Ammonia in the 21st Century: Challenges for Measurements and Mitigation

Dr Christine Braban and CEH colleagues
Centre for Ecology & Hydrology,
RMetSoc July 2019

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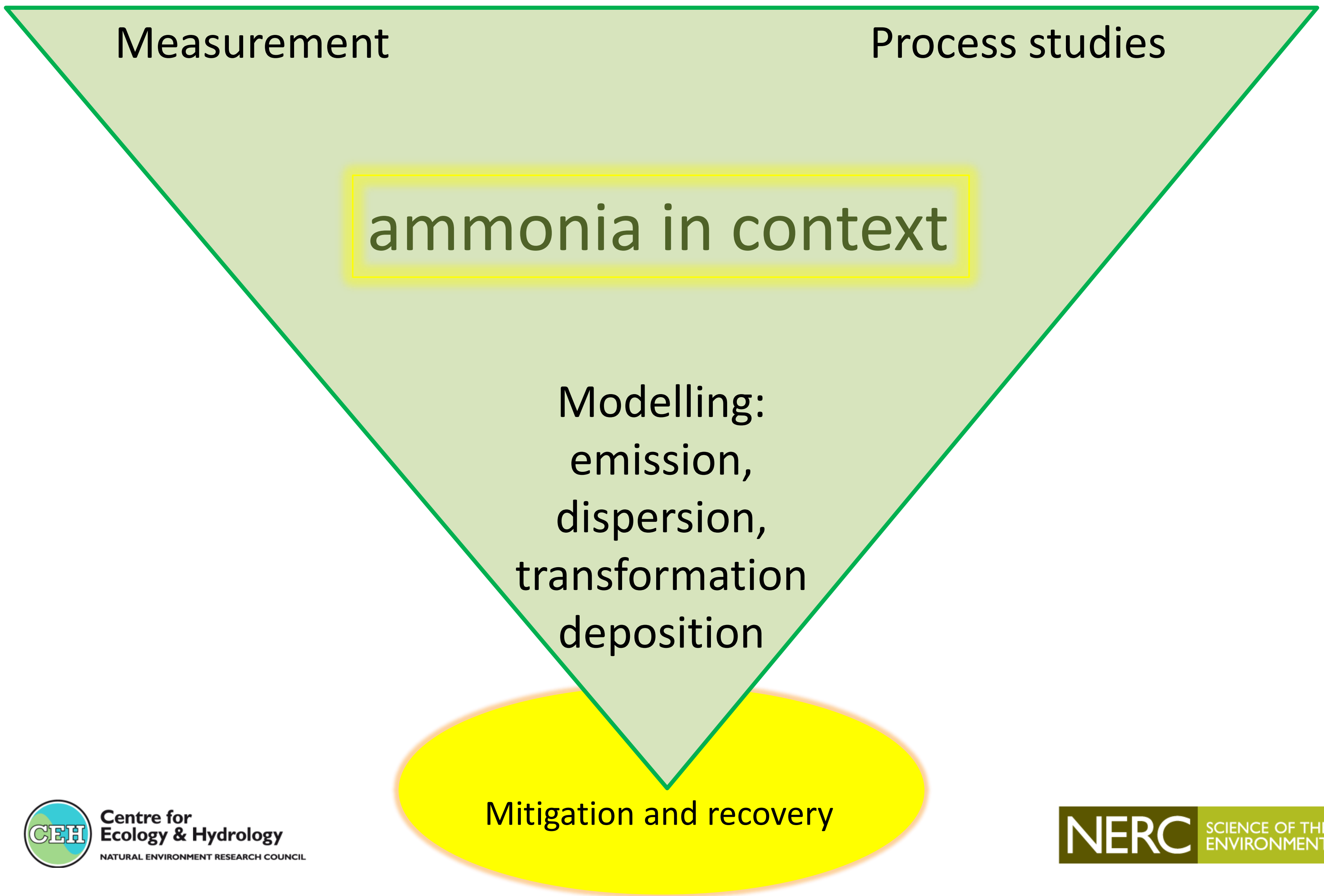
With content from colleagues at CEH including MM Twigg, YS Tang, MR Jones, S Leeson, U Dragosits-Harding, S. Riddick, C. Steadman, E Nemitz, M A Sutton

Work in collaborations with NPL, METAS, Ricardo and many others!

Knowledge gaps in all areas



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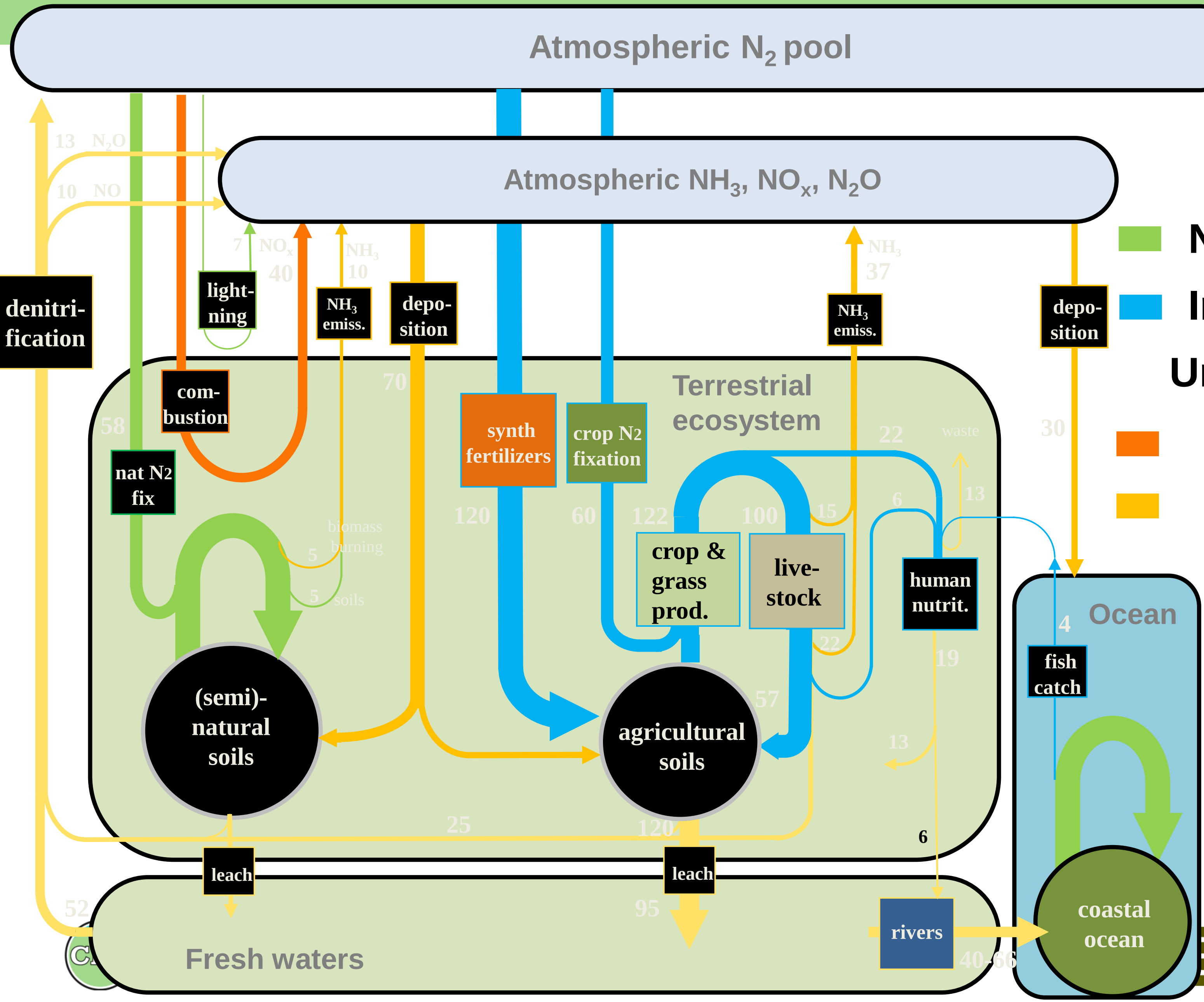
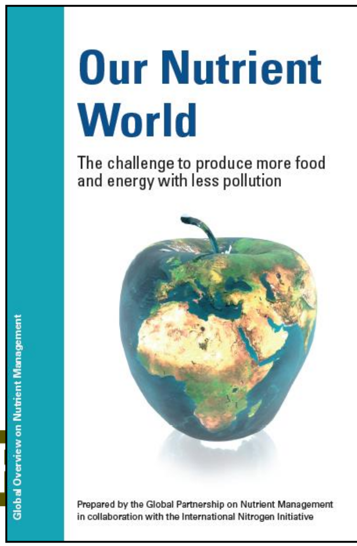
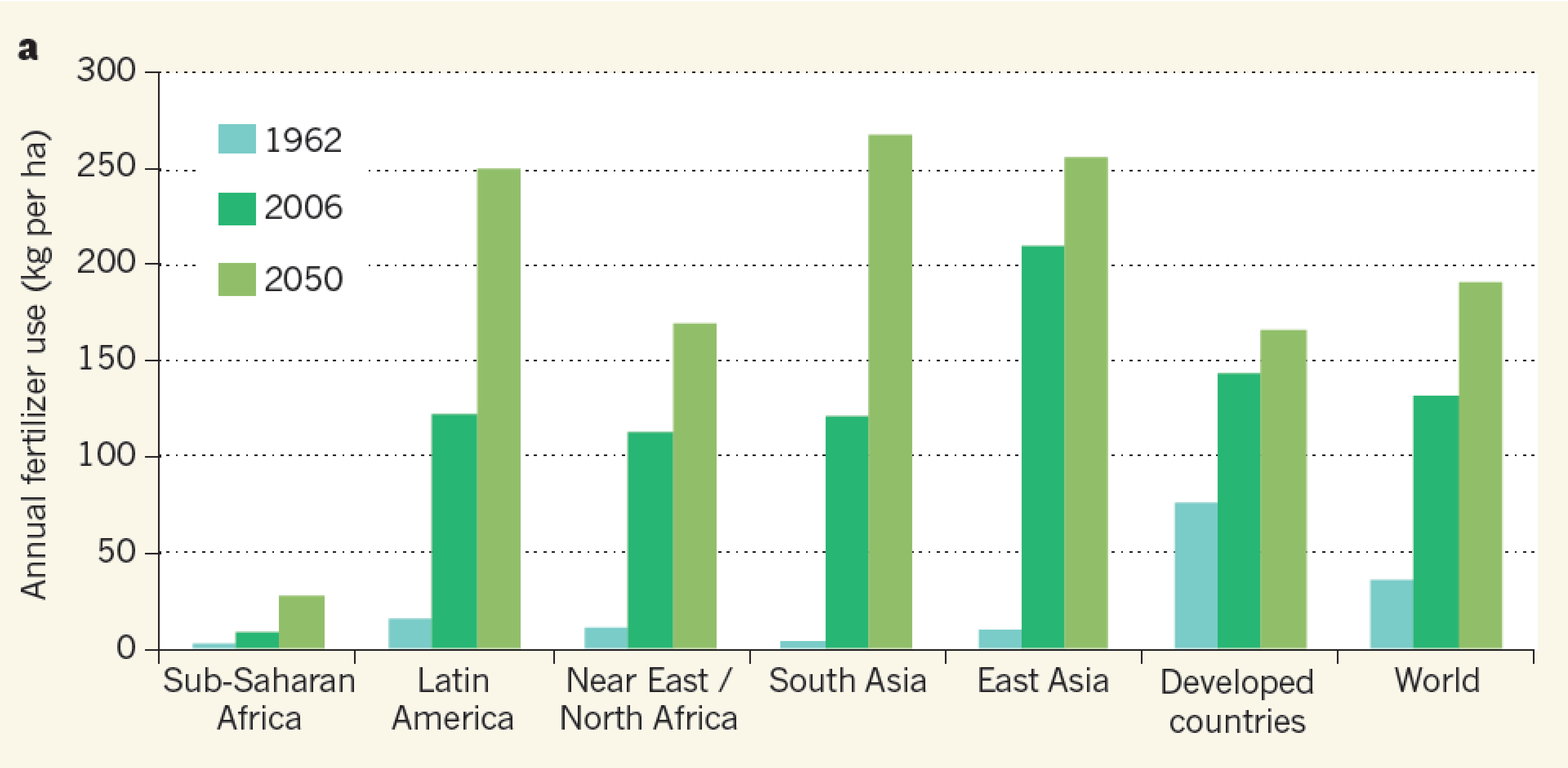
Global nitrogen flows around year 2000 (million tonnes N / year)





Past change – future risks Global fertilizer use



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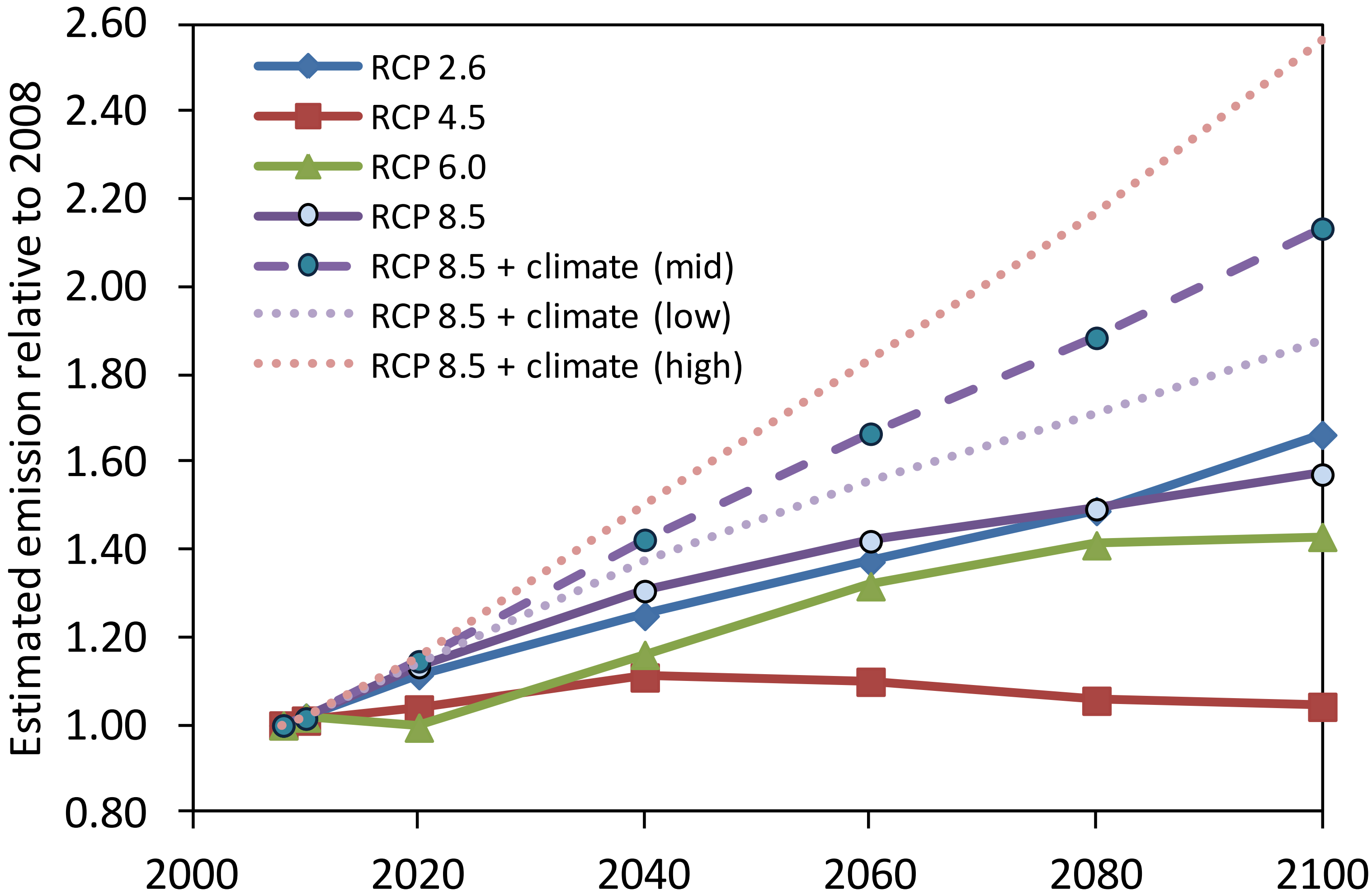
Sutton and Bleeker *Nature* 2013 based on FAO projections

Global ammonia in a future climate



Sutton et al. Phil Trans. Roy. Soc., 2013

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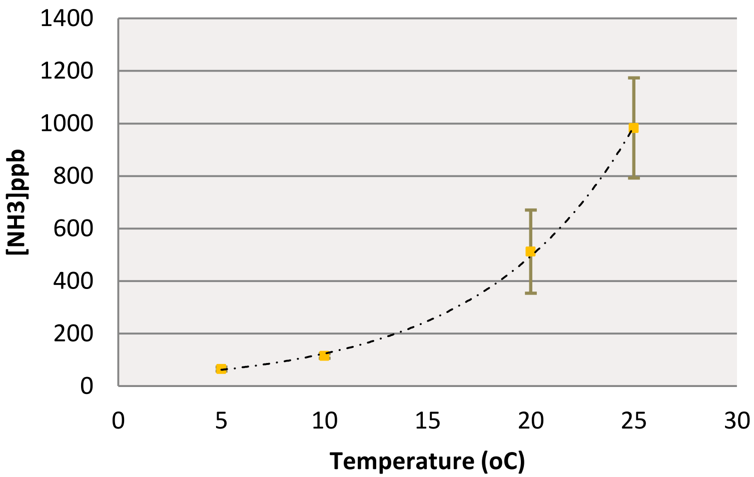
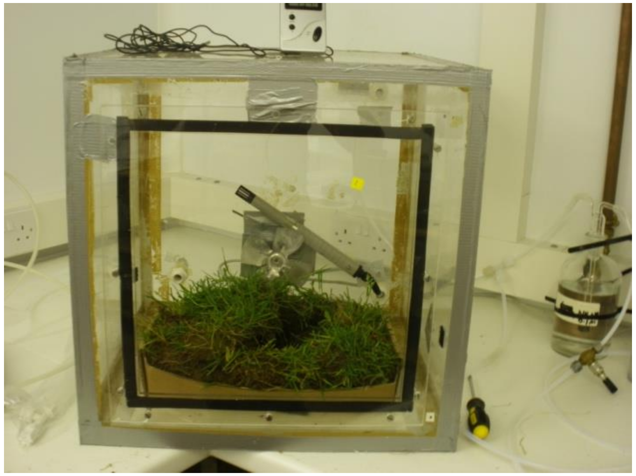
Controlled cuvette experiments

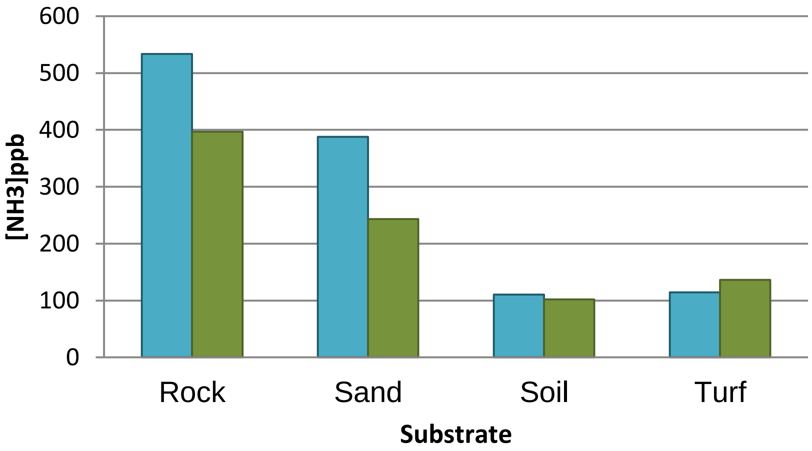
NH_3 emission at different temperatures



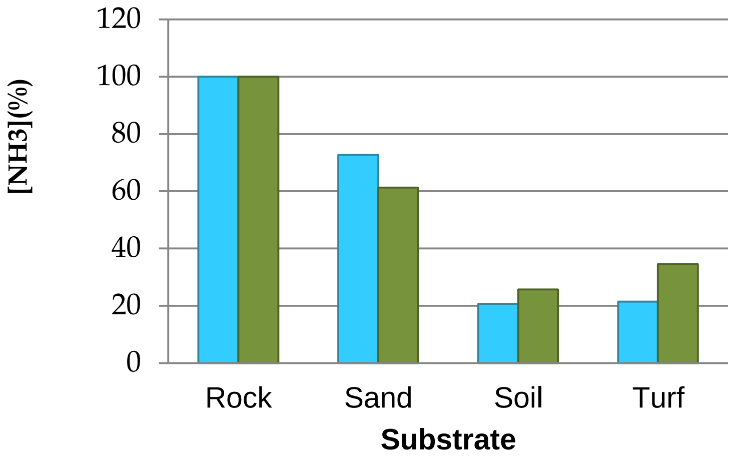
NH_3 emission from different nesting habits



NH_3 emission from different substrates



NH_3 emission from different substrates (%)



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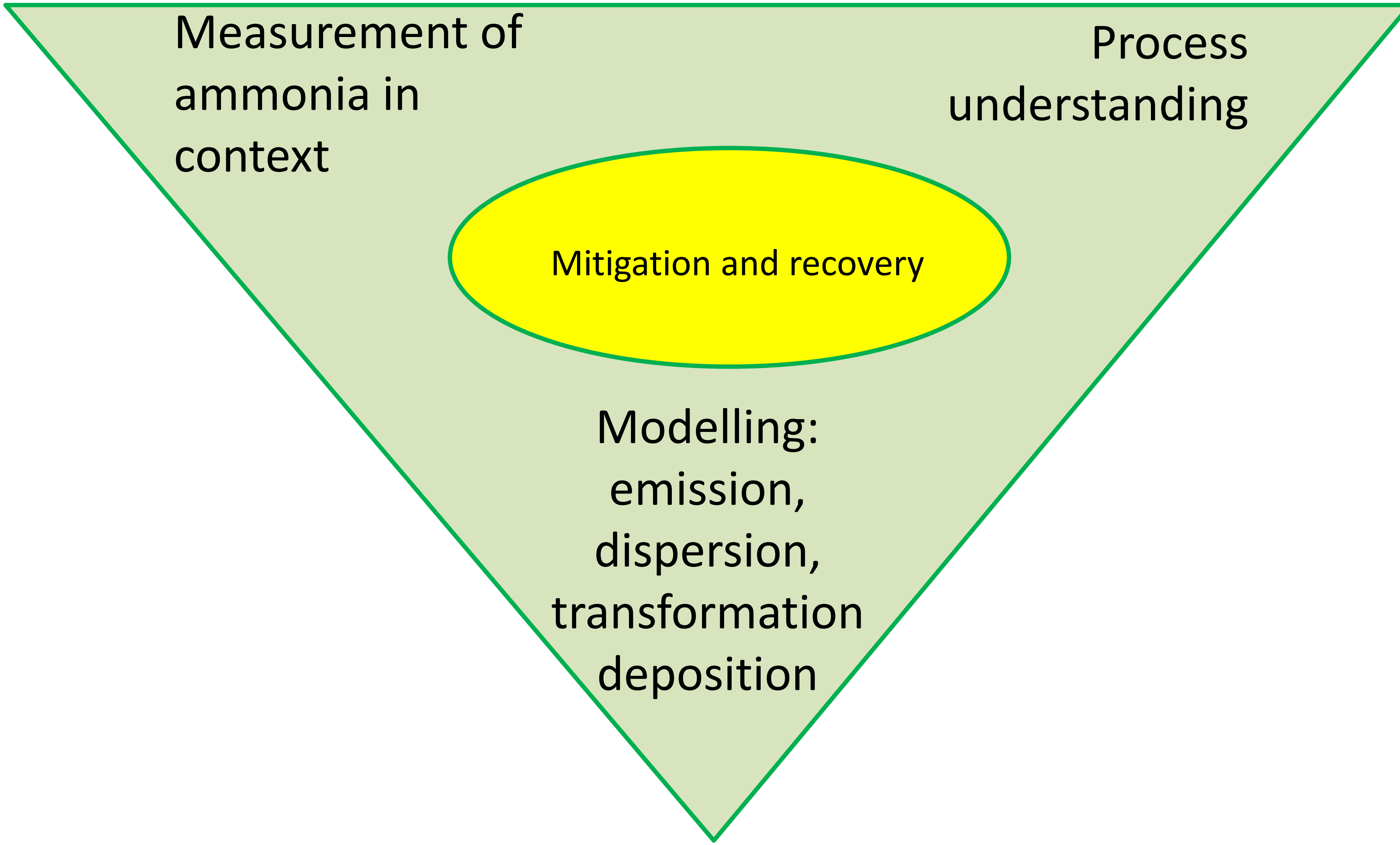
Perez-Alcon E. (project student, ERASMUS programme)

Knowledge gaps in all areas



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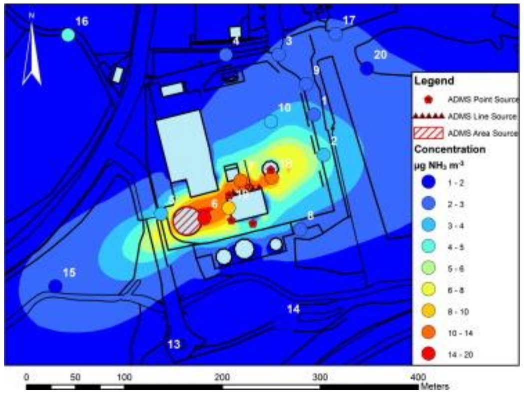
Emission inventories: e.g. UK National

?



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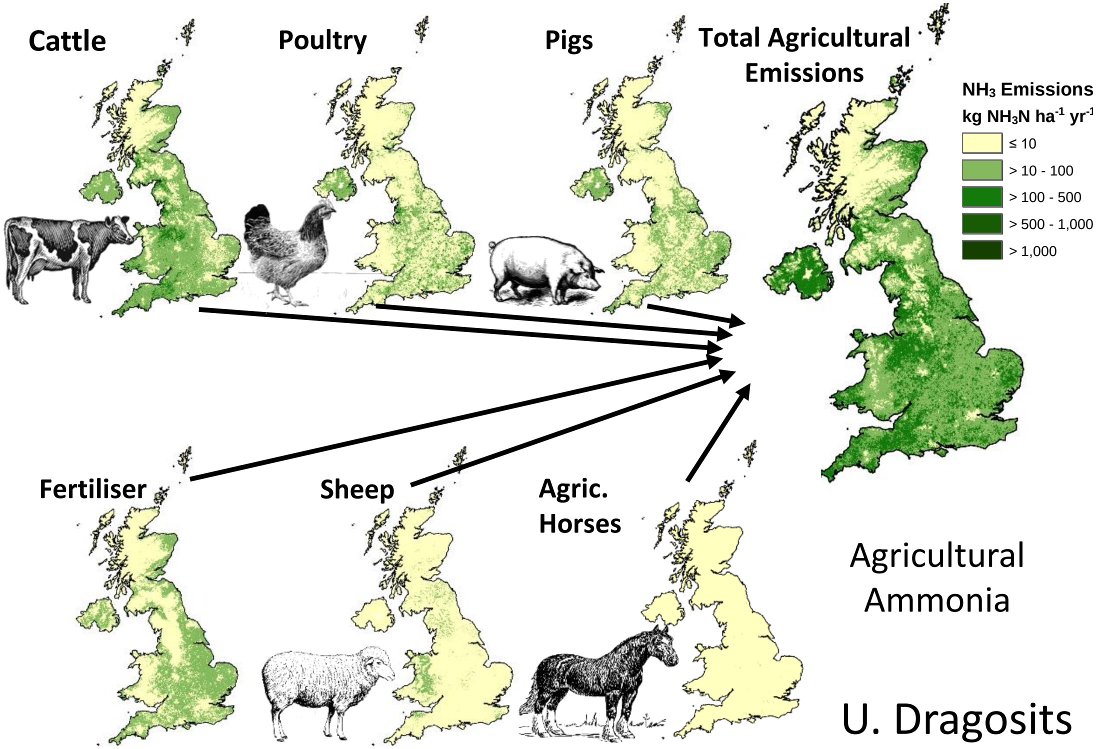
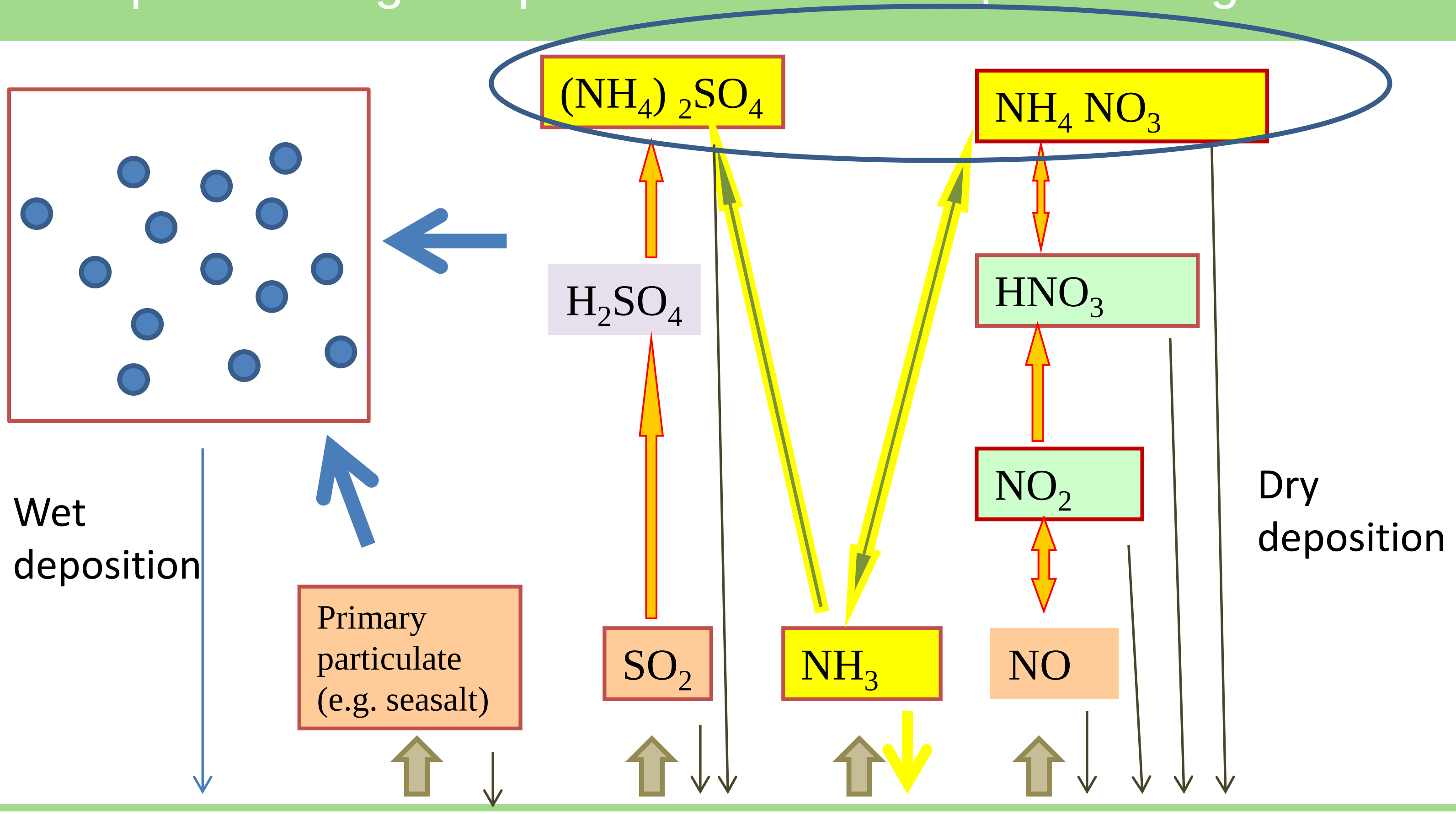


Agricultural Ammonia

U. Dragosits

A simplified inorganic picture of chemical processing in the atmosphere



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Measurement of ammonia in context

$NH_3 \longleftrightarrow NH_4$

- Amines
- Co-emitted
- organics

- Reaction
- Precipitation
- consumption
- Re-emission

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Ammonia measurement challenges

Environmental Pollution 251 (2019) 668–680

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

More obvious air pollution impacts on variations in bacteria than fungi and their co-occurrences with ammonia-oxidizing microorganisms in $PM_{2.5}$ ☆

Xiao-Yan Fan, Jing-Feng Gao*, Kai-Ling Pan, Ding-Chang Li, Hui-Hui Dai, Xing Li

g Laboratory for Advanced Municipal Wastewater Treatment and Reuse Technology, Beijing University of Technology, Beijing, 100124,

SCIENTIFIC REPORTS

OPEN

Diversity, abundance and activity of ammonia-oxidizing microorganisms in fine particula matter

Received: 23 June 2016
Accepted: 14 November 2016
Published: 12 December 2016

Jing-Feng Gao, Xiao-Yan Fan, Kai-Ling Pan, Hong-Yu Li & Li-Xin Sun

Atmos. Chem. Phys., 18, 3641–3657, 2018
https://doi.org/10.5194/acp-18-3641-2018

Atmospheric Chemistry and Physics
Open Access

Modeling reactive ammonia uptake by secondary organic aerosol in CMAQ: application to the continental US

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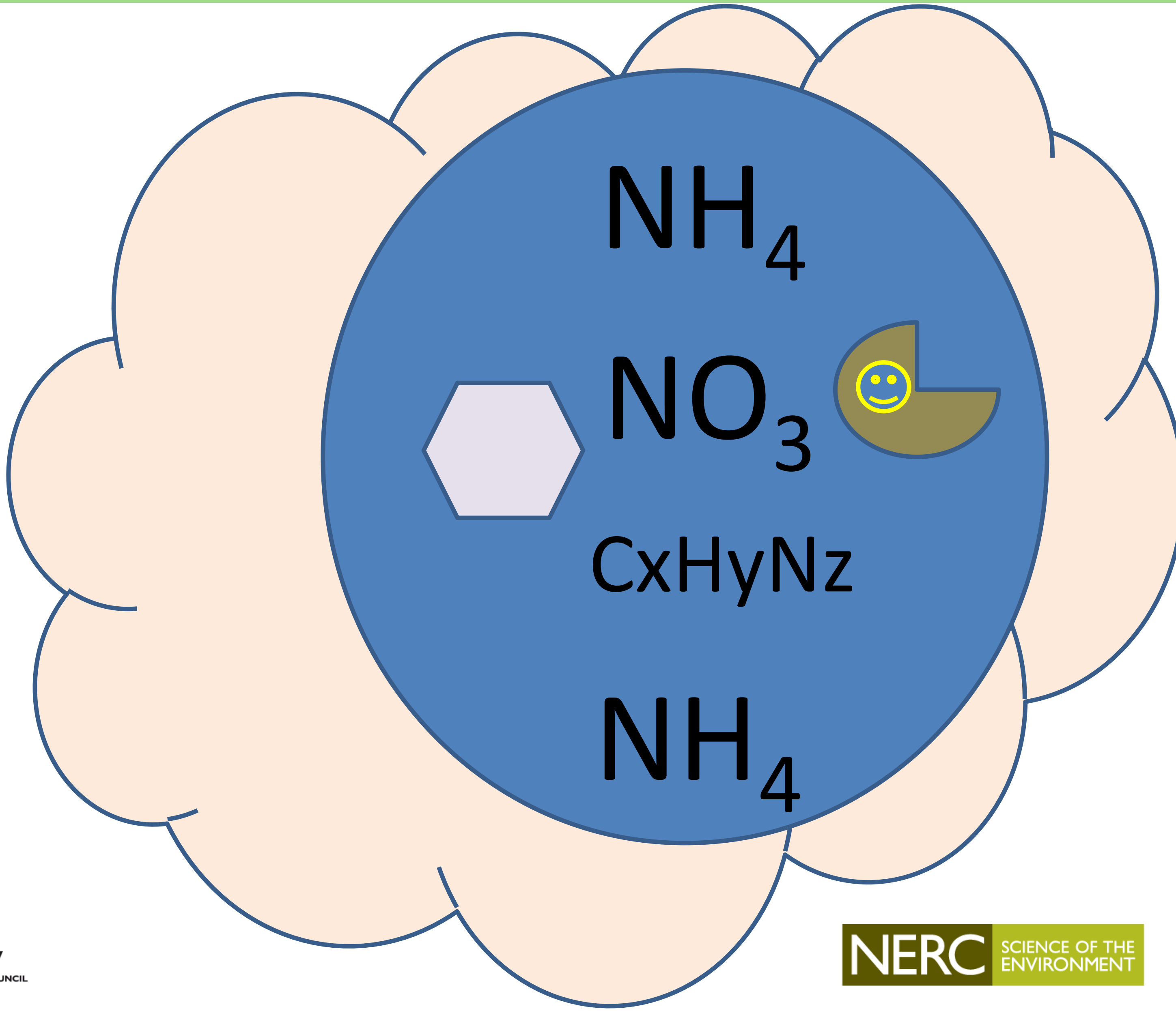
Correspondence: Donald Dabdub (ddabdub@uci.edu)

Received: 12 October 2017 – Discussion started: 6 November 2017
Revised: 1 February 2018 – Accepted: 1 February 2018 – Published: 13 March 2018

Measurement of ammonia in context

NH_3

CxHyNz



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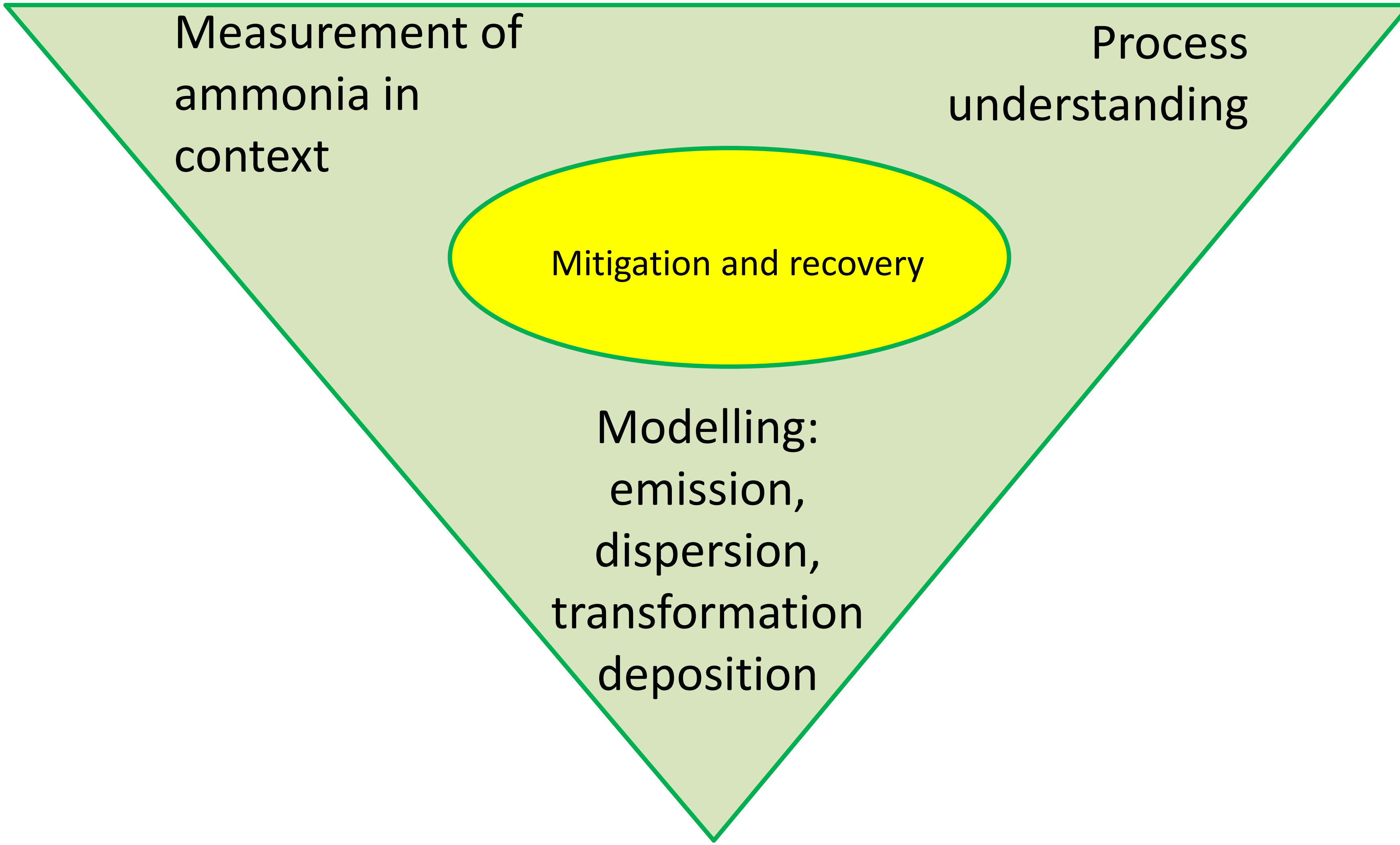
Knowledge gaps in all areas



Current Instrumentation

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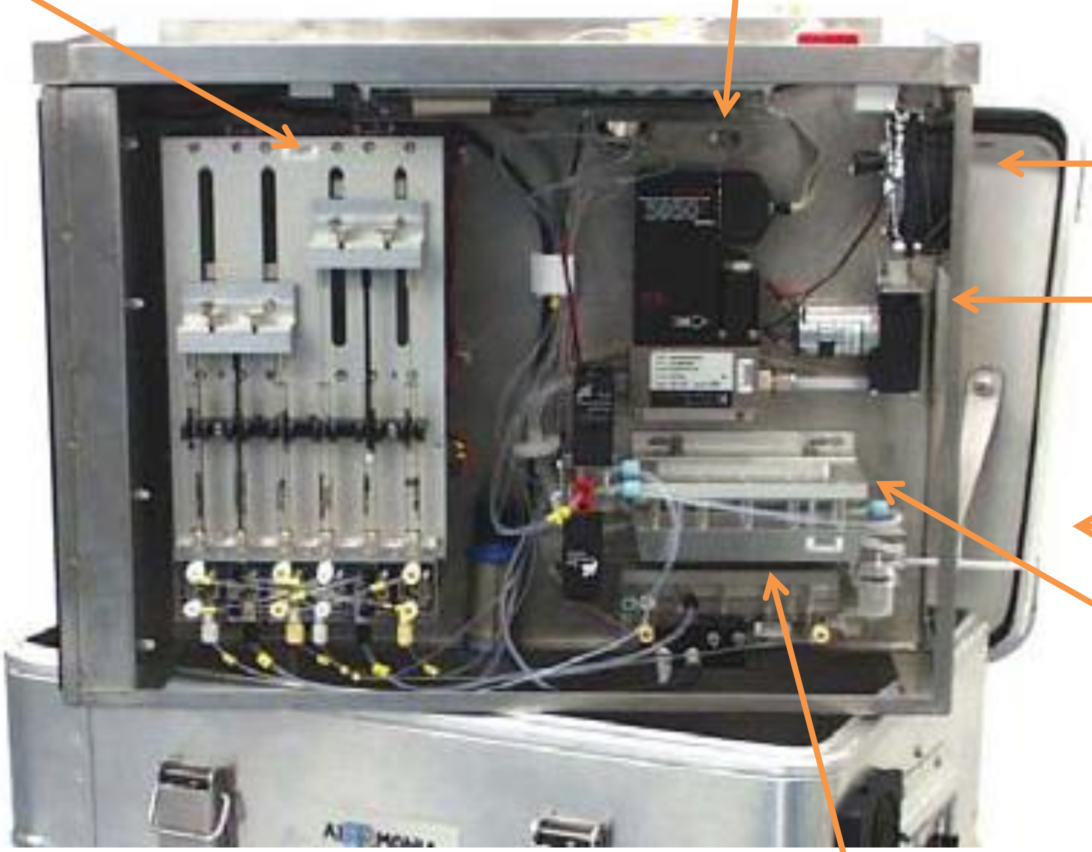
Wet chemistry



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Instrumentation

Non-extractive sampling

Most commercial spectrometers are based on infrared spectroscopy, though UV instruments also developing

Ammonia Sensors

Alphasense
NH_3 Sensor: NH3-A1
Range: 0 – 50 ppm

Alphasense
NH_3 Sensor: NH3-B1
Range: 0 – 100 ppm

http://www.indsci.com/products/ammonia/#

Personal single-gas detector GasBadge® Pro

Multi-gas detectors:
Ventis™ Pro Series
MX6 iBrid™
Radius™ BZ1 Area Monitor

Range = detect low ppm ammonia

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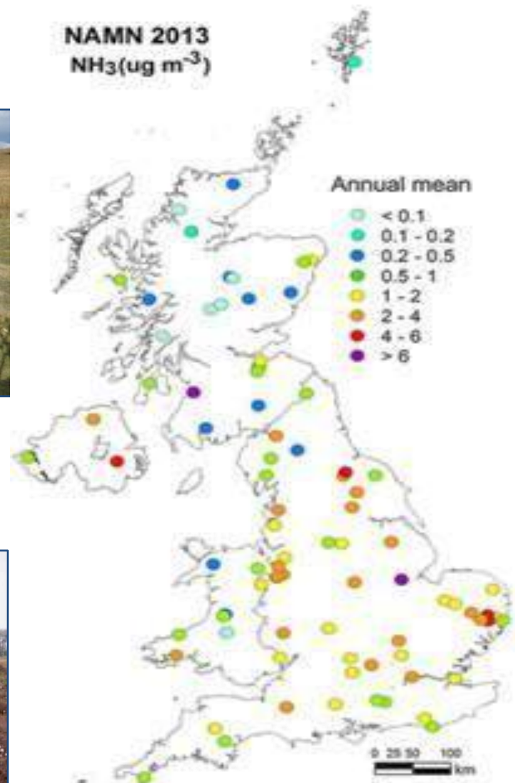
Atmospheric Composition Change

National Ammonia Monitoring Network



Local Environmental Impact information

Air pollution information service APIS

http://www.apis.ac.uk/

Screening tools e.g. SCAIL

http://www..scail.ceh.ac.uk/

Local Environmental Impact Assessments and planning

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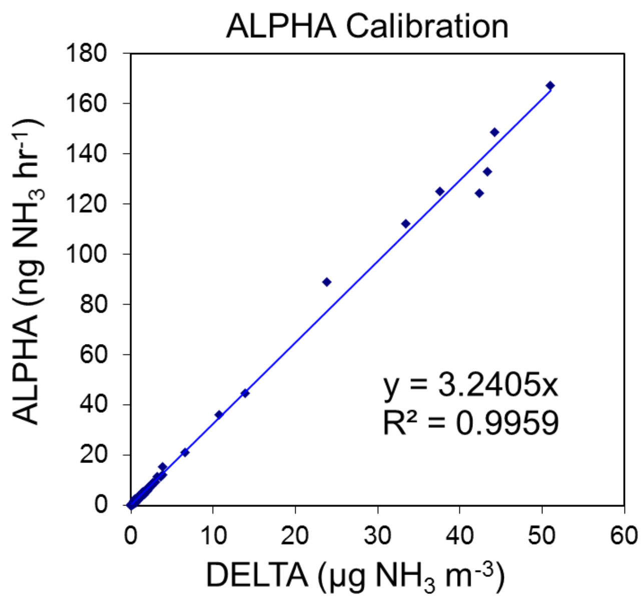
Calibration



	parameters	unit
Int diameter	0.021	m
Cross Area	0.000346361	m^2
Diffusion coefficient (@10ºC)	0.0000209	$m^2\ s^{-1}$
length(z)	0.00804	M
Sampling Rate	9.00365E-07	$m^3\ s^{-1}$
	3.24131472	$L\ hr^{-1}$
	0.003241315	**$m^3\ hr^{-1}$**

$$D(T,1) = D(0,1)(T/To)^{1.81}$$

D = 2.226 x 10^{-5} $m^2\ s^{-1}$ at 20°C (NH_3)

Calibrated Uptake Rate @ 20° C = 3.45 x 10^{-3} $m^3\ hr^{-1}$

cf 3.49 x 10^{-3} $m^3\ hr^{-1}$ (chamber exposure validation)

Martin N. et al. (2018) Validation of ammonia diffusive and pumped samplers in a controlled atmosphere test facility using traceable Primary Standard Gas Mixtures. Atm. Env. Submitted

$$V = DAt/L$$

t = time of exposure (s)
A = area of absorbent filter (m^2)
L = diffusion path length (m)
D = 2.09 x 10^{-5} $m^2\ s^{-1}$ at 10°C (NH_3)

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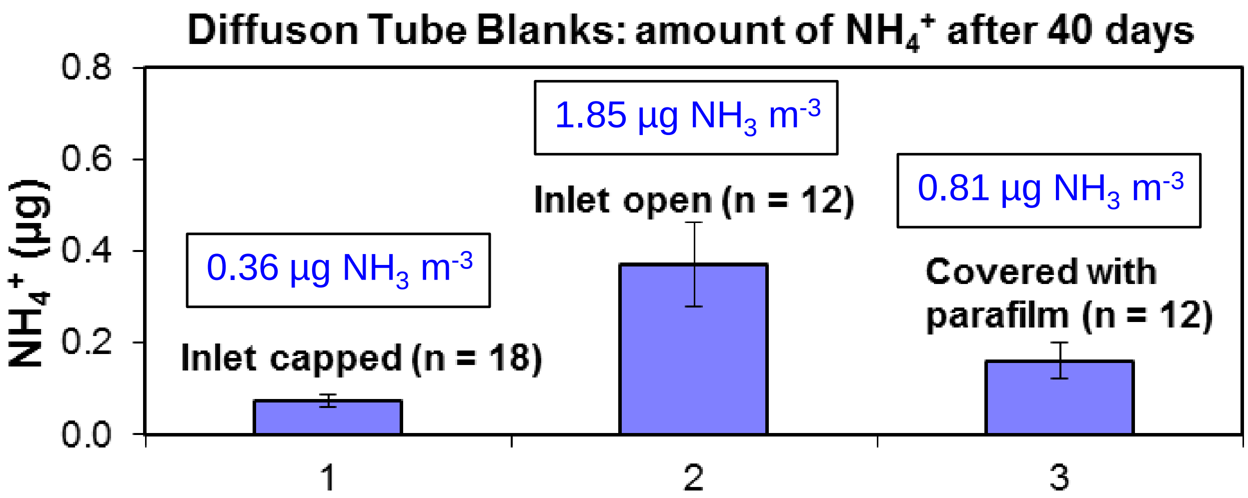
Contamination artefacts



Inlet	µg NH_4^+	µg NH_3 m^{-3}
Covered with Solid Cap	0.07 ± 0.01 (n = 18)	0.36 ± 0.07 (n = 18)
Not covered	0.37 ± 0.09 (n = 12)	1.85 ± 0.45 (n = 12)
Covered with parafilm	0.16 ± 0.04 (n = 12)	0.81 ± 0.19 (n = 12)

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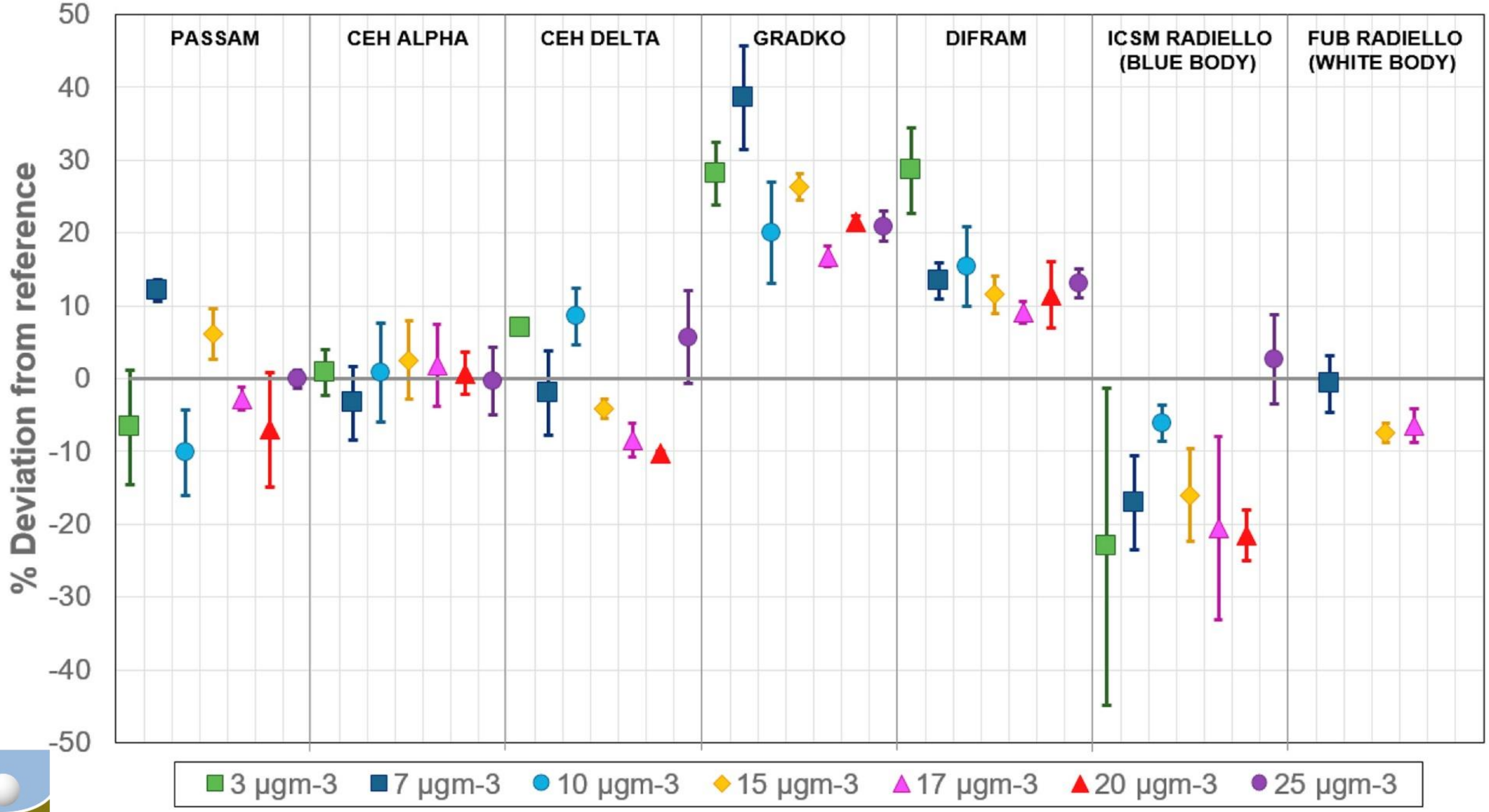
Diffusive and pumped samplers tested in NPL CATFAC



Martin et al. https://doi.org/10.1016/j.atmosenv.2018.11.038

MetNH3

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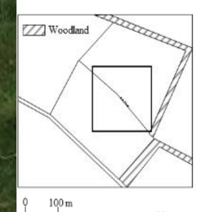
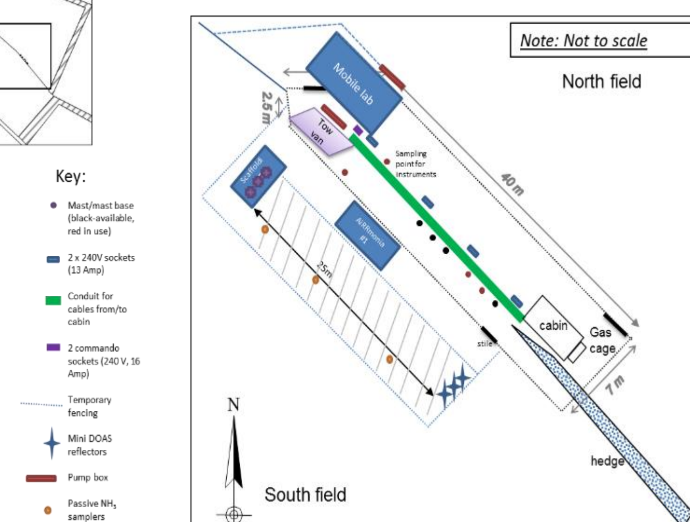
2016 Ammonia Intercomparison



Approximate sampling height 1.7 m



Twigg et al. *in prep*

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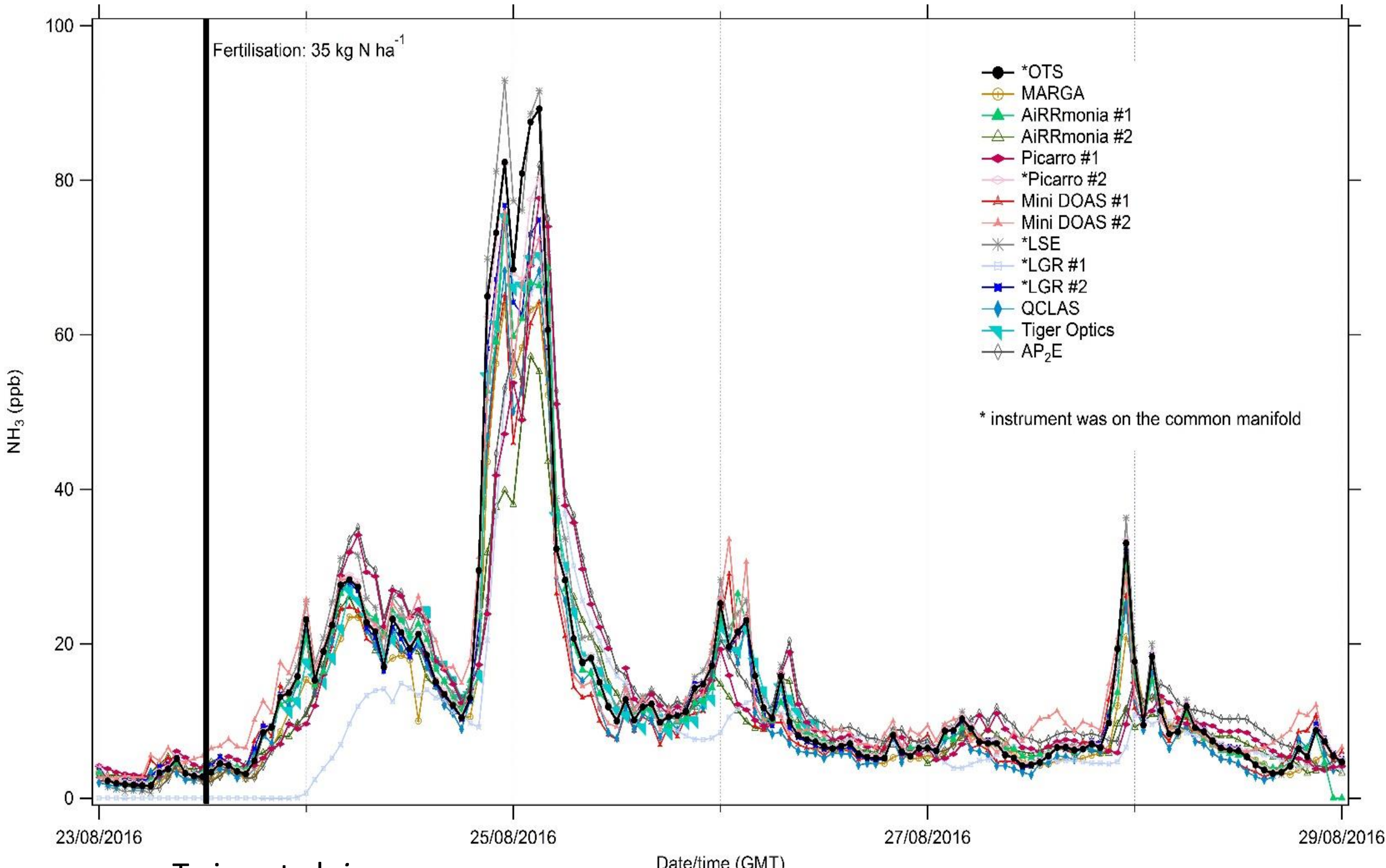
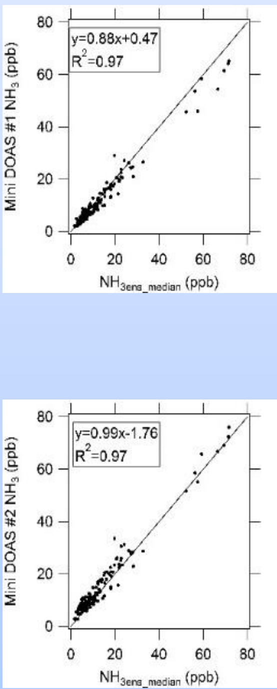


Twigg et al. *in prep*

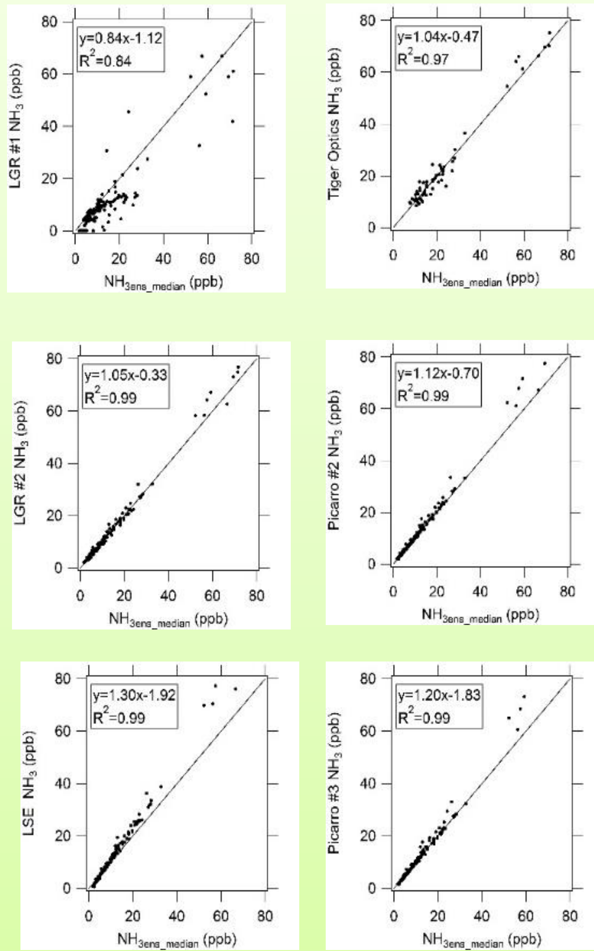
Instruments vs Ensemble median (23/08 -29/08)

MetNH3

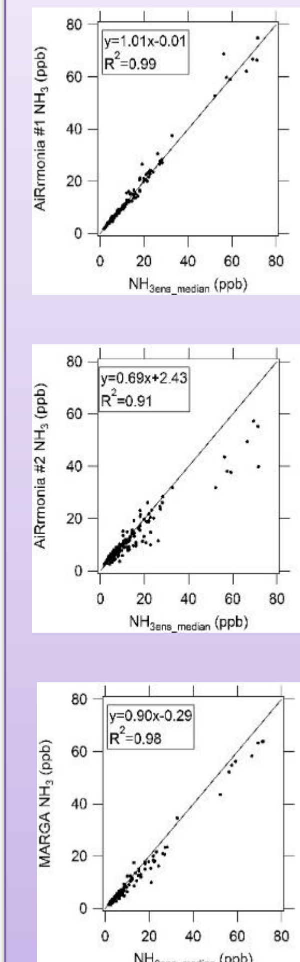
Mini DOAS



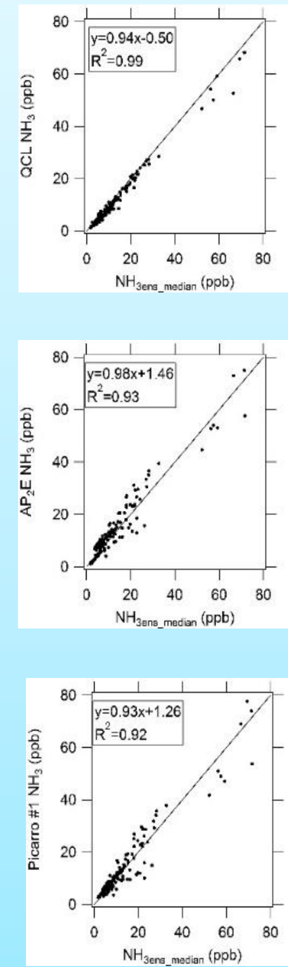
Manifold



Wet chemistry



Individual inlets



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Twigg et al. *in prep*

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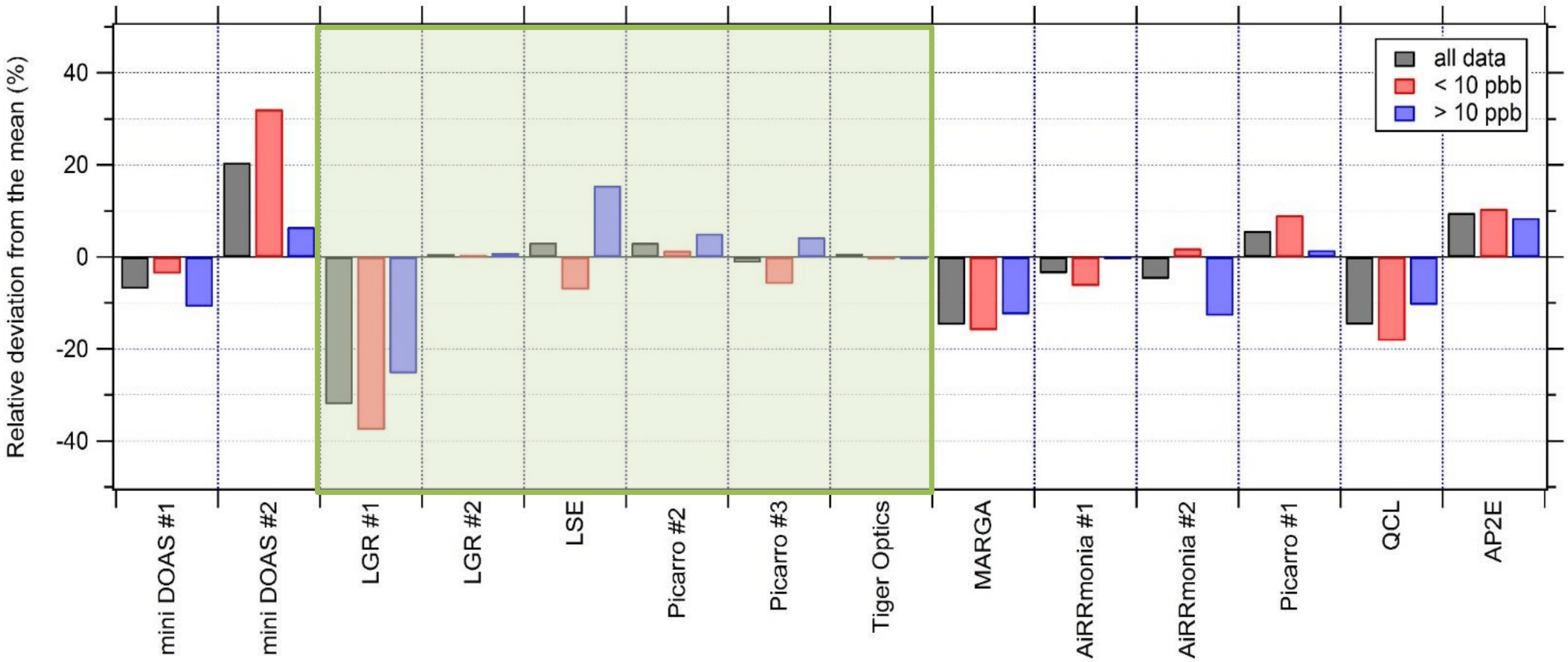
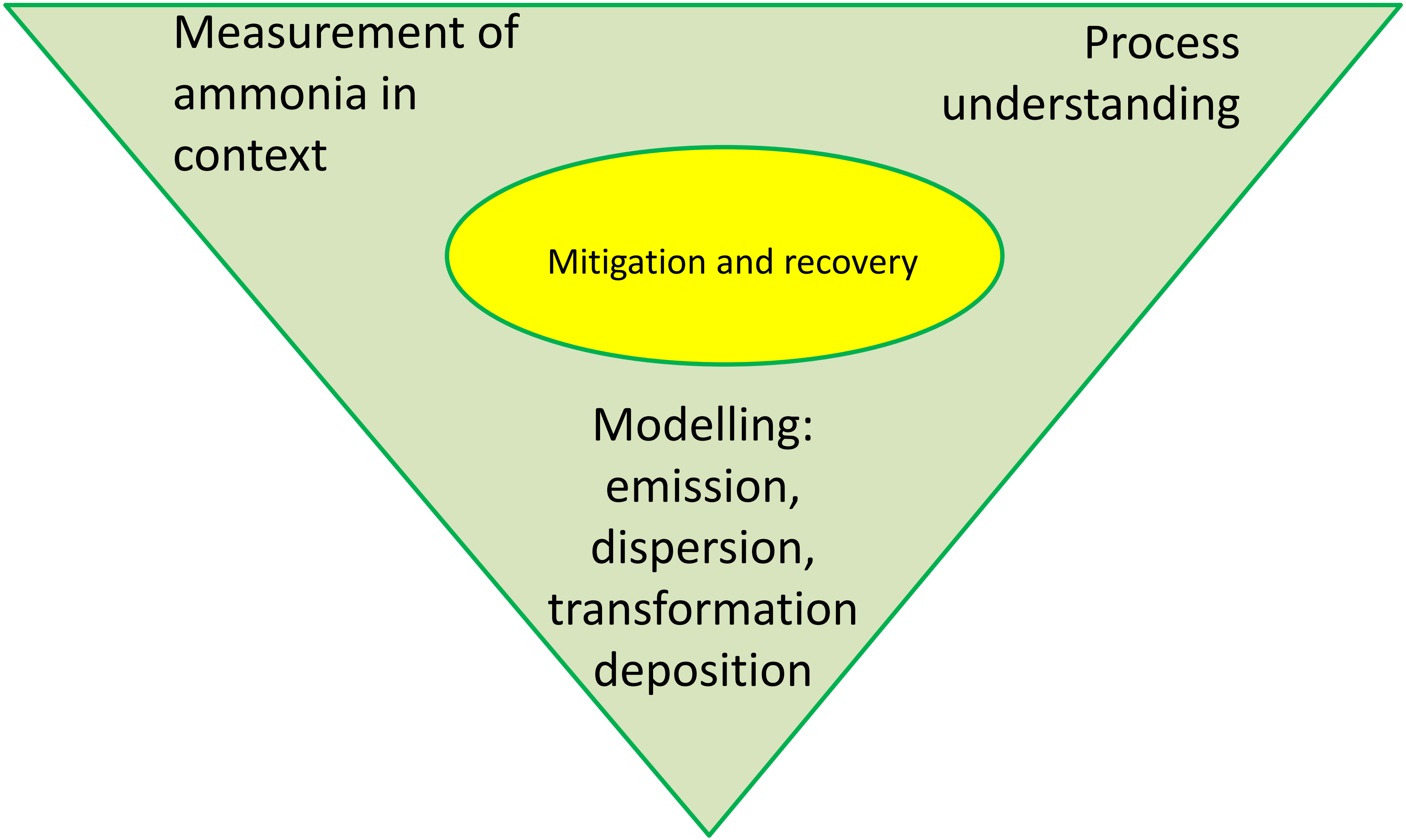
Relative deviation from the mean



Twigg et al. *in prep*

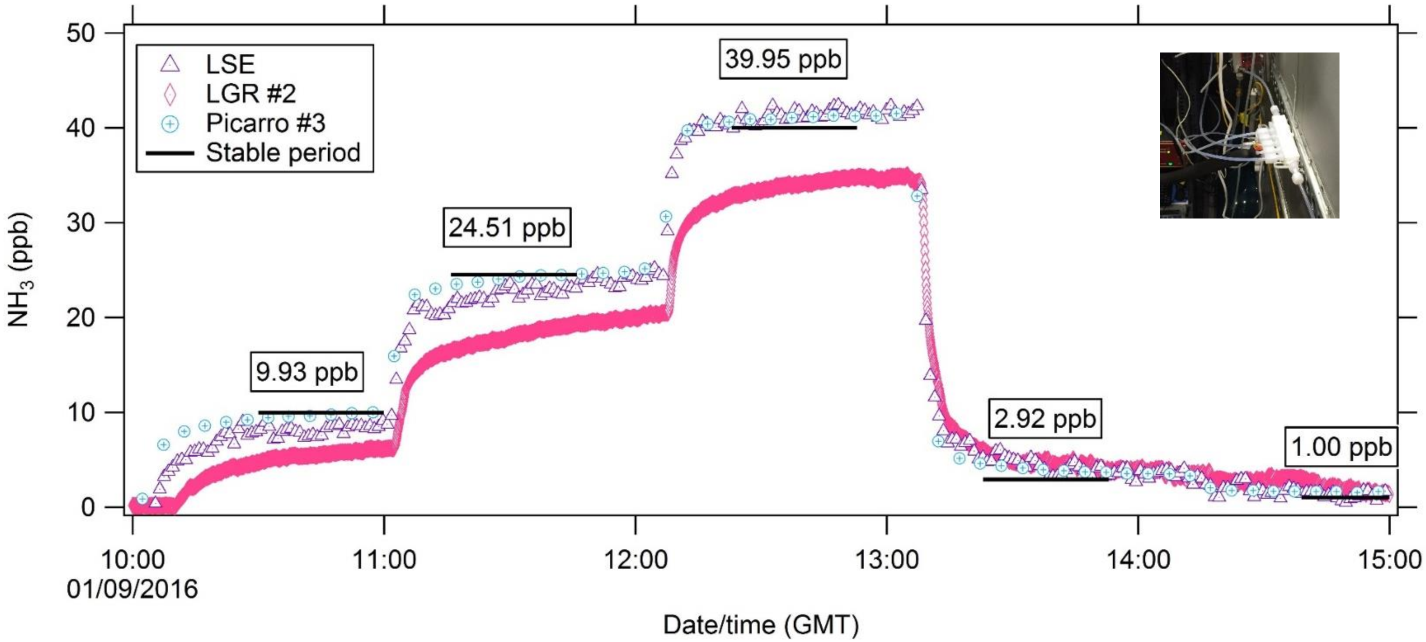
Knowledge gaps in all areas



Field calibrations

- 1 dynamic and 1 static calibration systems present
- METAS traceable reference gas generator (REGaS) used to check concentrations before and after intercomparison for low flow instruments (Picarro, LGR, LSE, Tiger Optics)
- NPL static calibrator used for high flow instruments and mini DOAS

Provisional field calibration results



REference GaS generator (ReGaS1) – dynamic gas generator developed and characterised by WP1 of MeNH3 project.

Twigg et al. *in prep*

Conclusions from state of the art instruments

SET UP IS MAJOR FACTOR IN GETTING HIGH QUALITY MEASUREMENTS OF NH_3

- Users still need some understanding in order to choose the right instrument for their application
- Instruments either need minimal inlet or a high-flow inlet with sub-sampling off for operation
- Dynamic calibration should work but instrument response time make calibration challenging
- Quantitative measurement at “background” to close to emissions challenging

MetNH3

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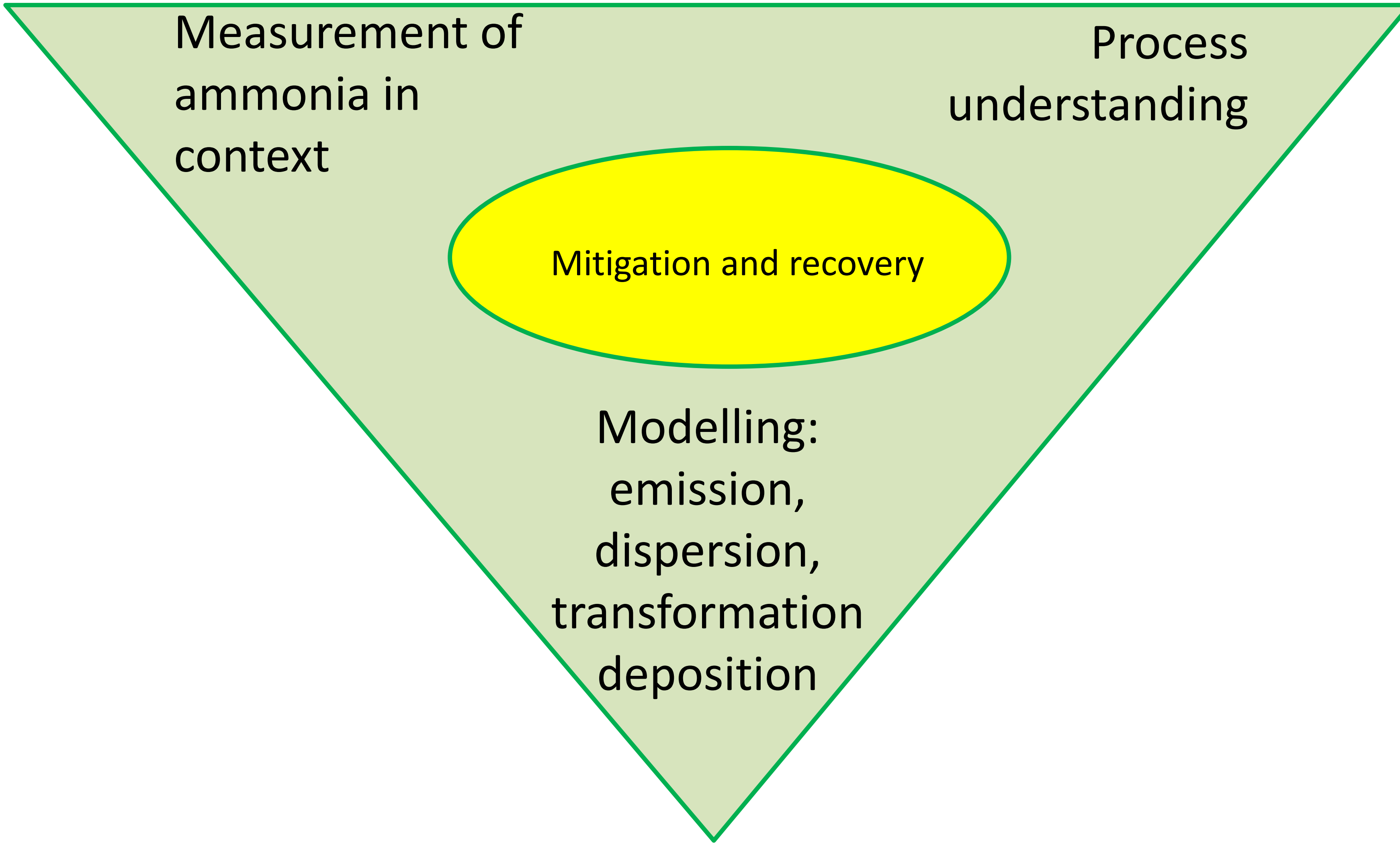
Knowledge gaps in all areas



How to improve the situation in the 21st century?

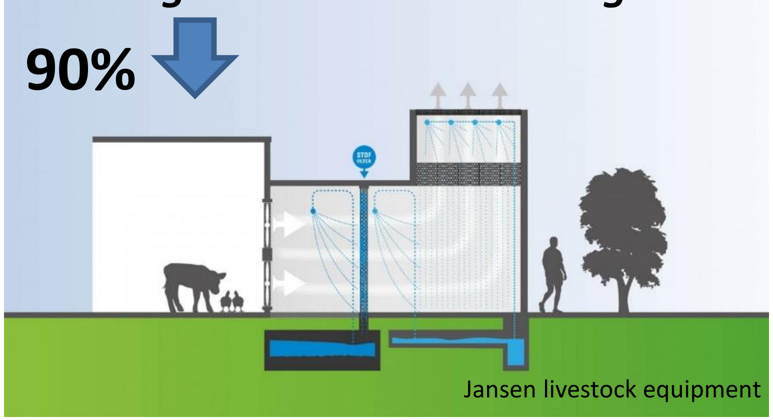
- Emitting less directly
  - Process change
  - Efficiency of use
  - Fewer "leaks" in the system
- Recapturing emissions
  - Green removal e.g. Agroforestry or "sacrificial" vegetation
  - Barriers (green or otherwise) between emissions and impacts

Mitigation Measures for Reducing Ammonia

Spreading - Injecting manure

Storage - covers

Housing – ammonia scrubbing



Increased grazing and woodland effect

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Multiple wins?

Tree belts for ammonia mitigation offers multi win wins for the famer and society

improved animal welfare under silvopastoral systems

reducing critical load exceedance on protected sites

carbon sequestration

visibility screening around housing units

supporting policy and regulators in emission reduction

supporting national afforestation policies.

price advantage of 'woodland chicken/pig' products

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Dis-benefits?

where NH_3 concentrations are high the rate of dry deposition is less

young trees may 'suffer' with increased NH_3 concentrations – careful species selection

adding nitrogen into the system can cause nutrient imbalances - availability of base cations

trees may encourage wild birds and bird-flu infection

opportunity cost – changing arable to woodland

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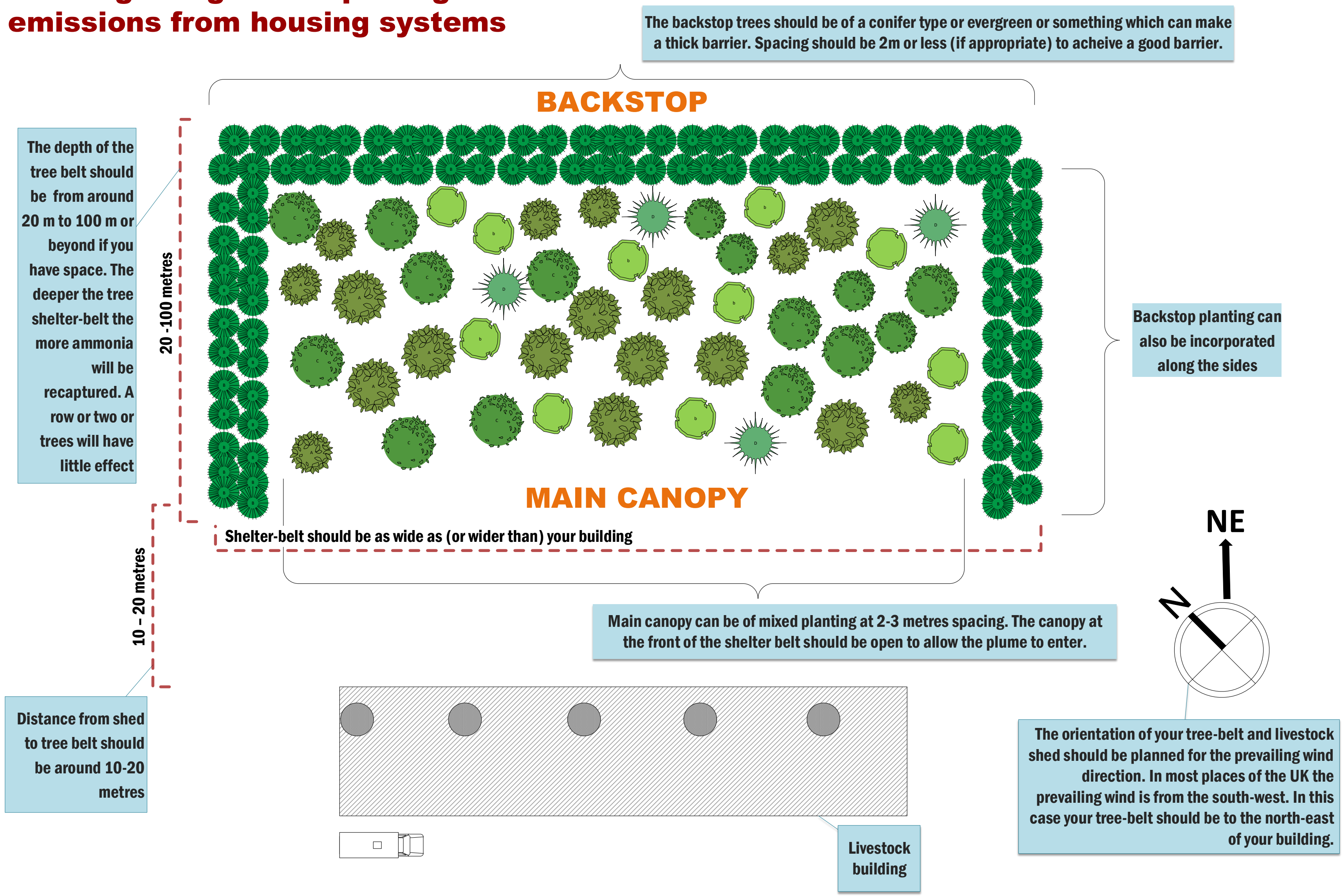
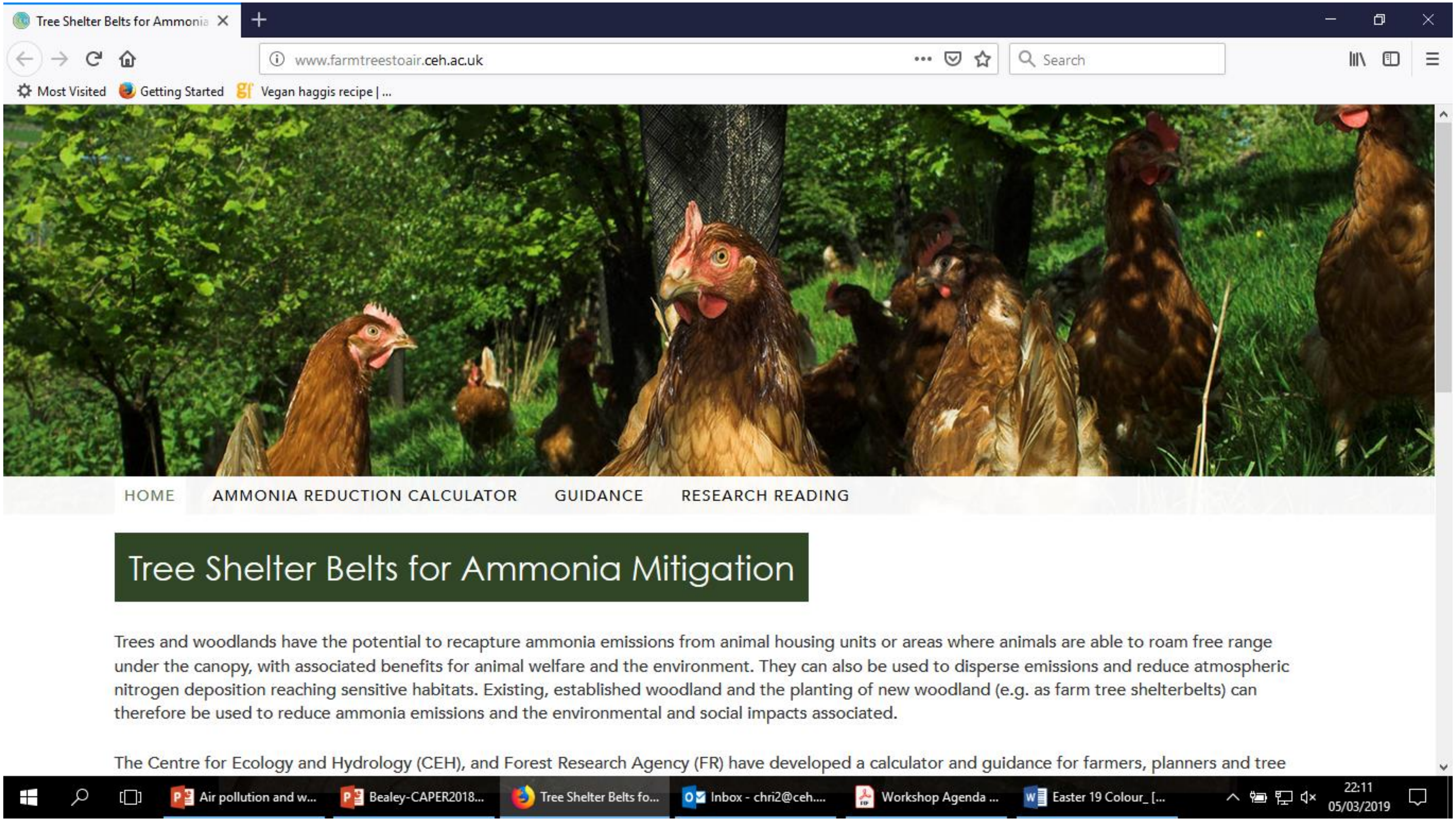
Planting Designs

Planting design for capturing ammonia emissions from housing systems



Farmtreestoair:
New tool based on current knowledge



http://www.farmtreestoair.ceh.ac.uk/

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Conclusions

- Atmospheric chemistry of ammonia is in its infancy
- Ecosystem, climate and human health impacts beginning to be well documented
- There is a need for laboratory process studies, further development of instrumentation
- On-line long term monitoring of ammonia beginning in the UK, and across the world
- Review paper on measurement protocols and knowledge gap in preparation
- Global emissions in most scenarios get bigger throughout the 21st century, so emission reduction and/or mitigation actions need to be prioritised

Thank you very much for your attention. ☺

Any questions.

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