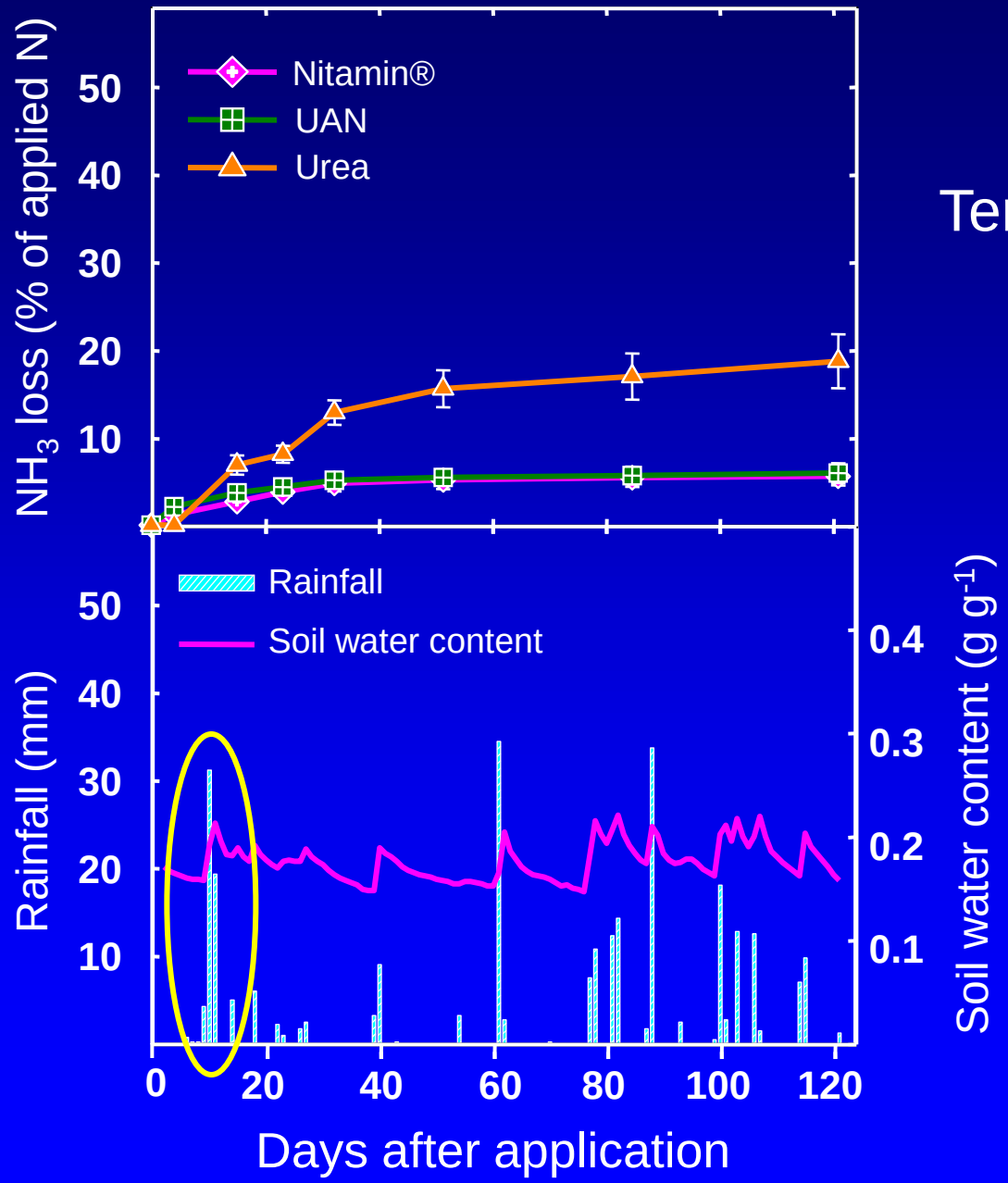
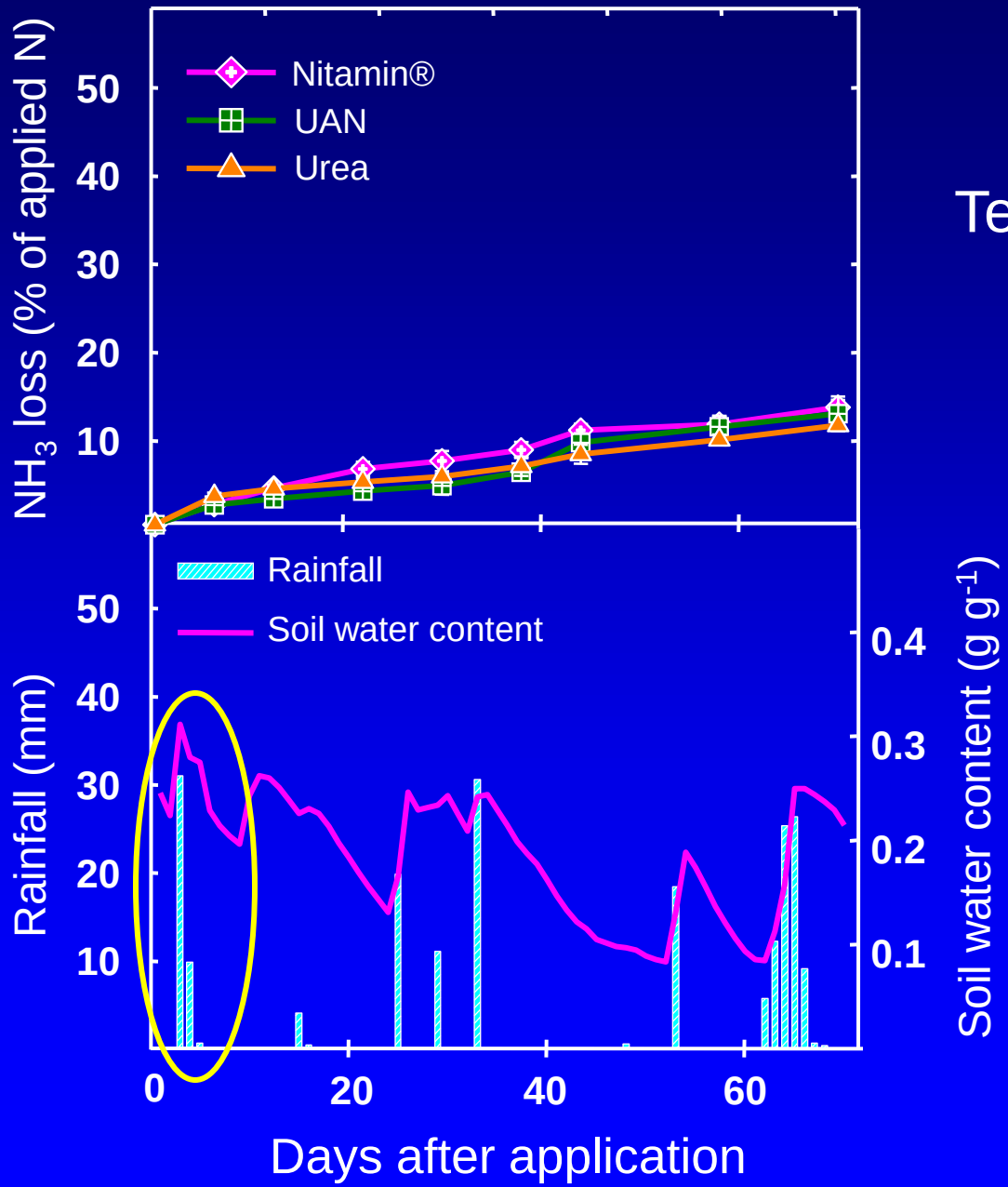
Urea Applied to Pasture - Fall 2004

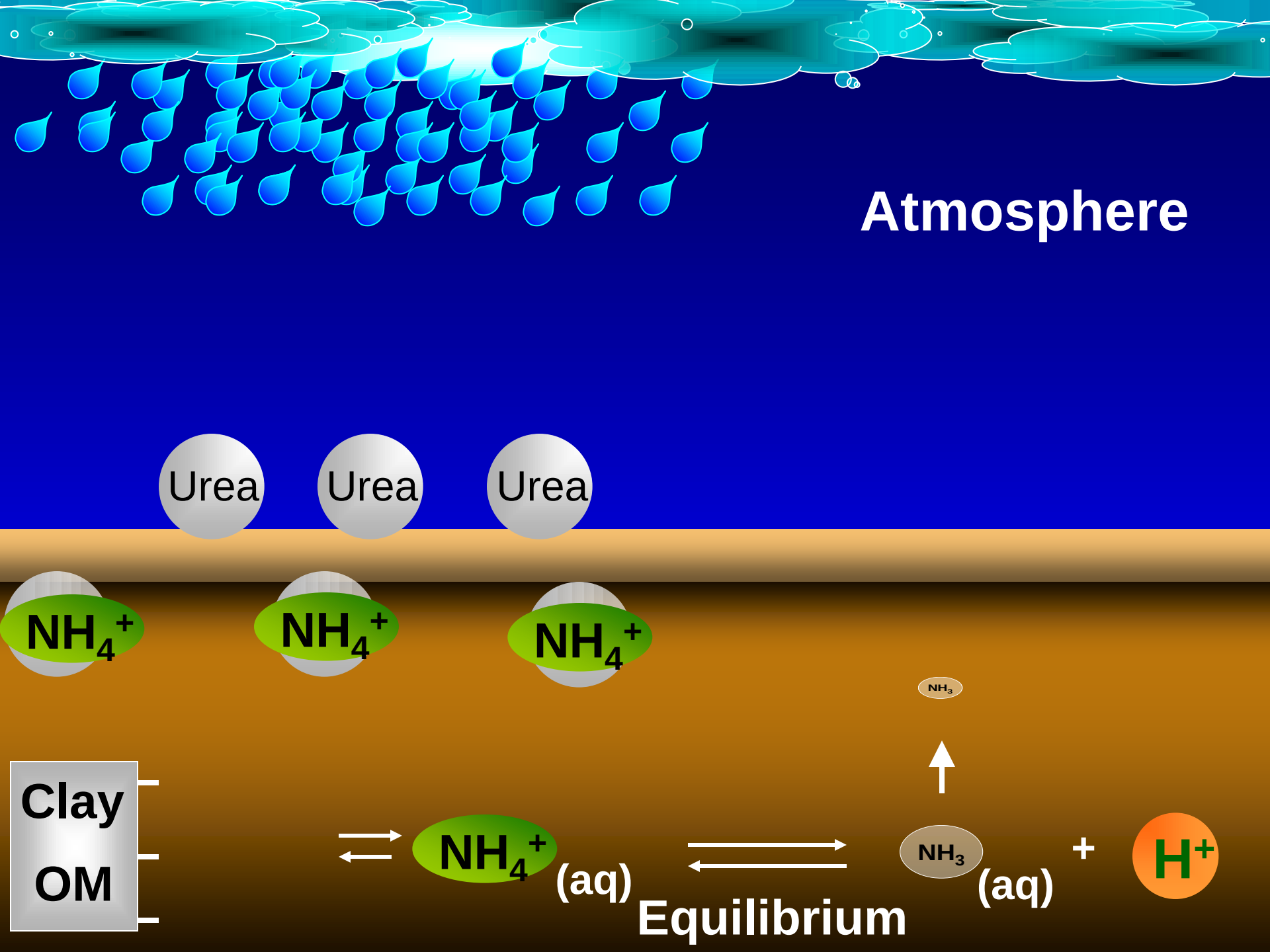


Temp = 47°F

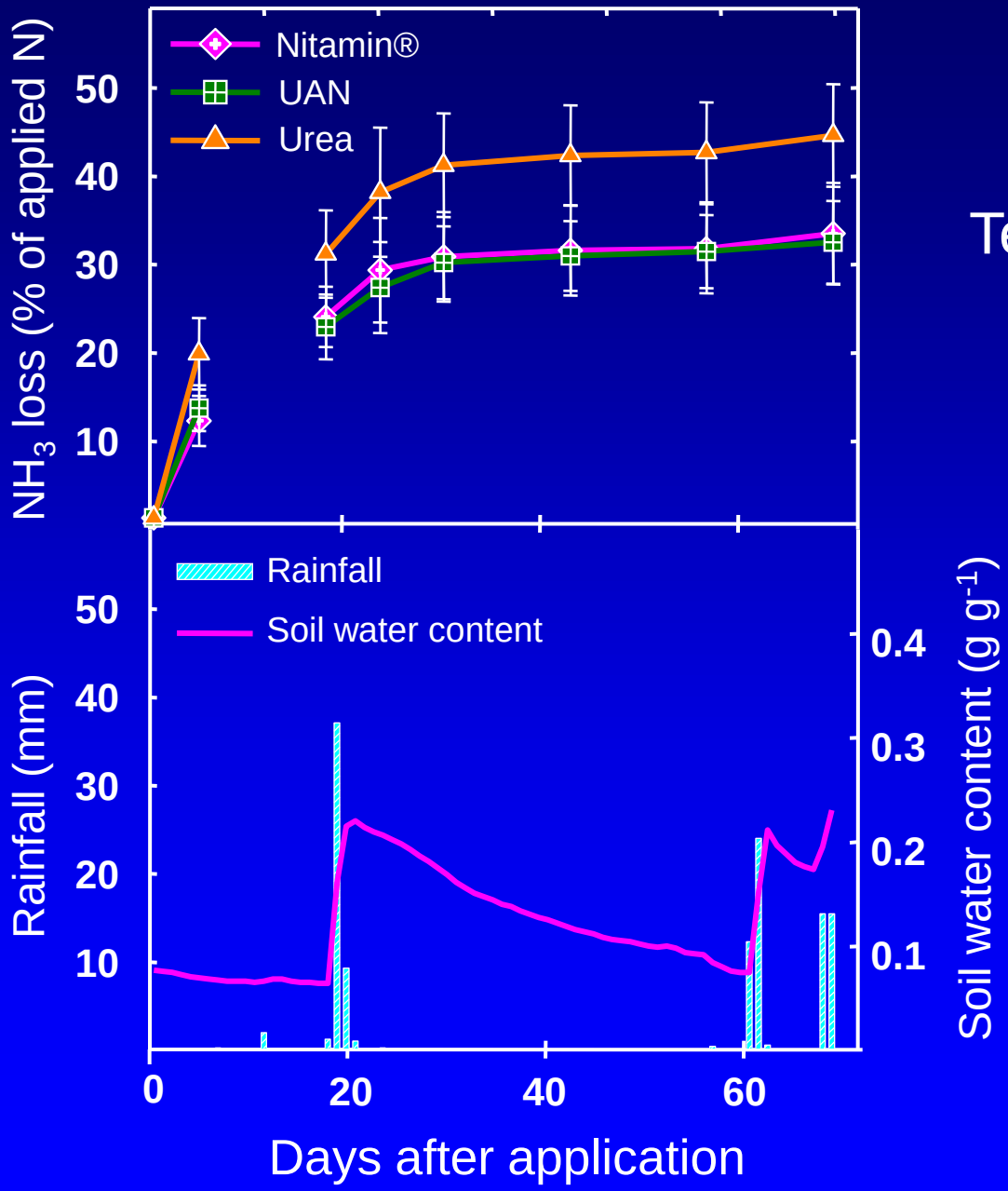
Urea Applied to Pasture – Spring 2005



Temp = 63°F

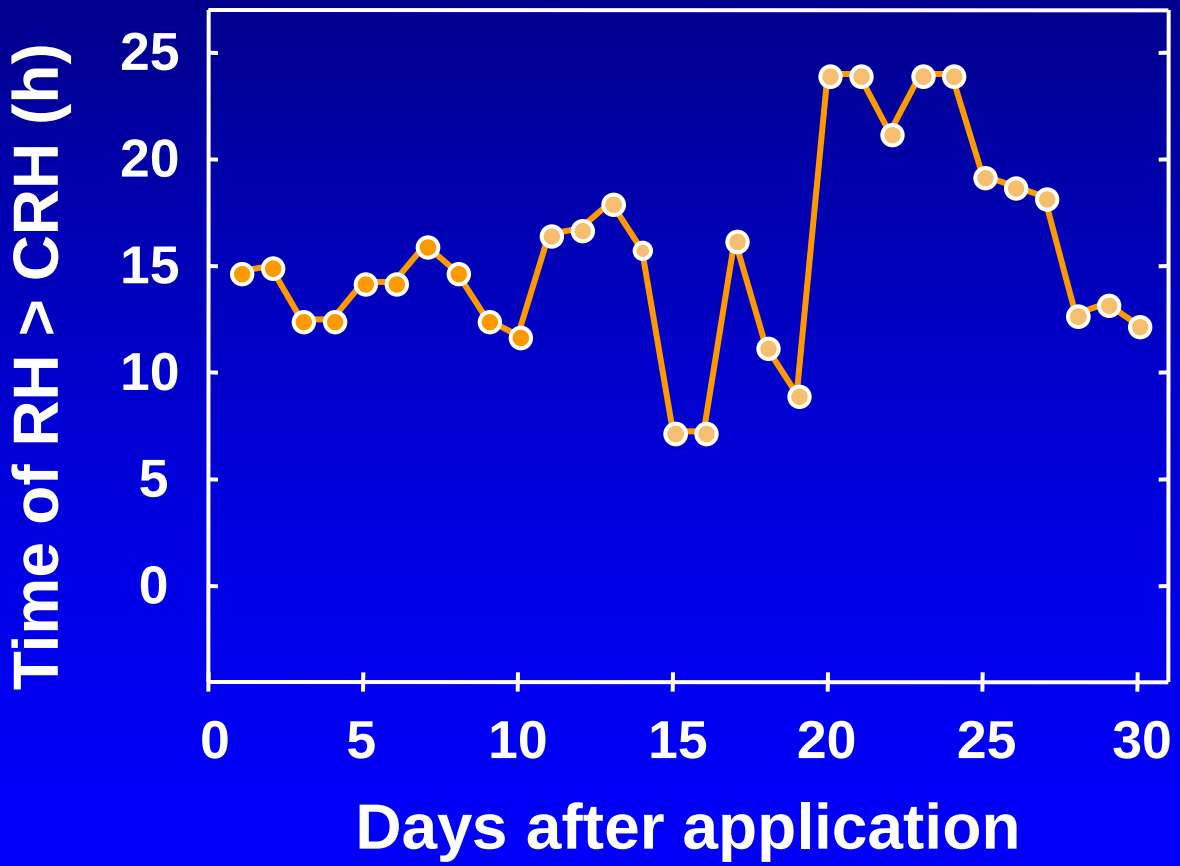

Atmosphere
Urea
Urea
Urea
NH_4^+
NH_4^+
NH_4^+
NH_3
Clay
OM
NH_4^+ (aq)
Equilibrium
NH_3 (aq)
+
H^+

Urea Applied to Pasture - Fall 2005



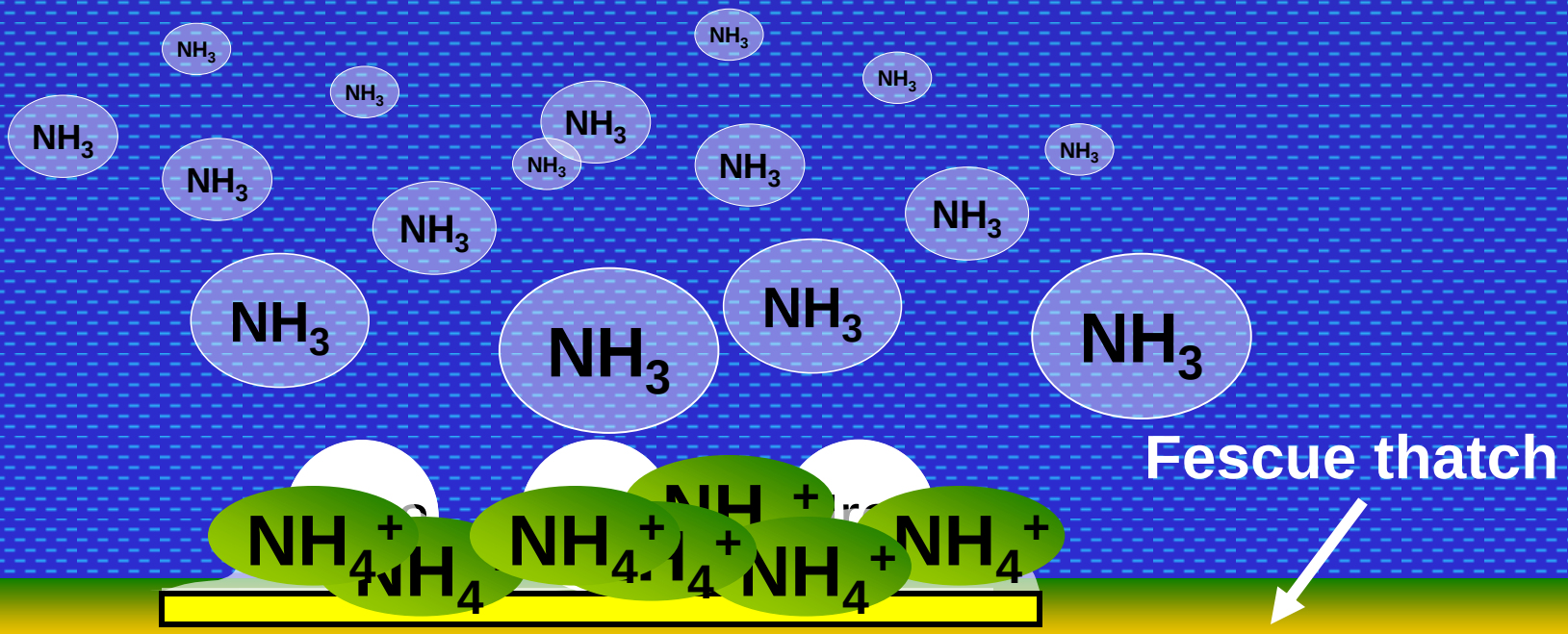
Temp = 62°F

Time of RH above CRH in the first 30 d



Total: RH > CRH = 193 hours

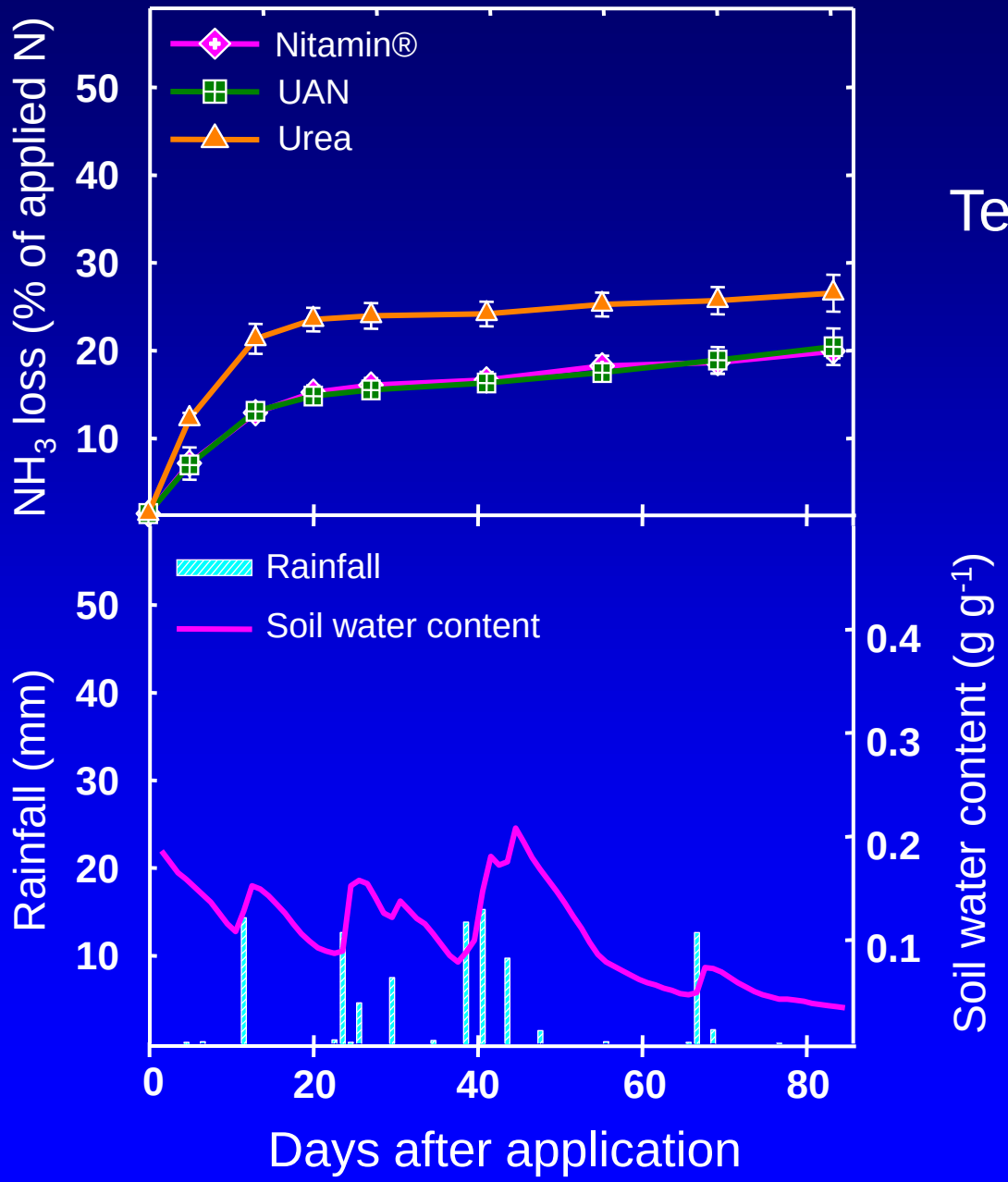
Atmosphere



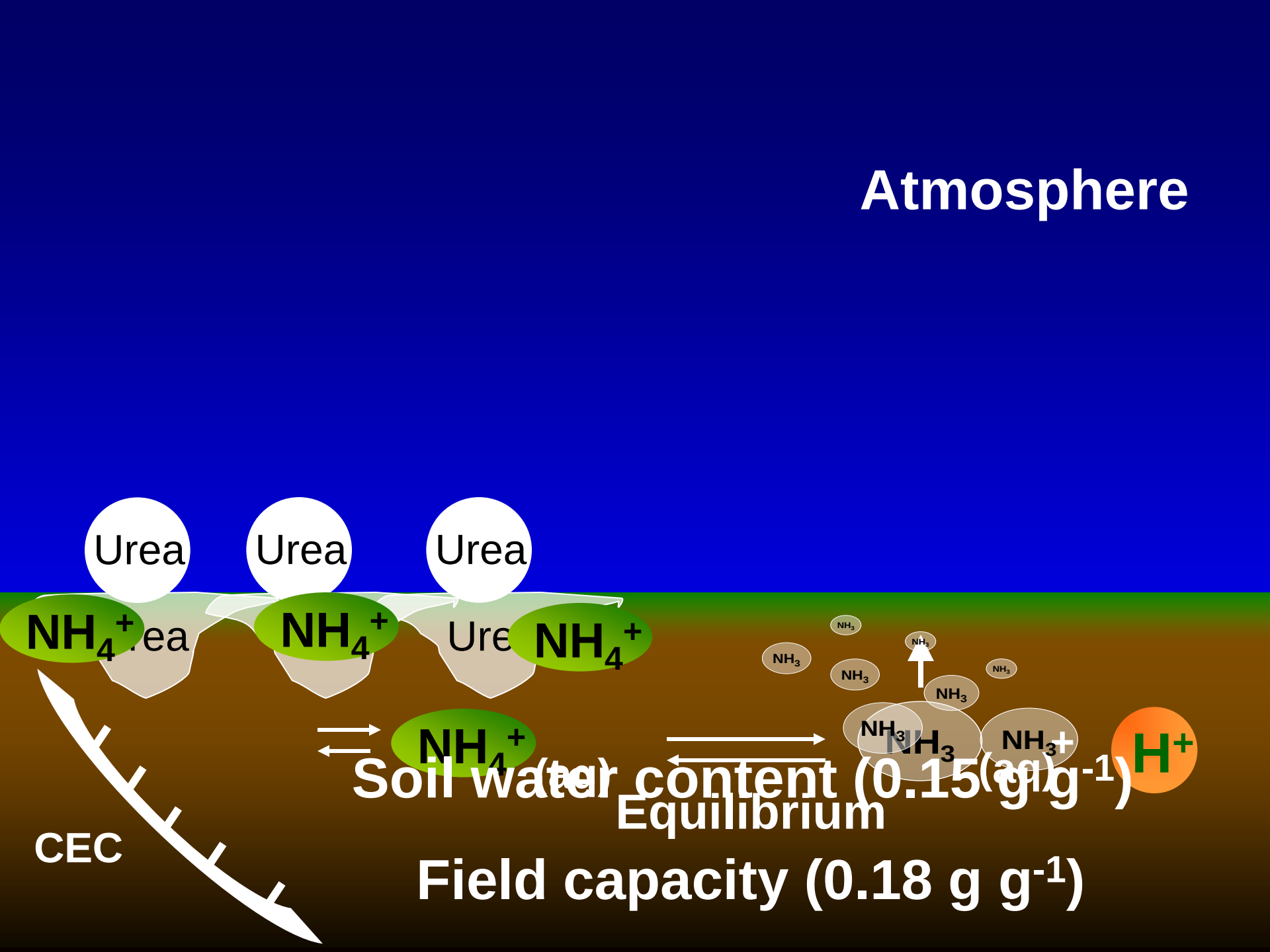
Soil water content (0.07 g g^{-1})

Permanent wilting point (0.04 g g^{-1})

Urea Applied to Pasture – Spring 2006



Temp = 69°F


Atmosphere
Urea
Urea
Urea
NH_4^+
NH_4^+
NH_4^+
NH_4^+
NH_3
NH_3
NH_3
NH_3
NH_3
NH_3
NH_3
H^+
CEC
Soil water content (0.15 g g-1)
Equilibrium
Field capacity (0.18 g g-1)

Summary of Pasture Results

Ammonia volatilization losses under field conditions

Fertilizer	Fall 2004	Spring 2005	Fall 2005	Spring 2006
	---------- Ammonia loss (% of applied N) ----------			
Urea	19 a*	12 a	46 a	24 a
UAN	6 b	13 a	33 b	18 a
Nitamin®	6 b	14 a	34 b	18 a

•Within a column, values followed by the same letter are not significantly different according to Fisher's LSD at p=0.05

Summary for Pastures/No-Till

Dry Soil, Dry Residue, RH < CRH: OK

Dry Soil, Dry Residue, RH > CRH: not OK

Wet Soil, Wet Residue: not OK

- Apply on dry soil, dry residue, expected low RH, and hope for 1 inch of rain whenever it rains.

- Apply on wet soil if 1 inch rain/irrigation is expected.

Summary for Clean-Till Crops

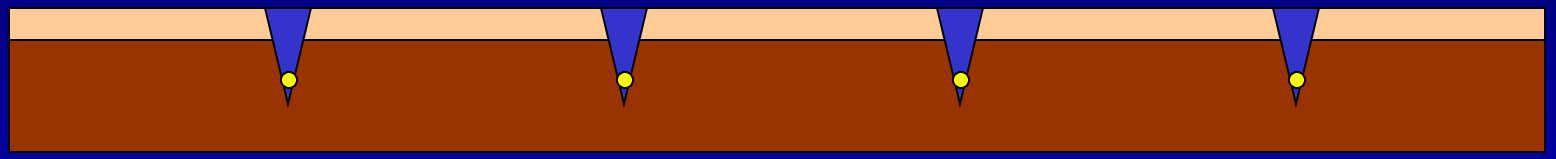
Dry Soil: OK

Wet Soil: not OK

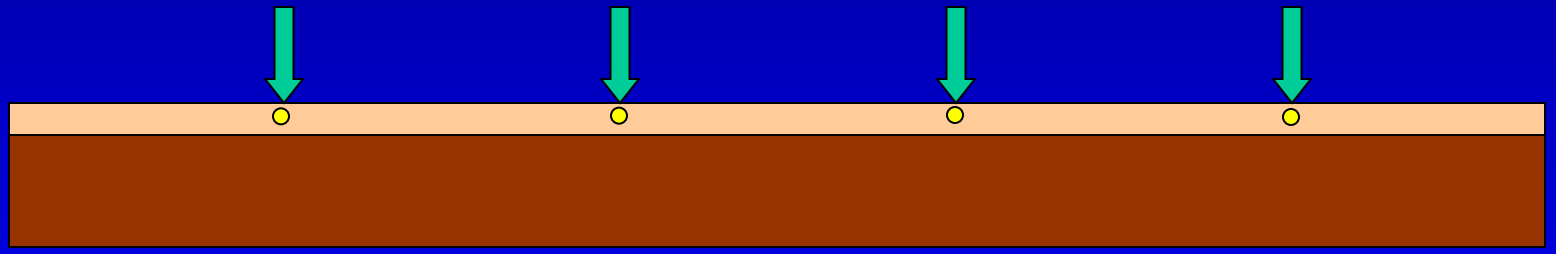
- Apply on dry soil and hope for 1 inch of rain whenever it rains.
- Apply on wet soil if 1 inch of rain/irrigation is expected.

Summary for Pastures/Crops

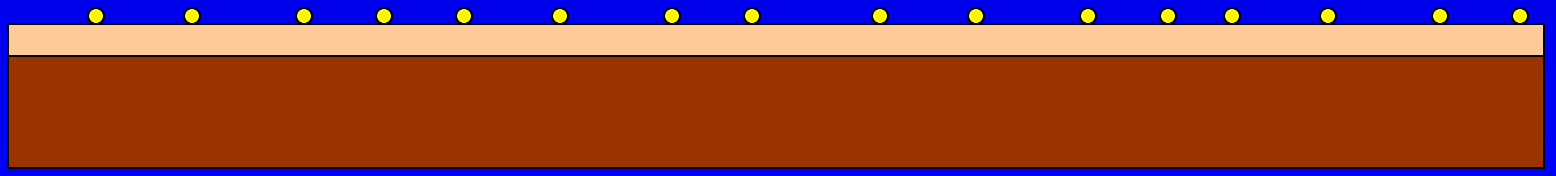
Knifed or disked in



Dribbled



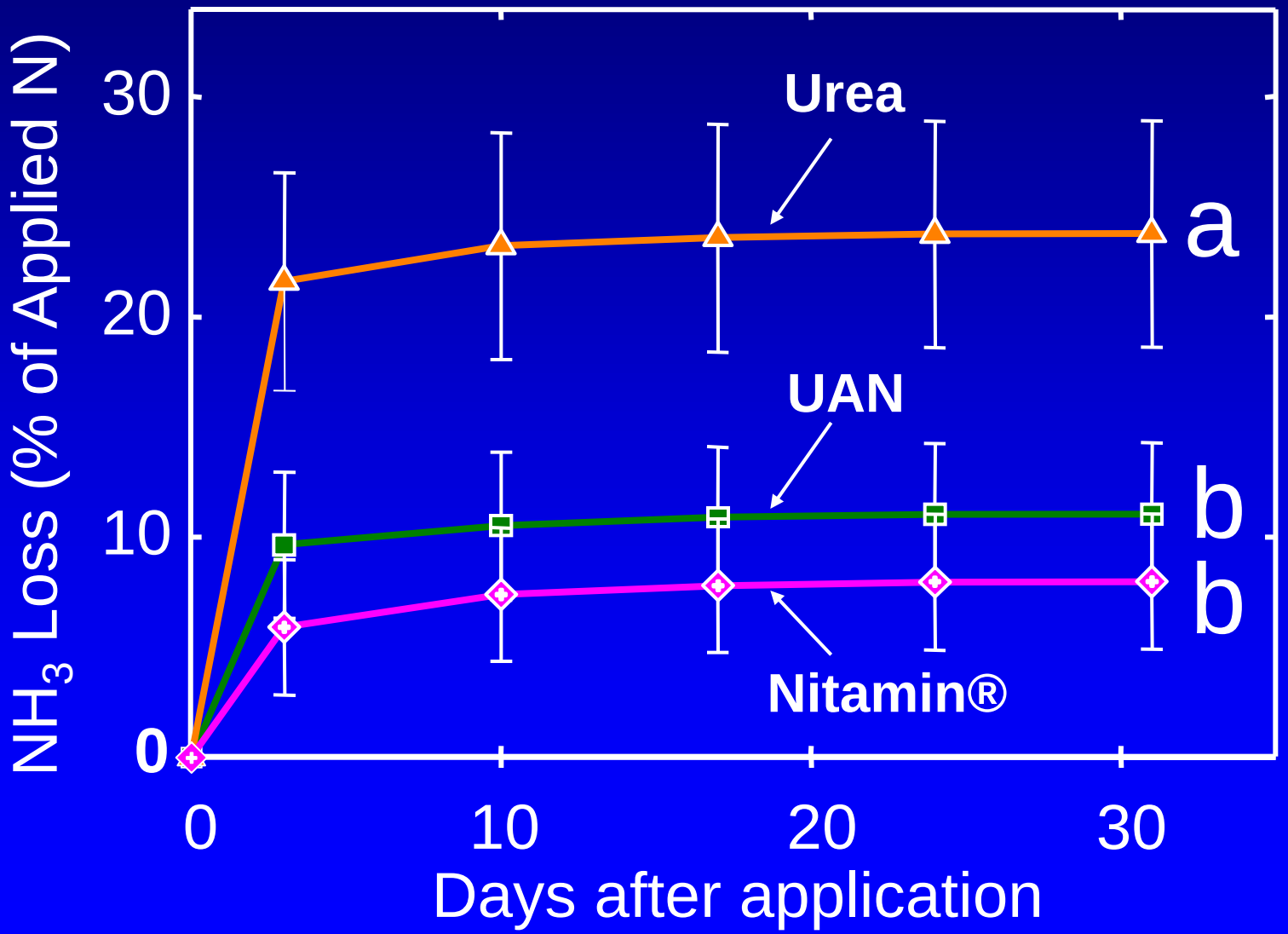
Broadcast



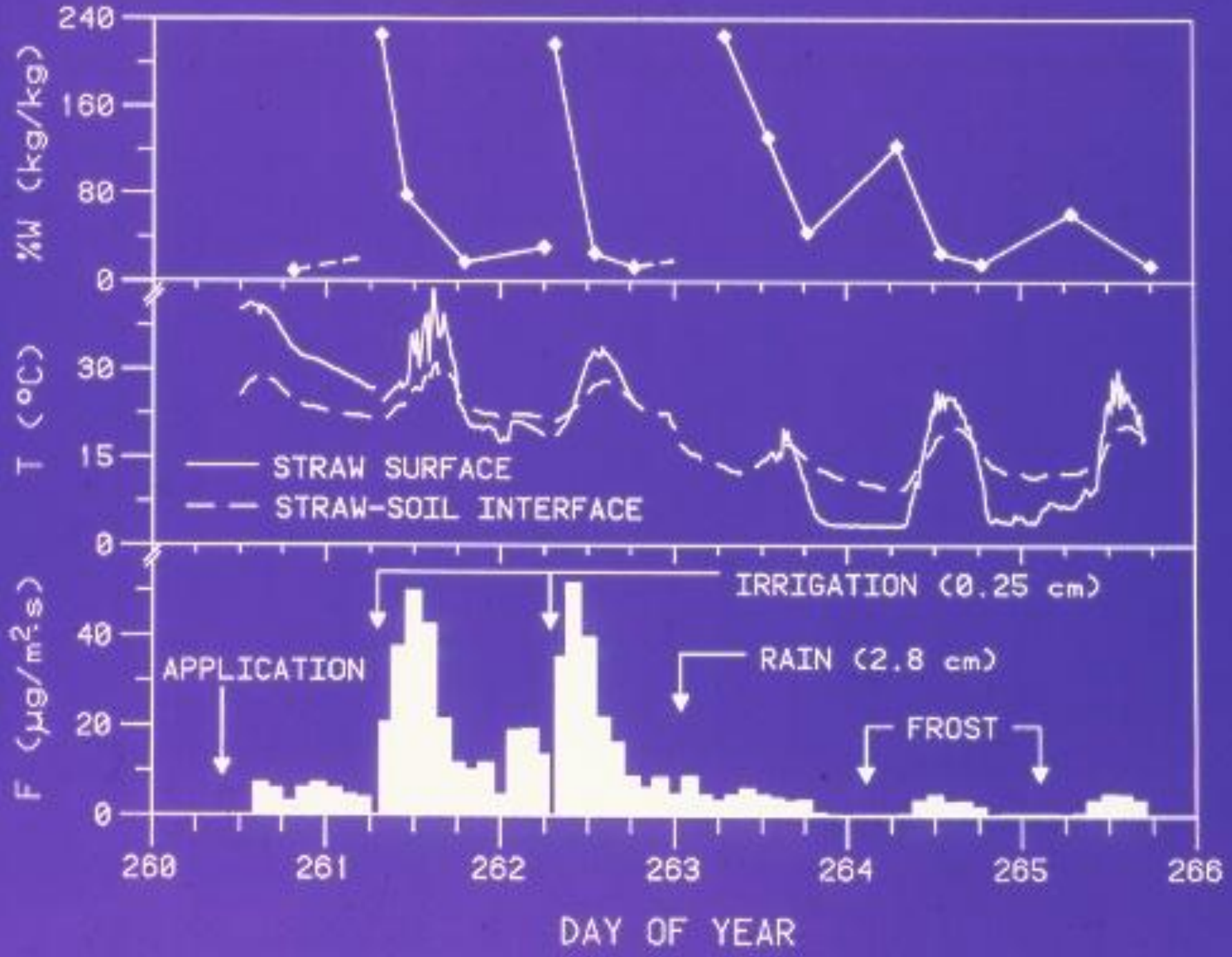
- Knifed or disked in better than Dribbled
- Dribbled better than Broadcast

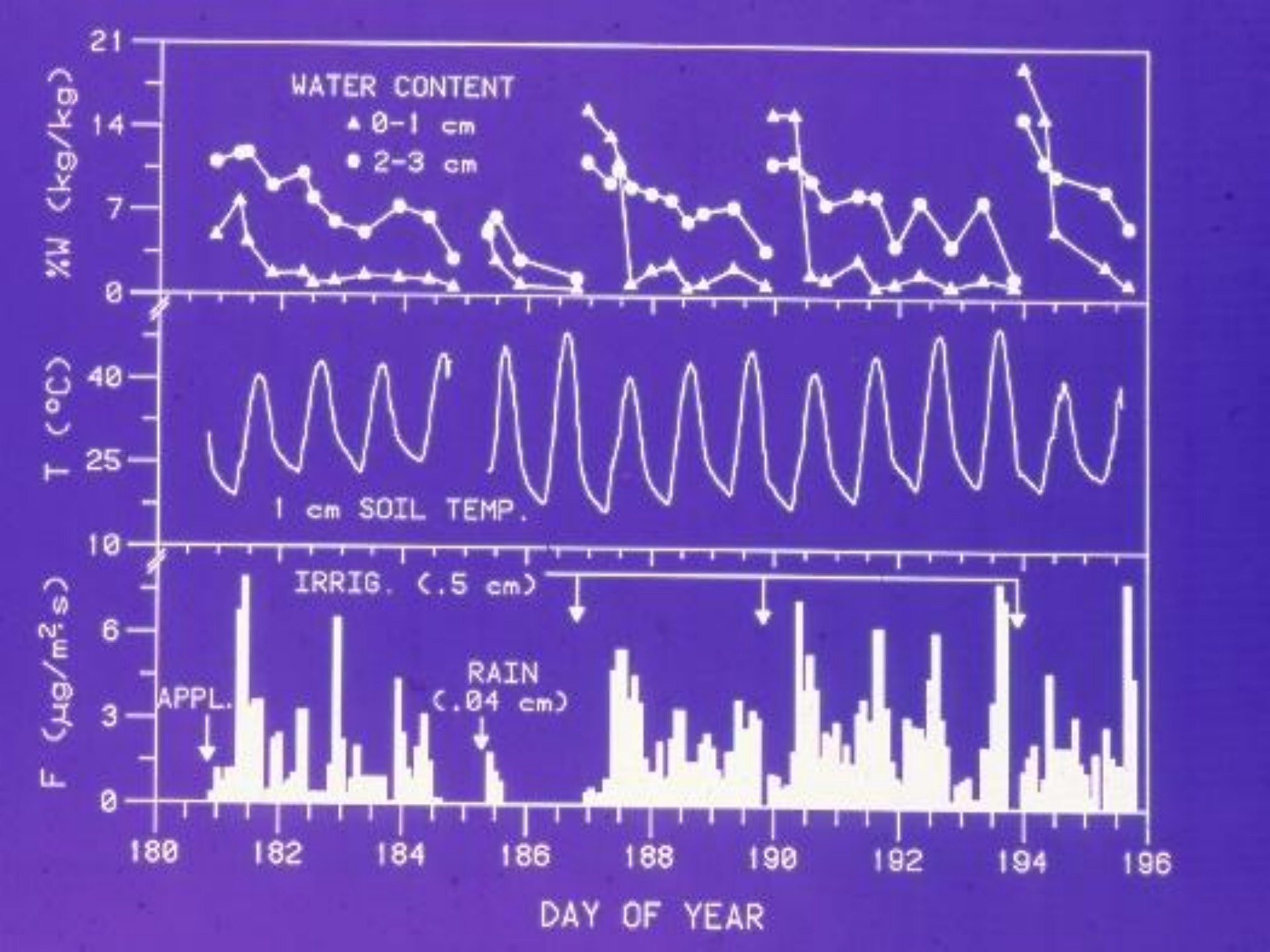
Laboratory Results (77ºF, 90% RH)

NH_3 volatilization in the lab



Some Results from Central Great Plains, Manhattan, Kansas


240
160
80
0
%W (kg/kg)
30
15
0
T (°C)
STRAW SURFACE
STRAW-SOIL INTERFACE
40
20
0
F (μg/m².s)
IRRIGATION (0.25 cm)
APPLICATION
RAIN (2.8 cm)
FROST
260
261
262
263
264
265
266
DAY OF YEAR


WATER CONTENT
▲ 0-1 cm
● 2-3 cm
%W (kg/kg)
21
14
7
0
T (°C)
40
25
10
1 cm SOIL TEMP.
IRRIG. (.5 cm)
APPL.
RAIN
(.04 cm)
F (μg/m²s)
6
3
0
180
182
184
186
188
190
192
194
196
DAY OF YEAR

Topdress N on Wheat
Kansas State Univ., NE KS

N, pounds/acre	N Source	Yield, Bu/acre
0		45.3
30	Urea	60.2
60	Urea	68.1
90	Urea	71.0
30	Amm. Nitrate	59.1
60	Amm. Nitrate	64.0
90	Amm. Nitrate	70.1

Ammonia loss from N uptake by Coastal Bermudagrass- Temple, TX Bill Hargrove – 1975, 1976

Treatment	N rate, pound/A	NH3 Loss (%)
Urea	100	0
Urea	200	0
Urea	400	3
UAN	100	8
UAN	200	2
UAN	400	0

Questions?