Ammonia emissions from hog farrow-to-wean waste lagoons

Grant, R.H[1]., M.T. Boehm[1], A.J. Lawrence[2], A. J. Heber[3], B.W. Bogan[3] and J.C. Ramirez-Dorronsoro[4]. Departments of Agronomy[1] and Agricultural and Biological Engineering[3], Purdue University, Isabella Thoburn College[2], India, and Natural Resources and Environmental Management[4], Ball State University

Introduction

- This study part of a national study to evaluate emissions from concentrated livestock feeding operation over a range of climates and for an extended period (2 years)
- Ammonia a major reactive nitrogen species influencing secondary aerosol formation and ecosystem health and reportable under the Emergency Planning and Community Right-to-Know Act (**EPCRA)**.

- Here look at what influence anaerobic lagoon loading, temperatures and winds have on NH_3 emissions from sow breed to wean hog operation across a range of climates.

Introduction

- Hog operations :

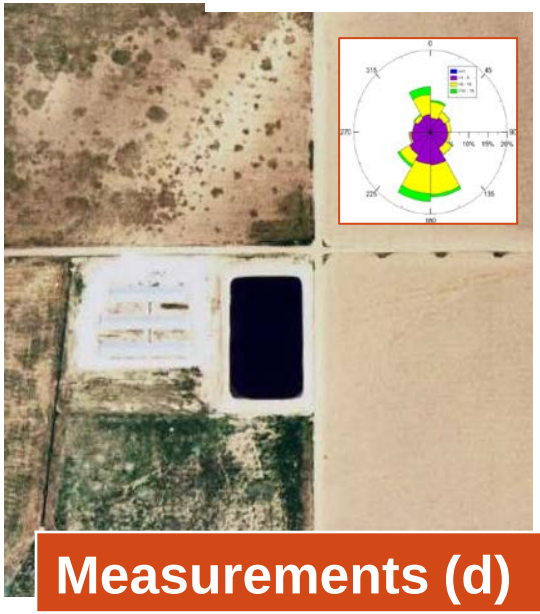
  sows take16 weeks to birth, piglets take 2-3 weeks to wean

Farm population	OK	IN	NC
Sows	2784	1400	2000
Piglets	3898	1960	2800
AU (1AU=500 kg)	1279 AU)	624 AU	815 AU

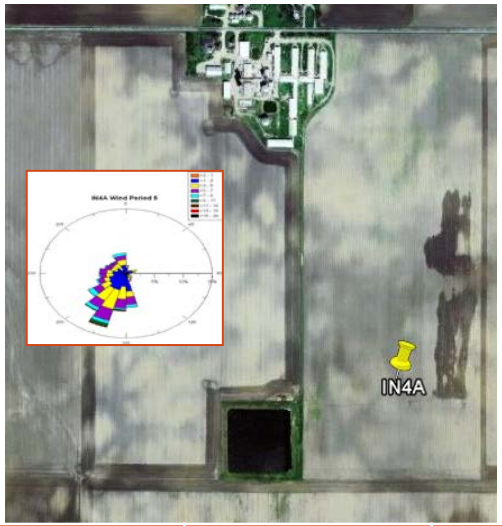
Manure transfer	OK	IN	NC
Collection	Pull-plug recharge	Deep pit	Pull-plug recharge
Transfer into lagoon	Daily	Every 2 weeks	Every week
Removal from lagoon during study	No events	17 events	14 events

Measurement locations

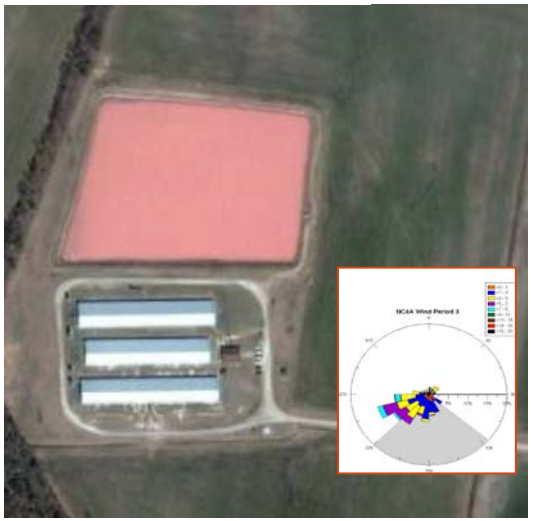
OK



IN

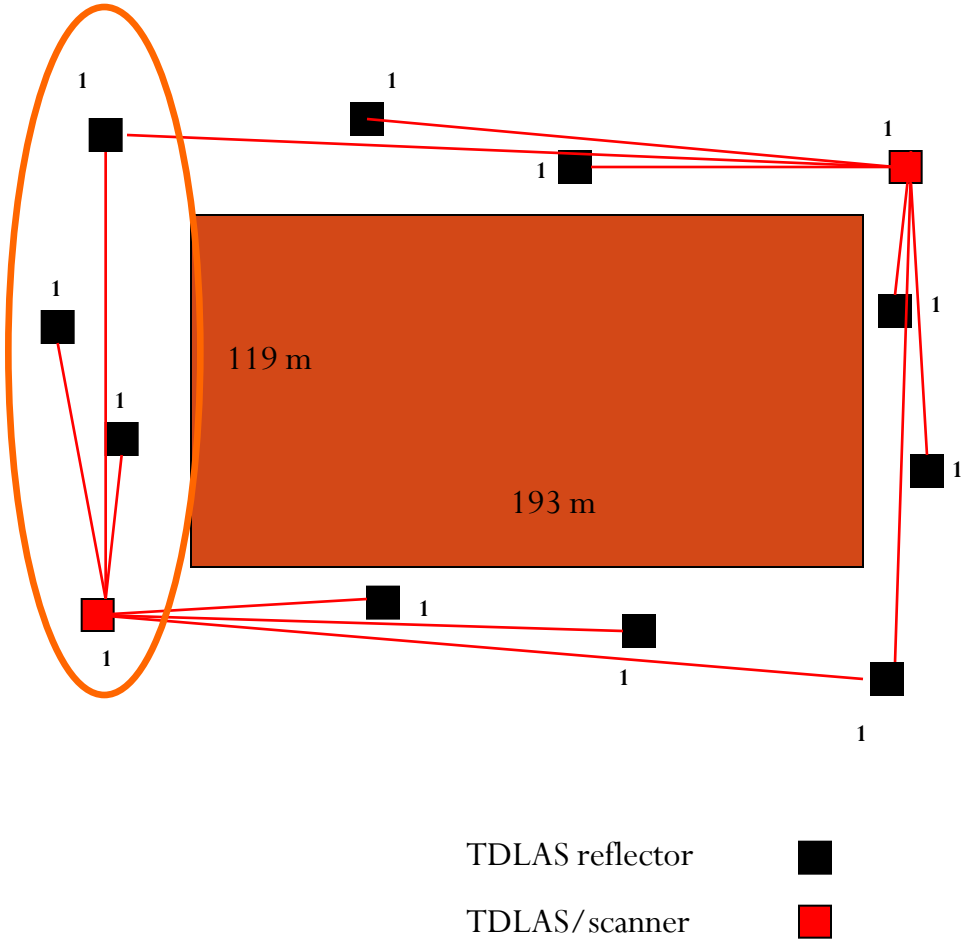


NC



Measurements (d)	OK	IN	NC
On-site NH3 measurements	181	303	131
Valid NH3 emissions	87.4	90.5	48.7
Fraction valid	48%	30%	37%

NH_3 Measurements

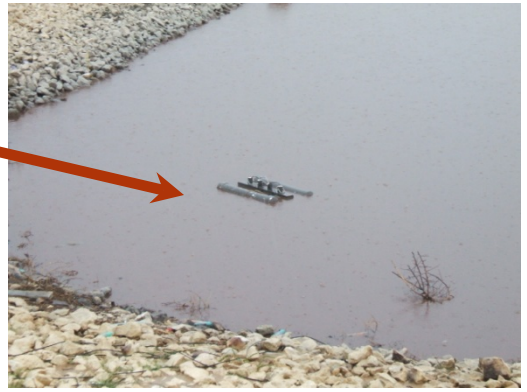


Other Measurements

- Atmospheric properties
  - Turbulence (16Hz)
  - Air temperature, humidity, barometric pressure, surface wetness, solar radiation

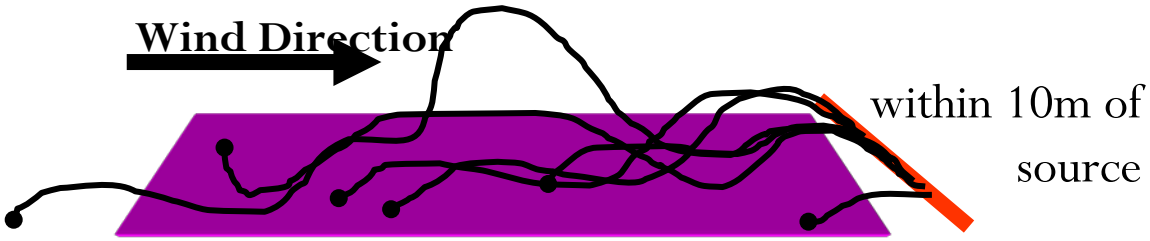
- Lagoon properties

  temperature, pH, redox potential



- Collected operation and production records from producer

NH_3 emissions by bLS (WindTrax)



Turbulence measured on berm (2.5 m)

NH_3 measured on m=12 optical paths giving 12 PICs (1 m)

$$a_i = \frac{(PIC_i / path_i - C_{bkgr})}{[C_{sim} / Q_{sim}]}$$

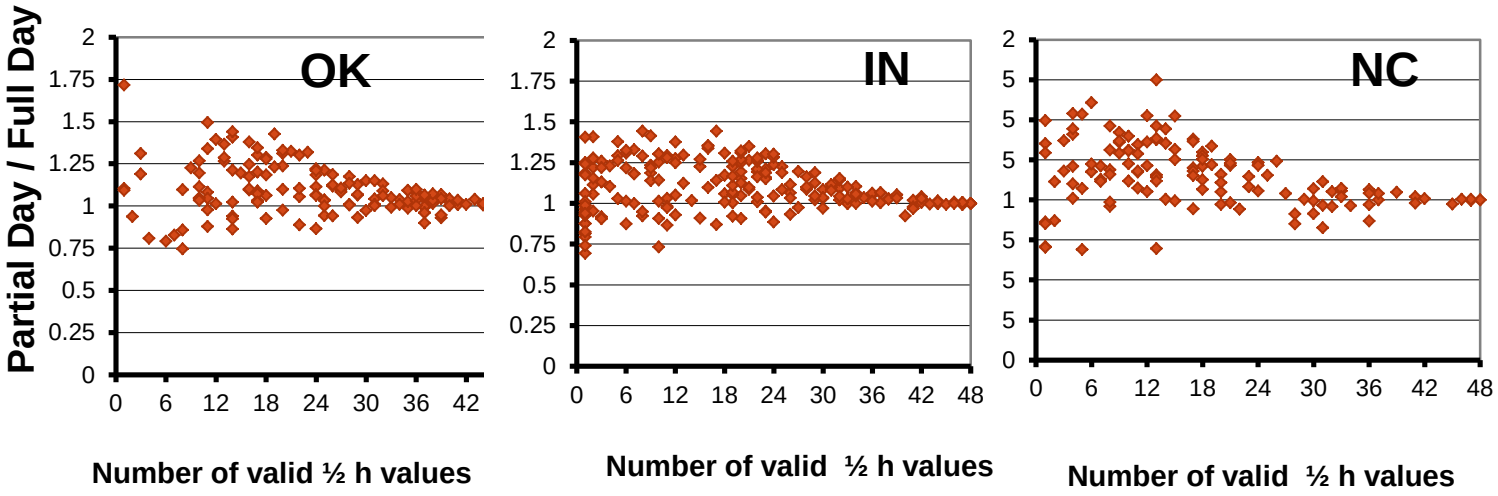
with C_{bkgr} *and* Q *solved from*:

$$Q = (PIC_i / path_i - C_{bkgr}) / a_i$$

$$Q = (PIC_m / path_m - C_{bkgr}) / a_m$$

Emissions calculated on ½ intervals

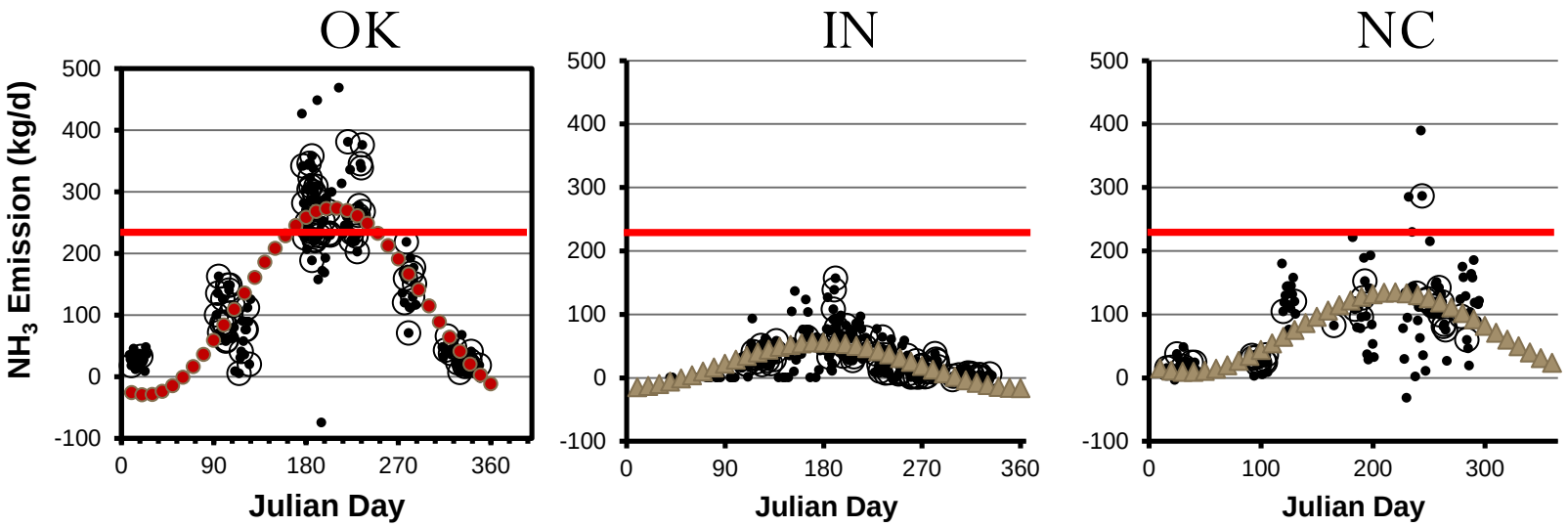
Defining daily emission measurements



Daytime emissions higher than nighttime, but only 52% of typical day needs to be measured to represent the daily emissions to within 25%

Measurements (d)	OK	IN	NC
Valid NH3 emissions	87.4	90.5	48.7
Valid day NH3 emissions	83	76	16

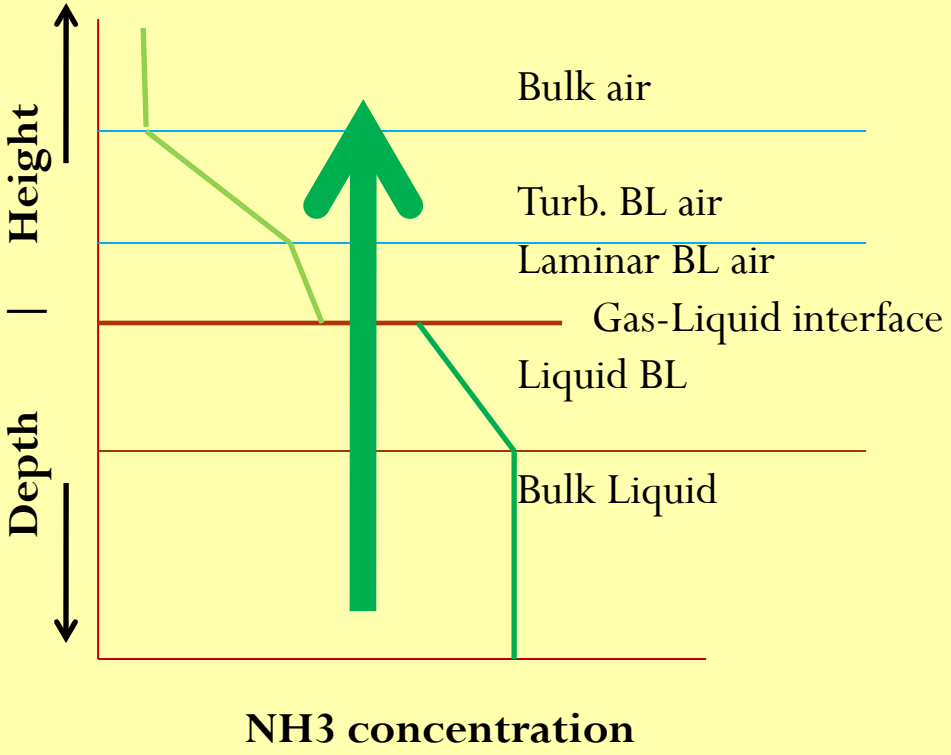
Annual pattern of daily emissions



- Large circles indicate valid daily emission
- Emissions trends generally under EPCRA reporting (220 kg/d)

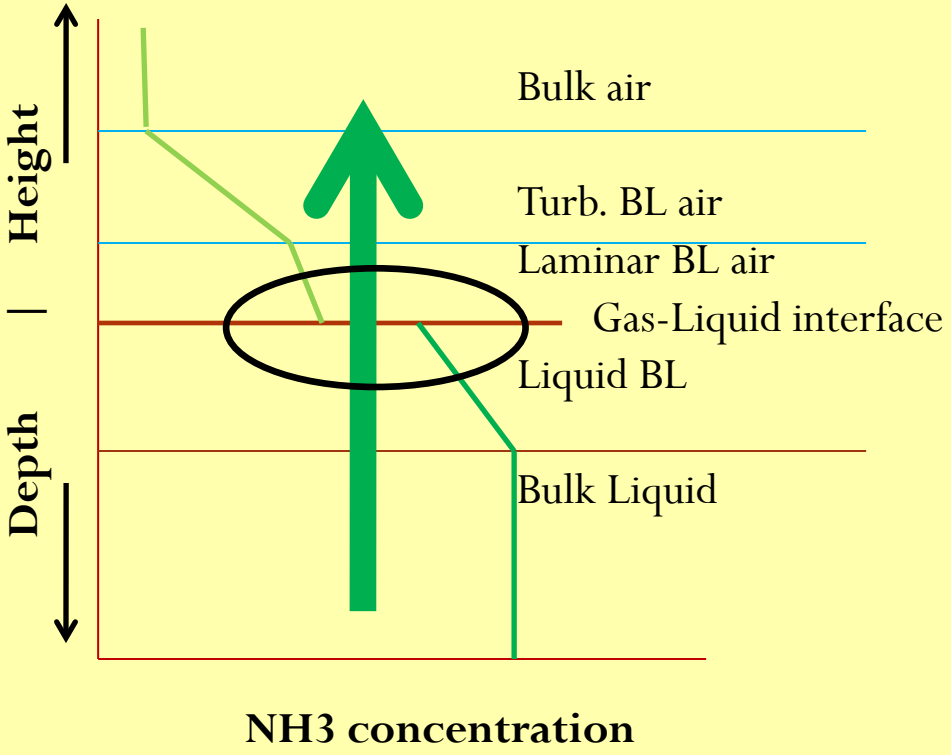
NH3 Emissions: Two film theory

- Emission depends on
  - Bulk [NH_3] of lagoon
  - Liquid diffusion properties
  - NH_3 solubility properties
  - Air flow/transport properties



NH3 Emissions: Two film theory

- Emission depends on
  - Bulk [NH_3] of lagoon
  - Liquid diffusion properties
  - NH_3 solubility properties
  - Air flow/transport properties

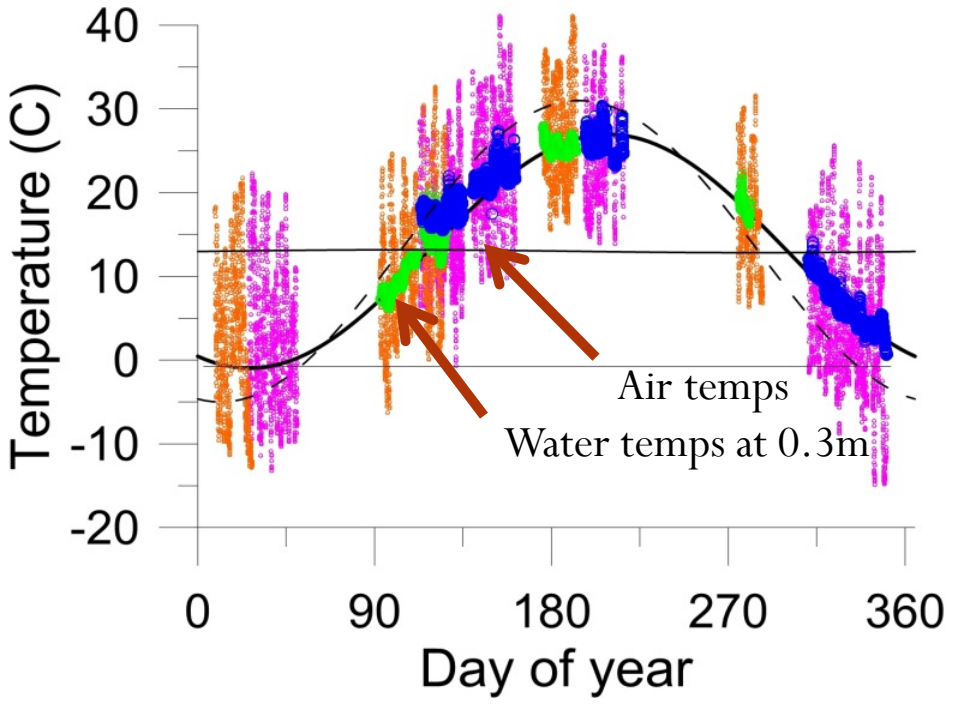


Influence of solubility on emissions

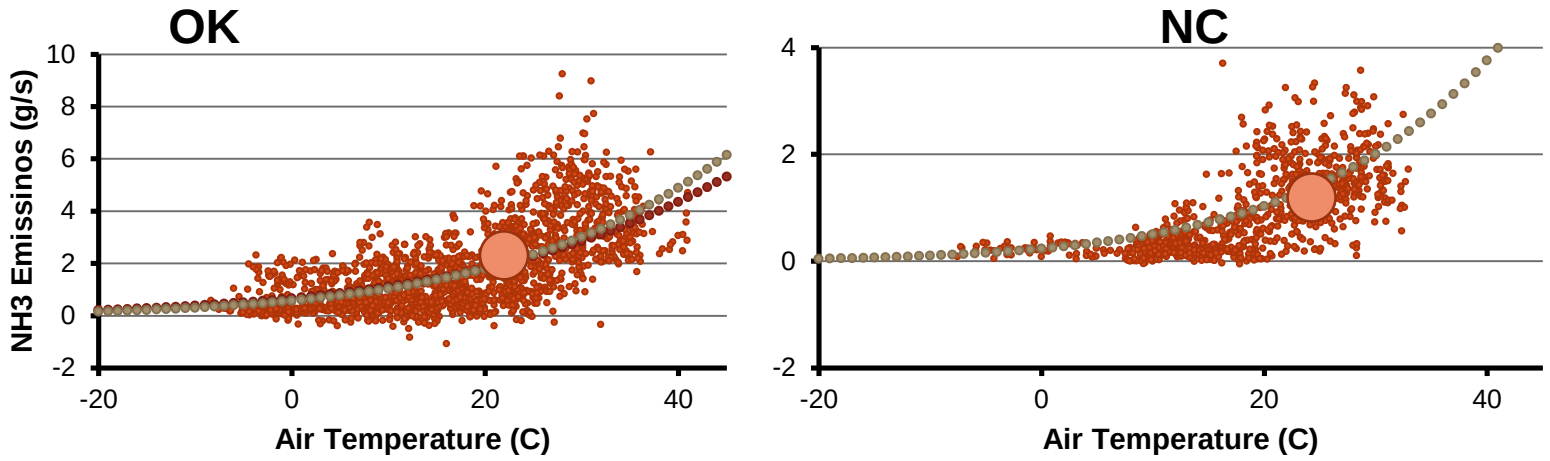
Solubility of NH_3 influenced by Van't Hoff equation:

$$e^{-B\left(\frac{1}{T_{air}}-\frac{1}{298}\right)}$$

Proxy of air for water temperature at interface



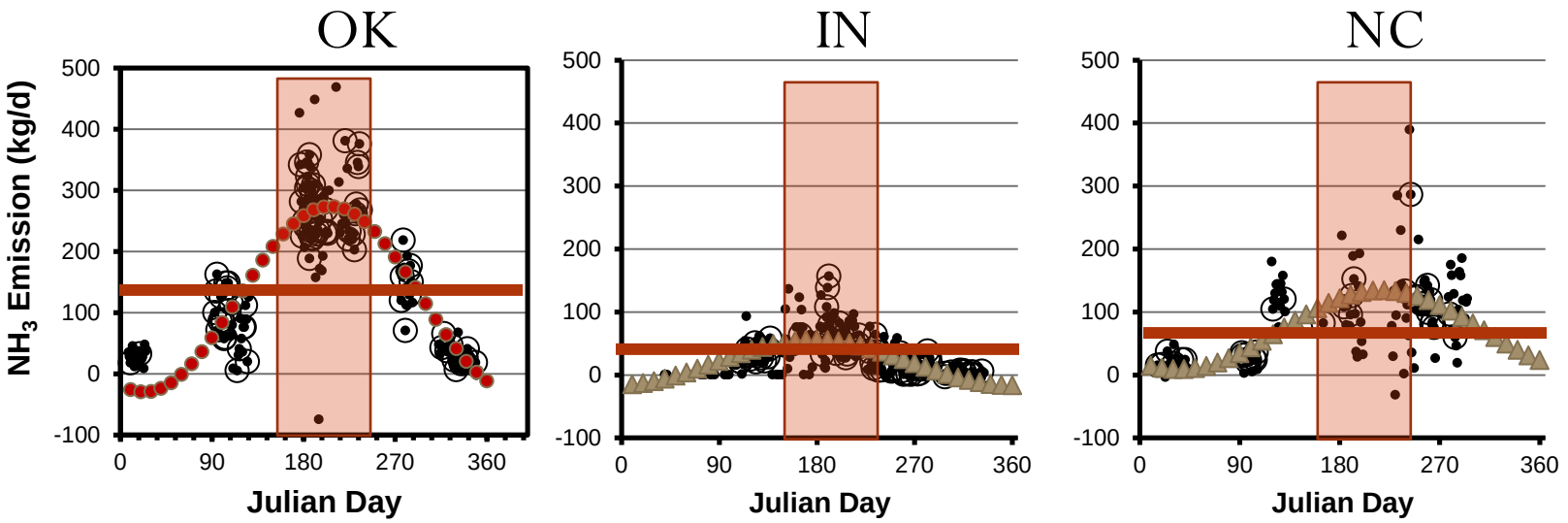
Influence of solubility on emissions



- Proxy of air temperature for water temperature at interface overstates variability
- Narrow range of emissions and temperature at NC limits accuracy of exponent coeff.

	$Ae^{-B\left(\frac{1}{T_{air}}-\frac{1}{298}\right)}$			
	A (g/s)	A (kg/d)	B	R^2
OK	2.32	200.4	-4594	0.55
IN	0.81	70.0	-4932	0.41
NC	1.43	123.6	-5944	0.31
Henry's Law			-4200	

Annual pattern of daily emissions



- Mean annual daily emissions
- Maximum mean daily emissions: Mean summer emissions

Annual and Summer emissions

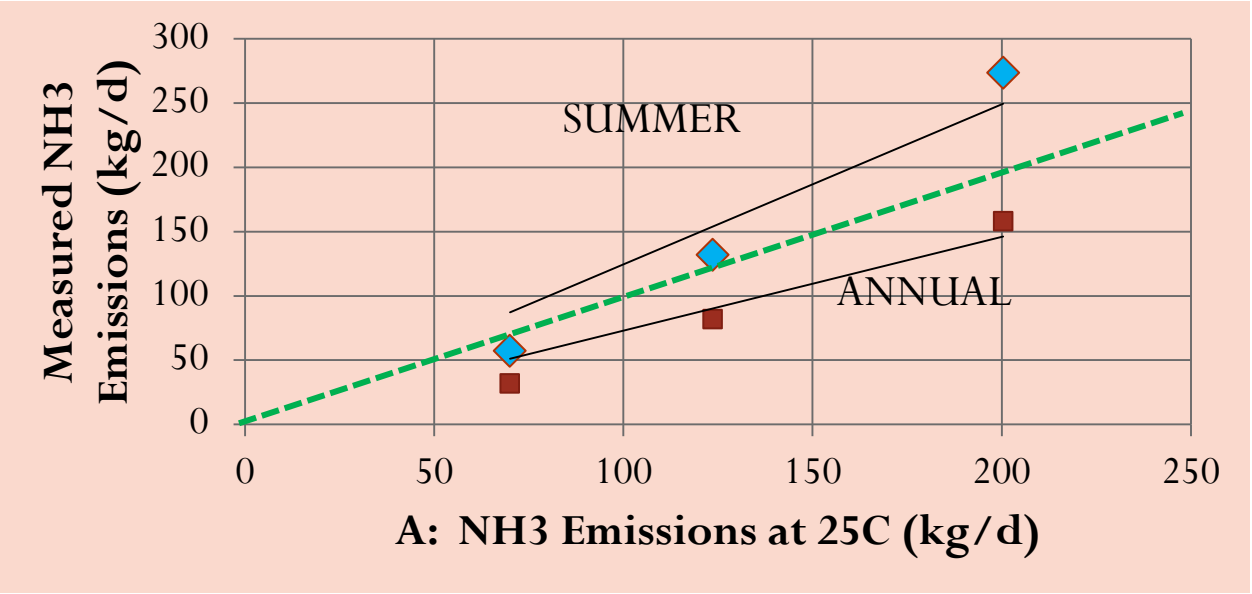
Daily Emission	OK	IN	NC	OK summer	IN summer	NC summer
Kg d^{-1} (T=25C)	*200*	*70*	*124*	*200*	*70*	*124*
Kg d^{-1}	158	32	82	273	57	132
Mean air temp. (C)	13	6.5	13.5	26.3	22.3	24.4

$$Ae^{-B\left(\frac{1}{T_{air}}-\frac{1}{298}\right)}$$

Normalized emissions to 25C indicates strength of source and efficiency of transport and excludes temperature influence:

A= source strength &transport measure.

Annual and Summer emissions

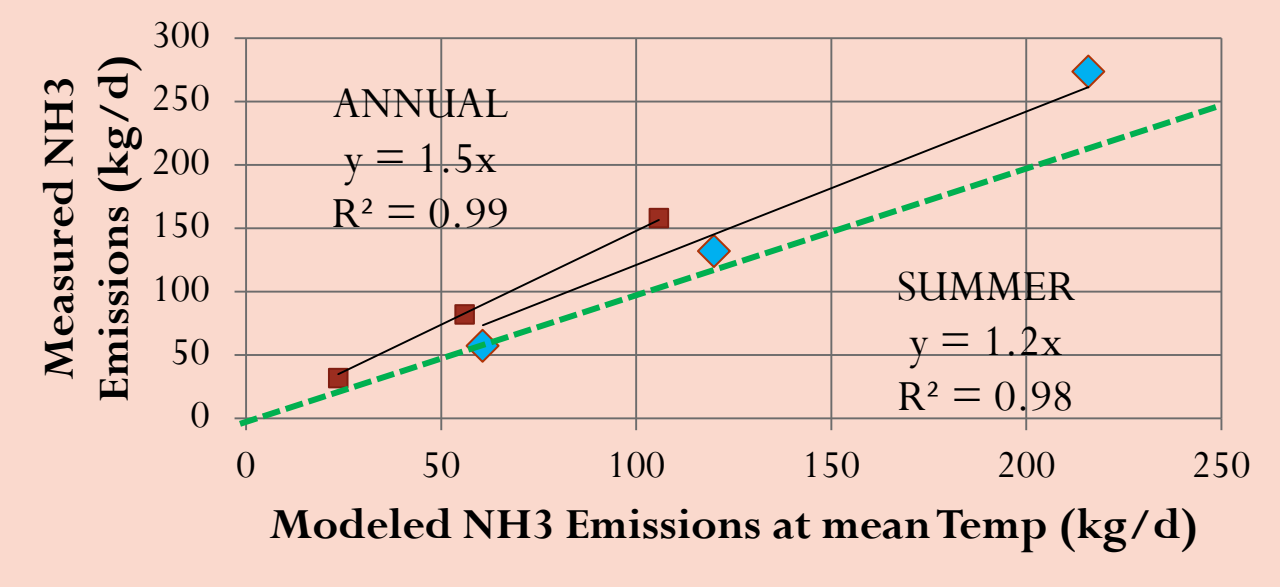


$$Ae^{-B\left(\frac{1}{298}-\frac{1}{298}\right)}$$

High correlation between source strength/transport and mean emissions

- Rate of volatilization/dissociation a controlling factor in emissions

Annual and Summer emissions



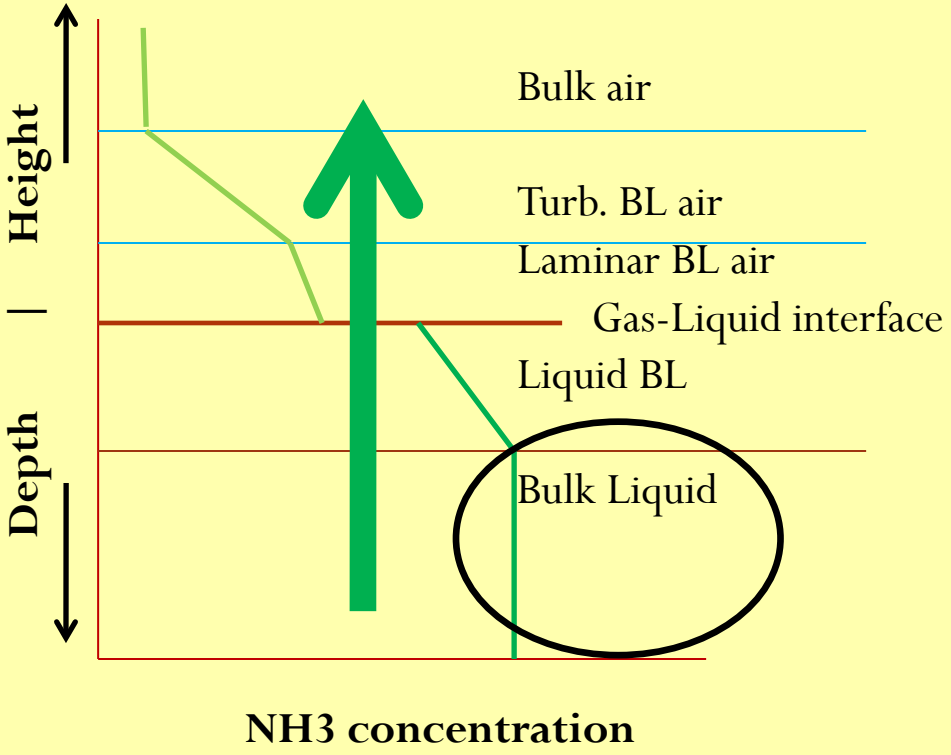
$$Ae^{-B\left(\frac{1}{T_{air}}-\frac{1}{298}\right)}$$

Using mean Temp. as only variate:

- Summer emissions overestimated by <1%
- Annual emissions underestimated by 50%

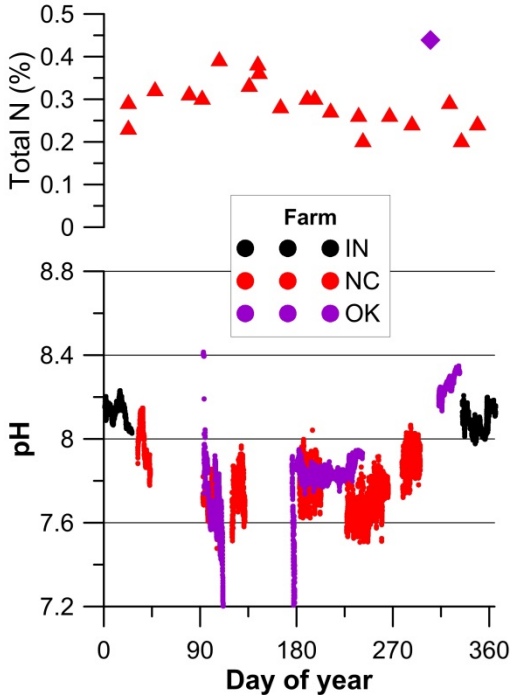
NH3 Emissions: Two film theory

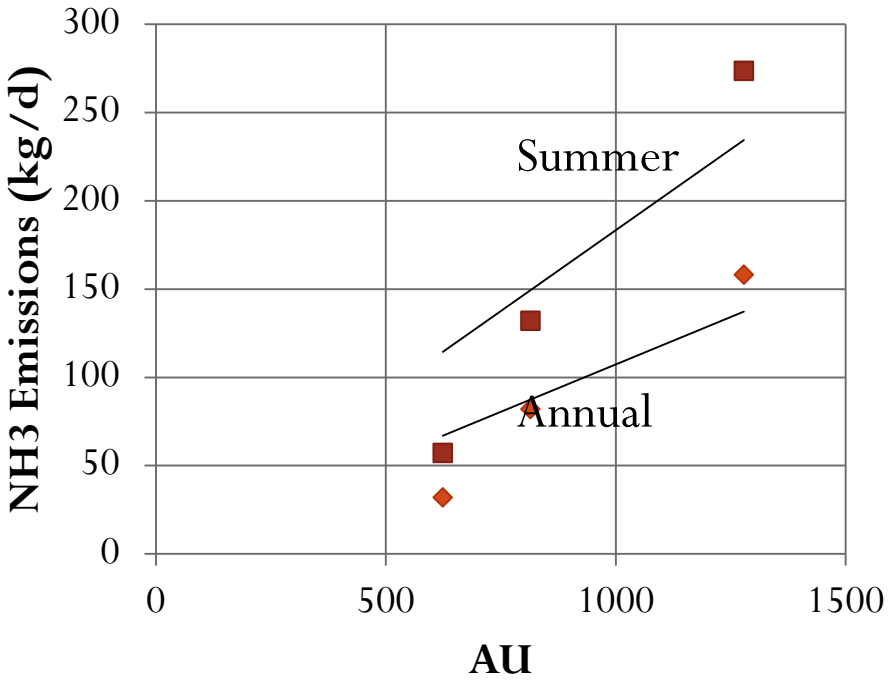
- Emission depends on
  - Bulk [NH_3] of lagoon
  - Liquid diffusion properties
  - NH_3 solubility properties
  - Air flow/transport properties



Lagoon composition

- Bulk lagoon chemical composition info very limited
- Emissions correlated (R^2=0.79) with AU (1AU=500kg), and hence waste production



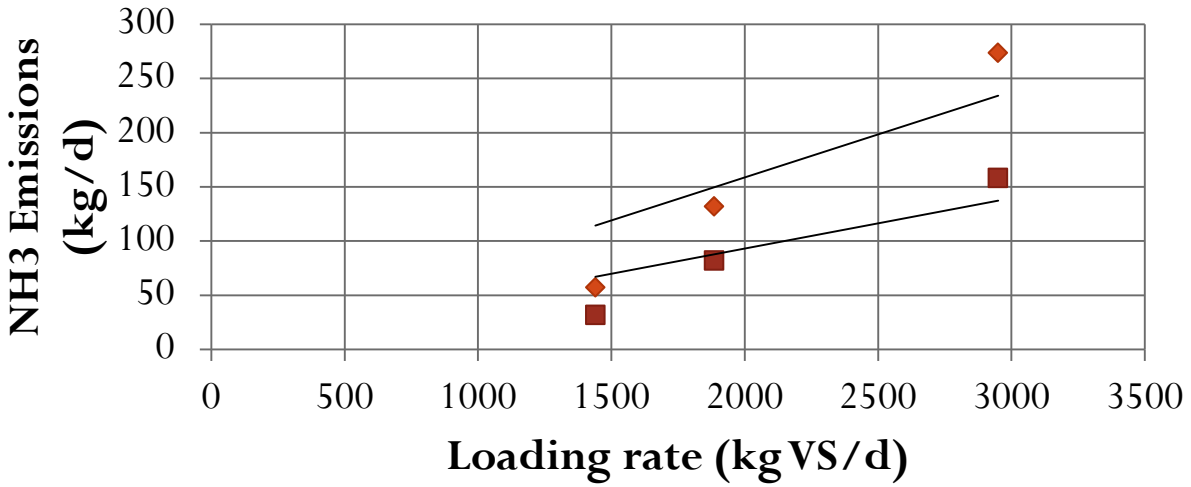


Lagoon composition

Estimated Volatile Solids (VS) Loading

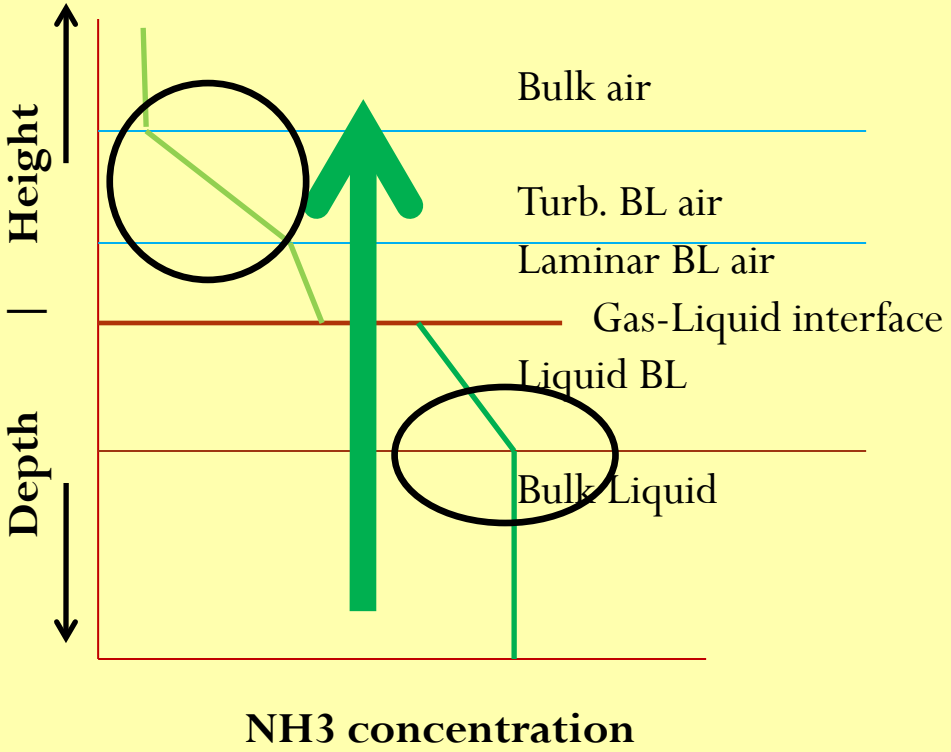
Modelled Daily Emission	OK	IN	NC	OK summer	IN summer	NC summer
Kg d^{-1}	157	52	70	229	65	111
mg kg VS^{-1}	53	36	37	78	45	59
MWPS Loading rate (kg VS d^{-1})	2950	1440	1886	2950	1440	1886

$R^2 = 0.79$



NH3 Emissions: Two film theory

- Emission depends on
  - Bulk [NH_3] of lagoon
  - Liquid diffusion properties
  - NH_3 solubility properties
  - Air flow/transport properties



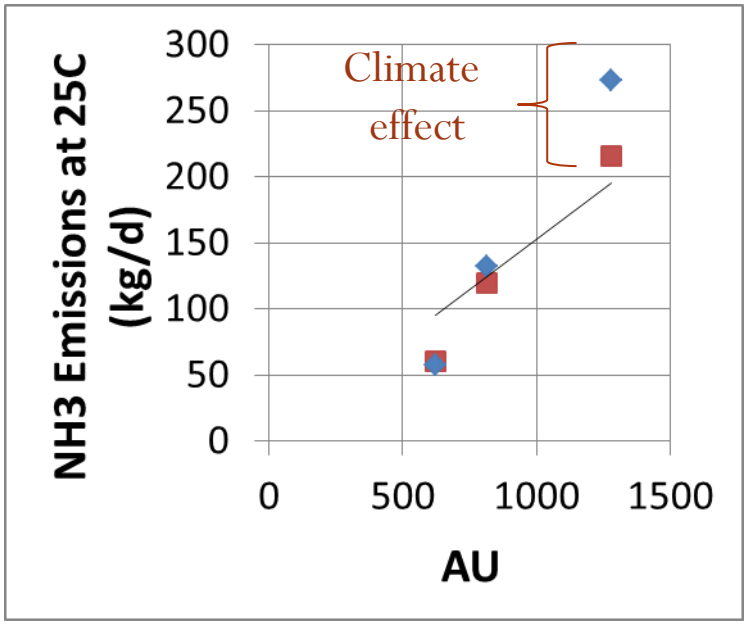
Climate effects on transport

- Assume summer emissions is maximum

Actual summer
25C

- Climate effects include vapor pressure deficit, winds

Climate during study	OK	IN	NC
Mean Daily Max Temp. (C)	37	28	32
Mean VPD (kPa)	1.8	0.9	0.6
Mean wind speed (m/s)	4.4	2.7	1.6



Conclusions

- Annual emissions can be modeled using solubility temperature influence function (~50% of variance)
- NH3 emissions are highly correlated with AU, estimated VS loading
- Climate effects (high VPD, winds) at OK enhance emissions

Acknowledgements

Thanks for those contributing to measurements:

- Technicians: Jenafer Wolf, Ben Evans, Scott Cortus, Chris Fullerton
- Undergraduates: Hans Schmitz, Derrick Snyder

Research was funded by livestock producers and the Agricultural Air Research Council, Inc.


Questions bubbling up?