

Measuring ammonia losses from agroforestry systems

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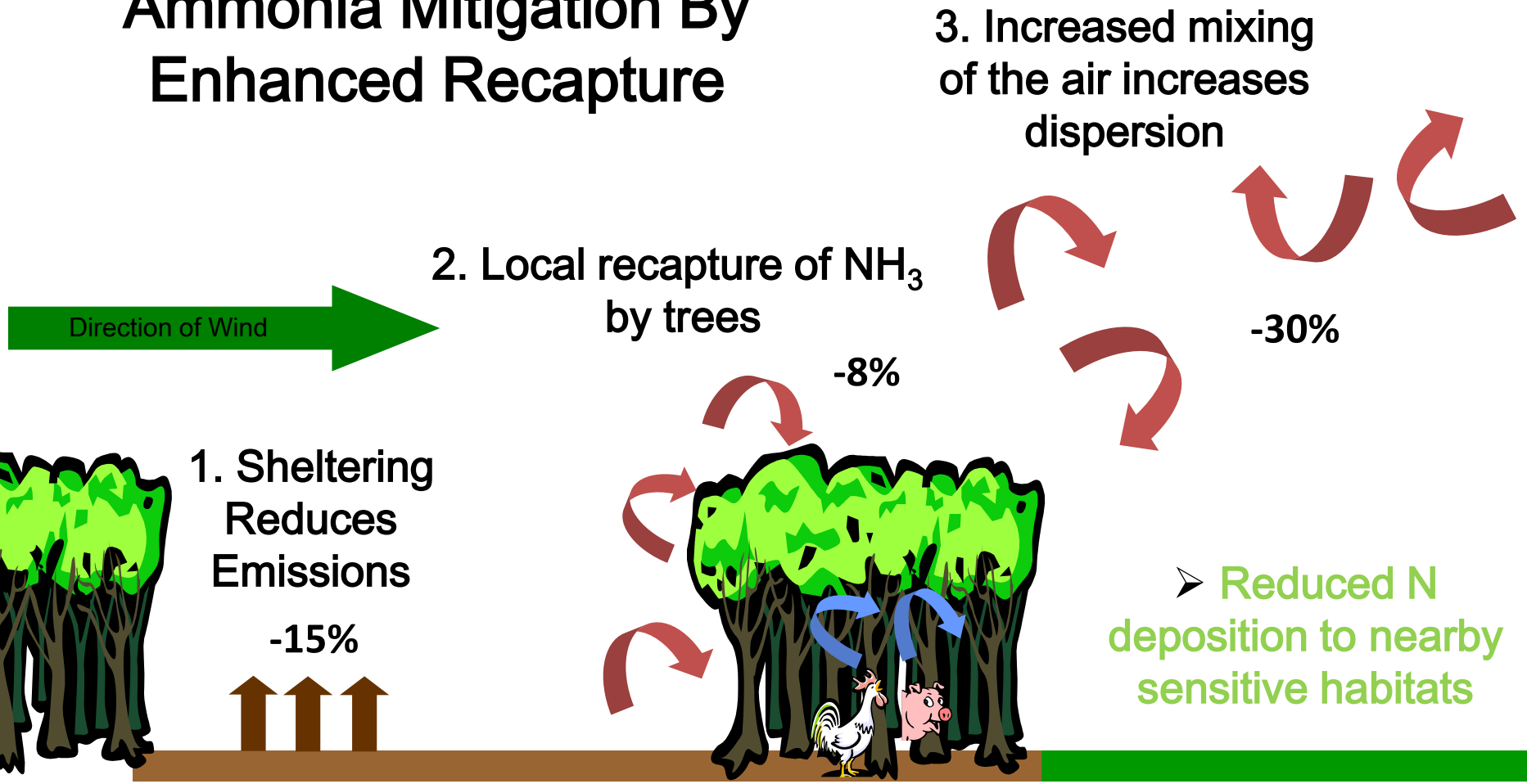


OUTLINE

- **SAMBA: agroforestry ammonia abatement**
- **Example measurement approaches for quantifying ammonia emissions**
- **Overview of ammonia measurement methods**
- **Ammonia Metrology Project: upcoming field intercomparisons in 2016**

SAMBA: : agroforestry ammonia abatement

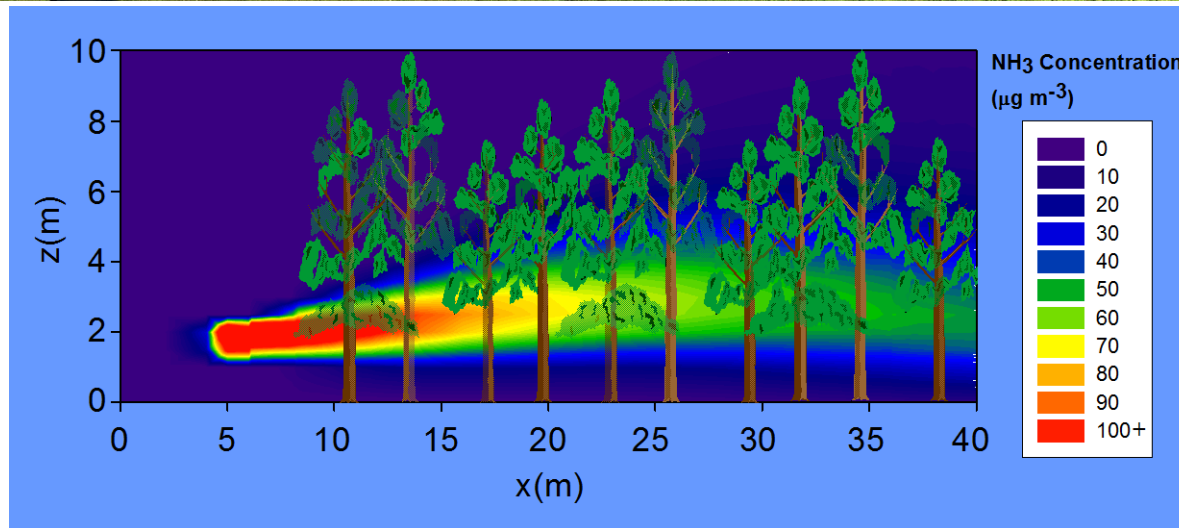
Ammonia Mitigation By Enhanced Recapture



Ammonia sources (slurry pits)

4. Recapture of NH_3 from livestock under trees -80%?

SAMBA: agroforestry ammonia abatement



- 1. Wind tunnel studies and modelling (and design): Efficacy of woodlands to recapture ammonia.**
- 2. Field measurements and modelling: Recapture of below canopy emissions.**
- 3. Case studies: Practical feasibility of agroforestry ammonia abatement.**

Bealey et al. (2015) Agroforestry Systems for Ammonia Abatement AC0201. Final Report to Defra.

Bealey et al. (2014) Modelling agro-forestry scenarios for ammonia abatement in the landscape.

Environ. Res. Lett. 9, 125001 (15pp)

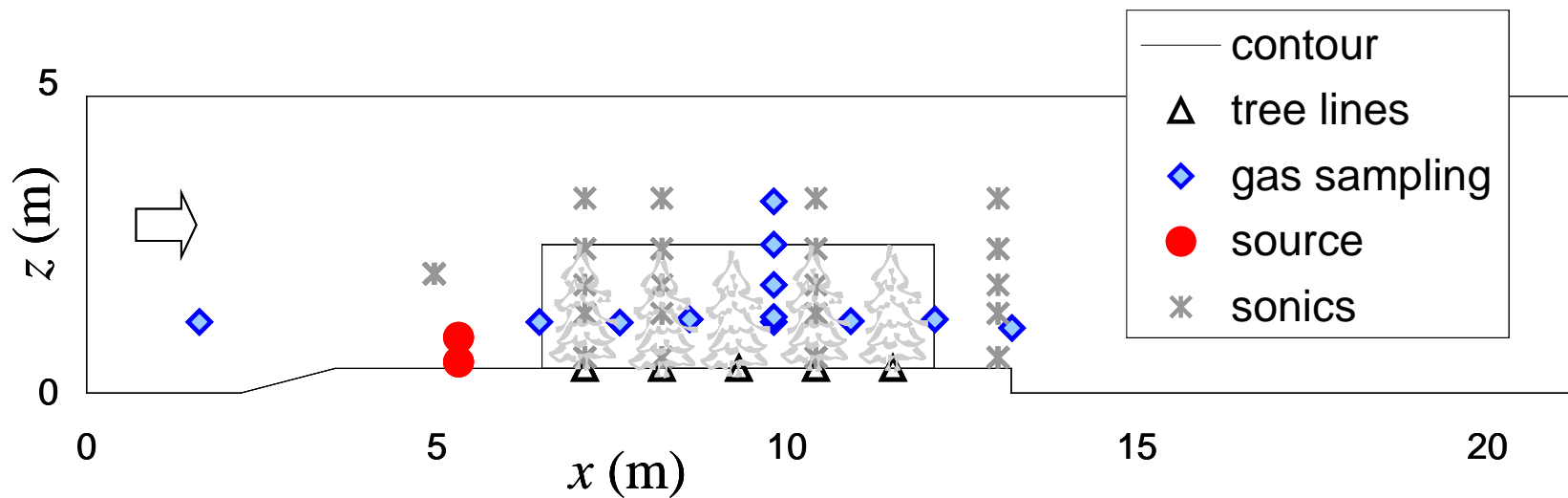
Wind Tunnel Experiment



“empty” wind tunnel



“conifers” in wind tunnel

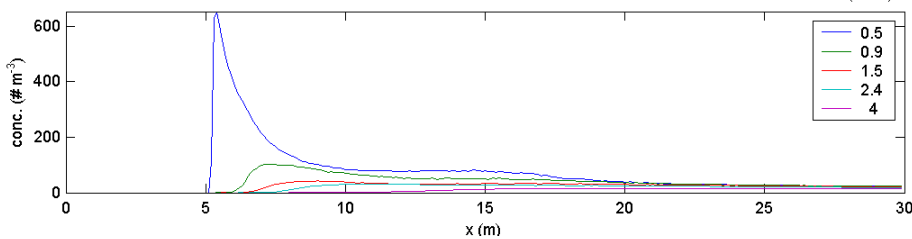
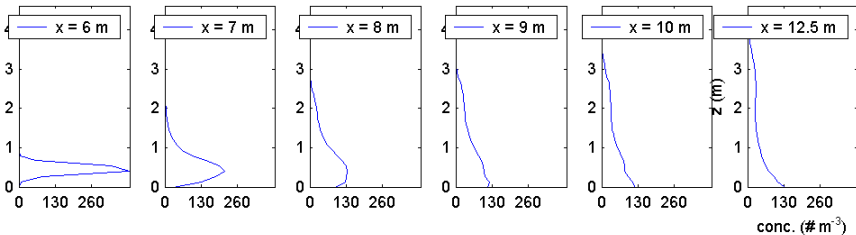
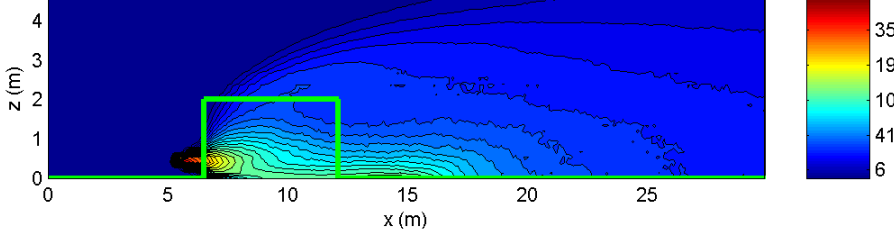


Wind Tunnel Experiment

METHANE

SAMBA Wind tunnel low flow average sans plexi

Concentration # m⁻³

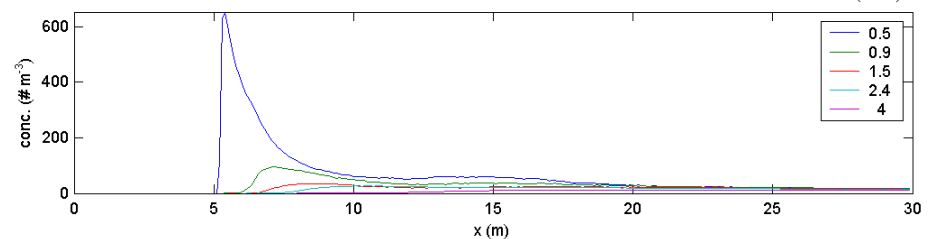
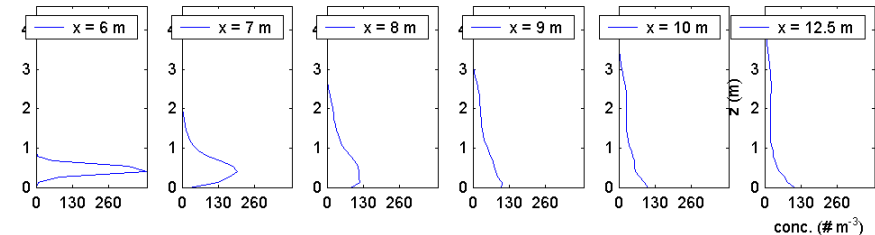
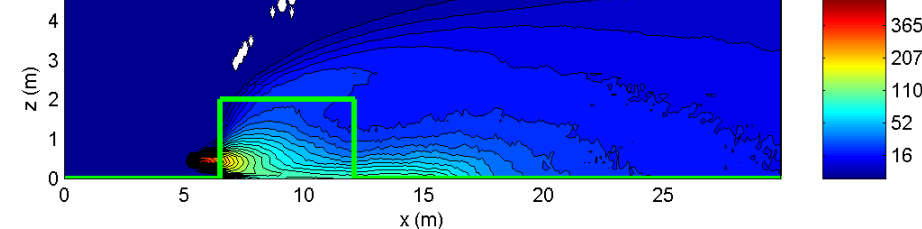


[CH₄] modelled by MODDAS-AQUILON at a source strength of 100 μg m⁻¹s⁻¹

AMMONIA

SAMBA Wind tunnel low flow average sans plexi with deposition

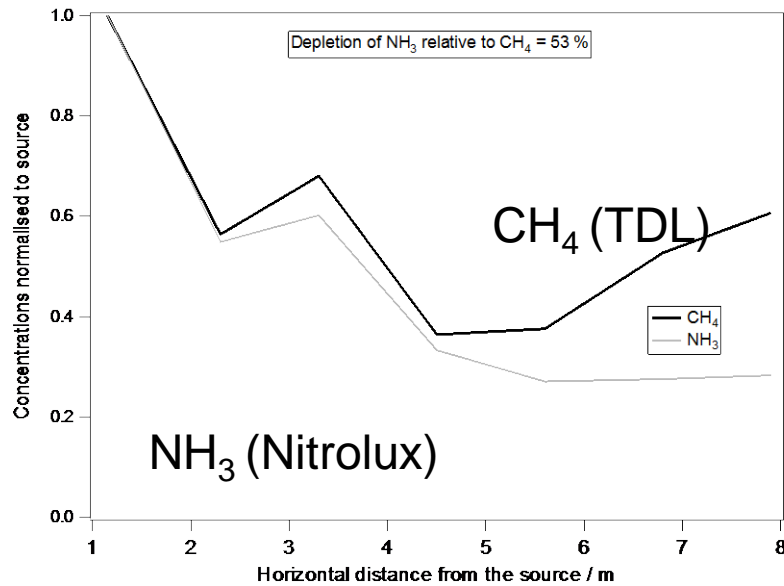
Concentration # m⁻³



[NH₃] modelled by MODDAS-AQUILON for a source strength of 100 μg m⁻¹s⁻¹

Turbulence data used to improve AQUILON - 2nd order closure turbulence model that predicts the flow and turbulence field of complex structures

Wind Tunnel Experiment

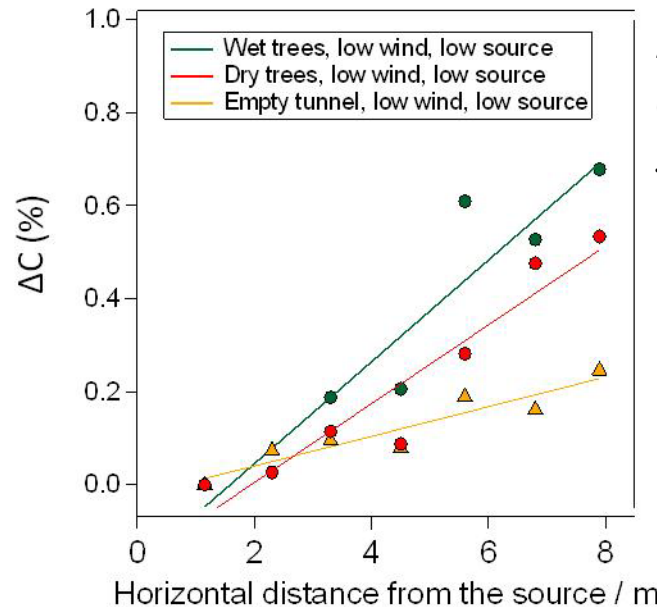


Example [CH₄] and [NH₃] profile along wind tunnel length

“depletion factor” ΔC is directly proportional to actual NH₃ uptake by trees

$$c_n = \frac{c - c_0}{c_1} \quad \text{E1}$$

$$\Delta C = \frac{c_n(\text{CH}_4) - c_n(\text{NH}_3)}{c_n(\text{CH}_4)} \quad \text{E2}$$



ΔC as a function of distance from line source for wetted trees (blue), unwetted trees (red) and empty tunnel (yellow)

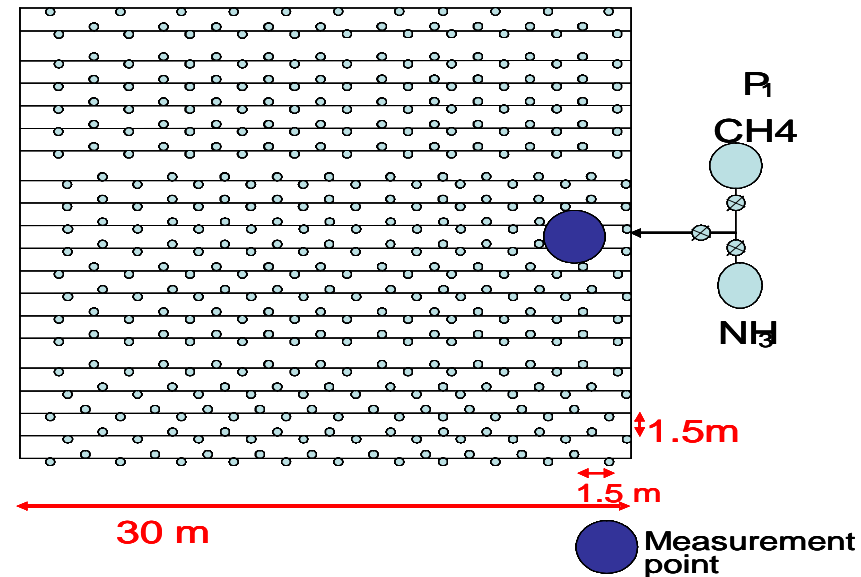
SAMBA: Forest recapture of NH_3

OBJECTIVE: quantify NH_3 recapture in a woodland after release of NH_3 underneath the canopy.



Network of gas release lines laid across woodland floor

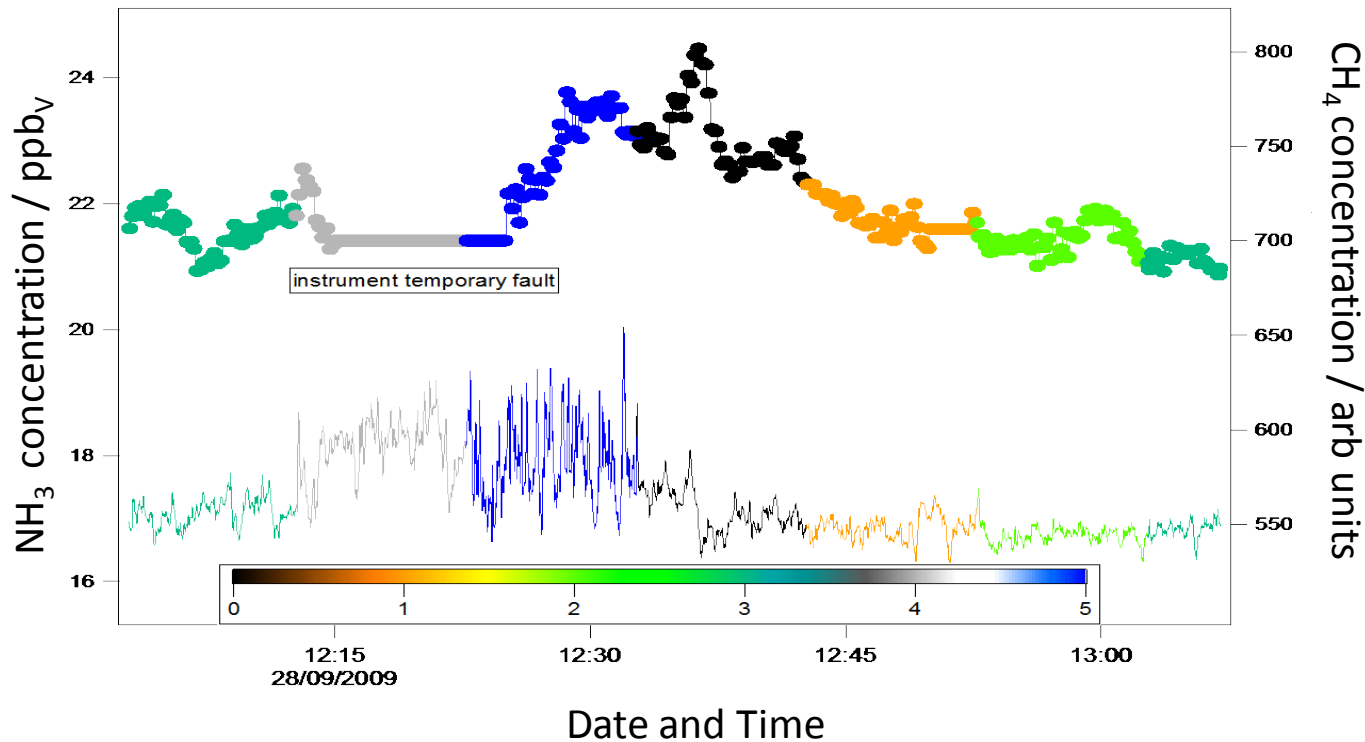
Schematic layout of “under-canopy” release experiment



Parameters measured:

- NH_3 (Nitrolux, Pranalytica)
- CH_4 (TDL)
- Wind profile, turbulence above & within canopy (mobile micro-sonic anemometer)
- Ambient meteorological conditions, leaf area index (LAI) and leaf wetness.

SAMBA: Forest recapture of NH_3



NH_3 and methane release experiment.
Colours represent measurements made at different heights
through the canopy

SAMBA: Case studies

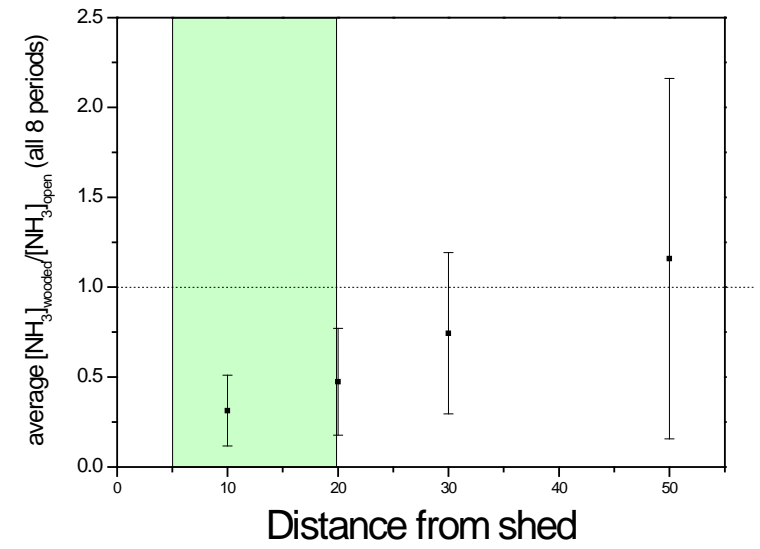
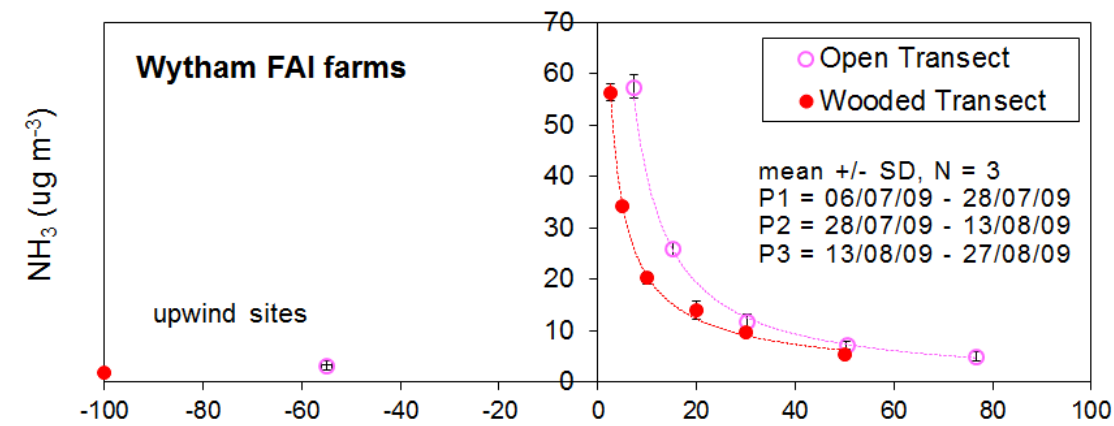
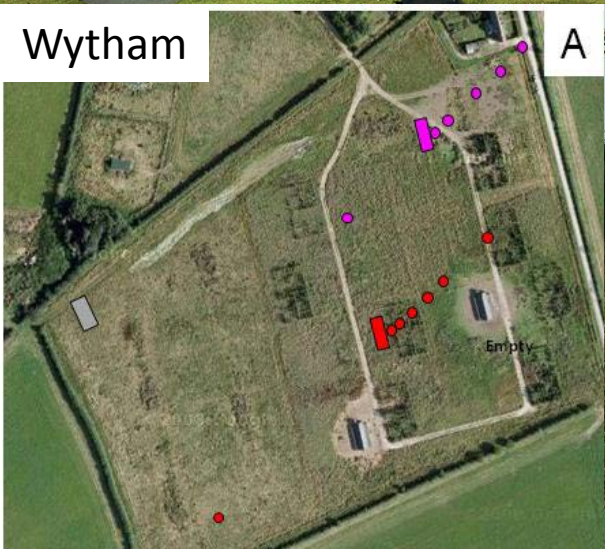
Farm	Farm type	Poultry type	Housing type	Bird #s/shed	Comment
A: FAI Farms, Wytham	Mixed animal farm	Free range	Arks	700	Research plot ¹
B: Din Moss, Fife	Poultry/ low intensity sheep	Free range	Sheds	3,000-20,000	Cleared conifer plantation
C: Freuchie Mill, Fife	Poultry	Free range	Sheds	5,000	Woodland egg scheme, new trees planted



[NH₃] measurements with Passive ALPHA samplers

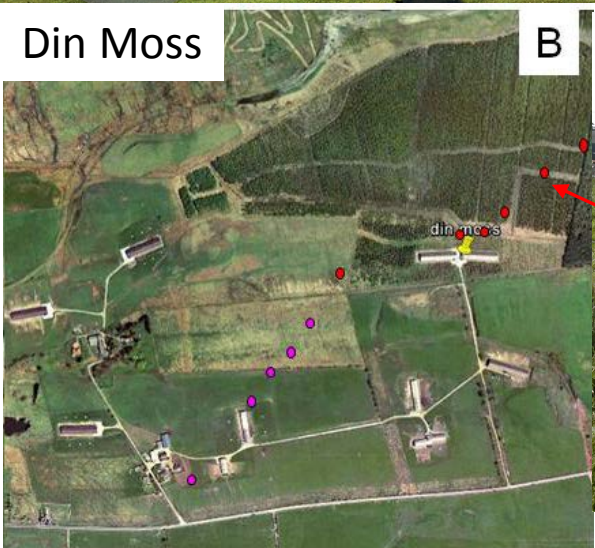
- Transects
- Monthly
- LOD = 0.03 $\mu\text{g m}^{-3}$

SAMBA: Case study 1

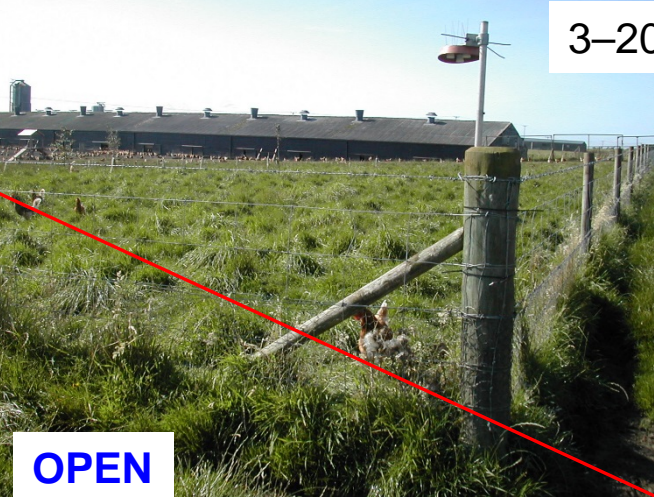


SAMBA: Case study 2

Din Moss



B

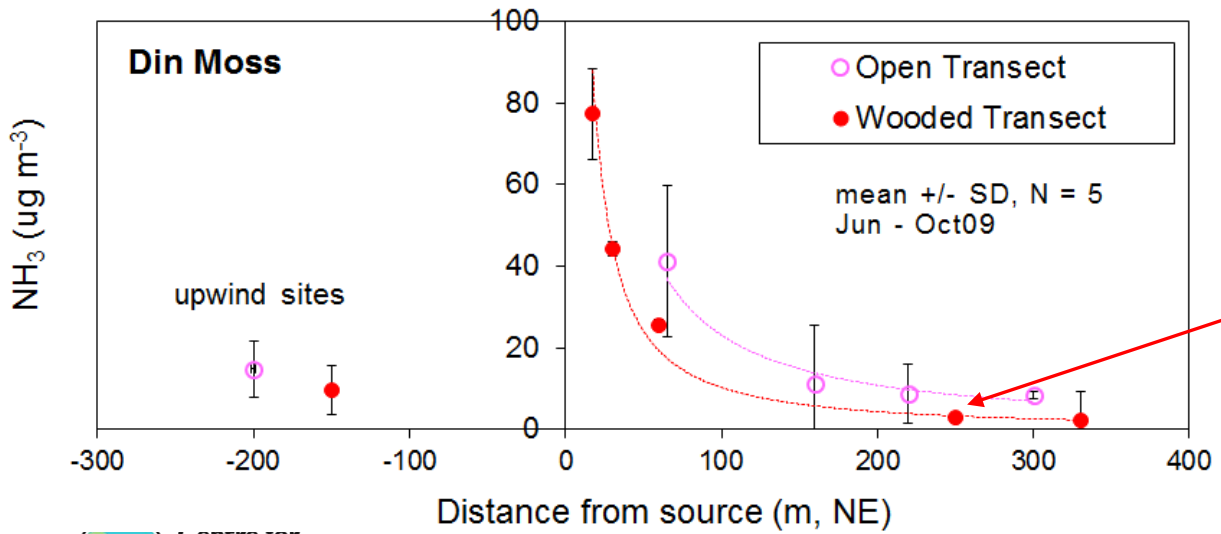


3–20K birds / shed

OPEN



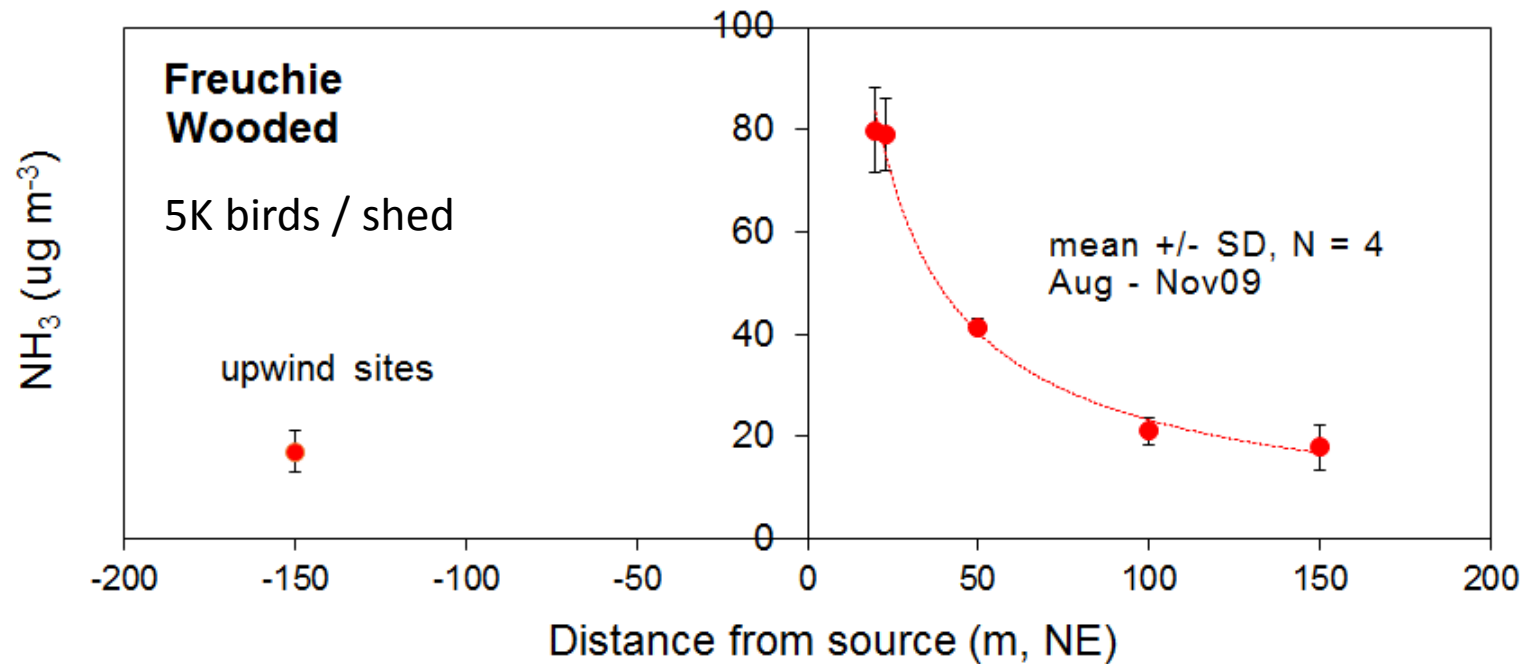
WOODED: Dense Conifer



SAMBA: Case study 3

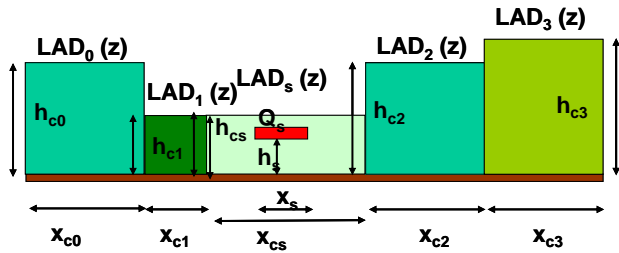


WOODED: broadleaf

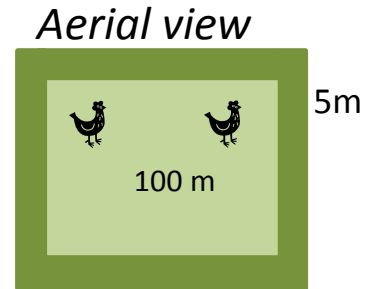


Modelling woodland scenarios

Different scenarios modelled using the INRA MODDAS-AQUILON to find out which setup is most efficient in capturing NH_3

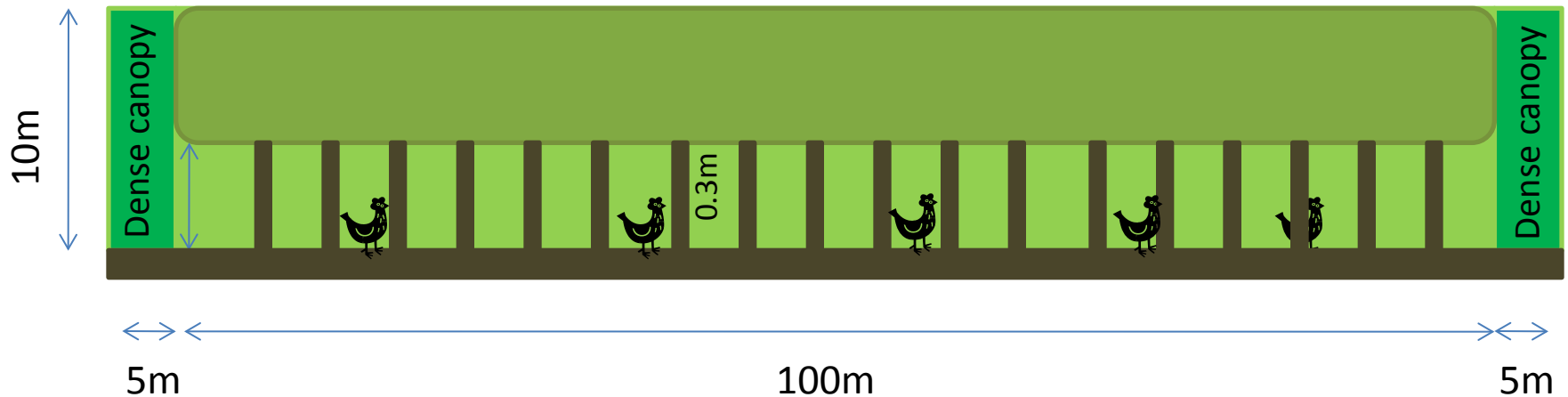


“under-storey” scenario



Deciduous (or pine) brushed up to 3-5m

Chicken roaming under the canopy on the ground, 0.3m



SAMBA: SUMMARY

- Wind tunnel experiment: tree belts capable of recapturing up to 18% of NH_3
- Case study woodland chicken farms demonstrates that woodland abates NH_3 levels at the local scale.
- Woodland designs modelled with INRA MODDAS-AQUILON to optimise recapture and dispersion.



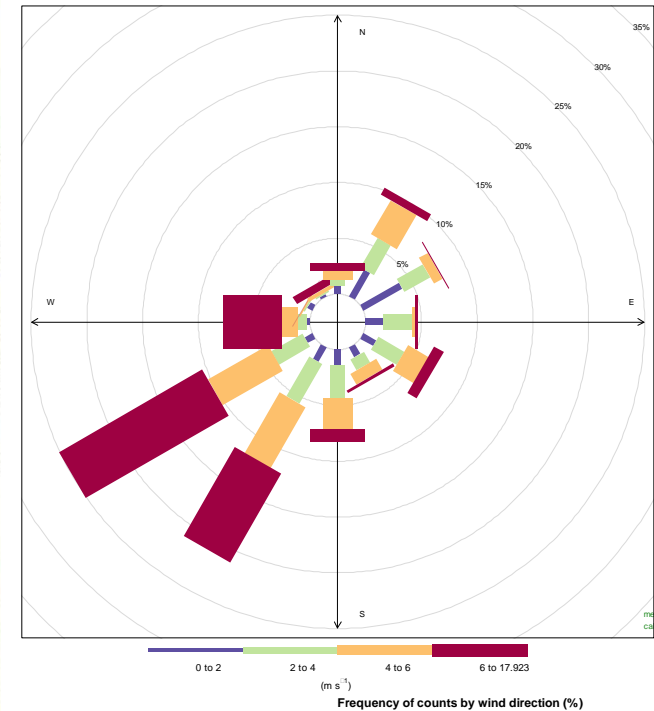
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Quantifying NH₃ emissions: SCAL validation



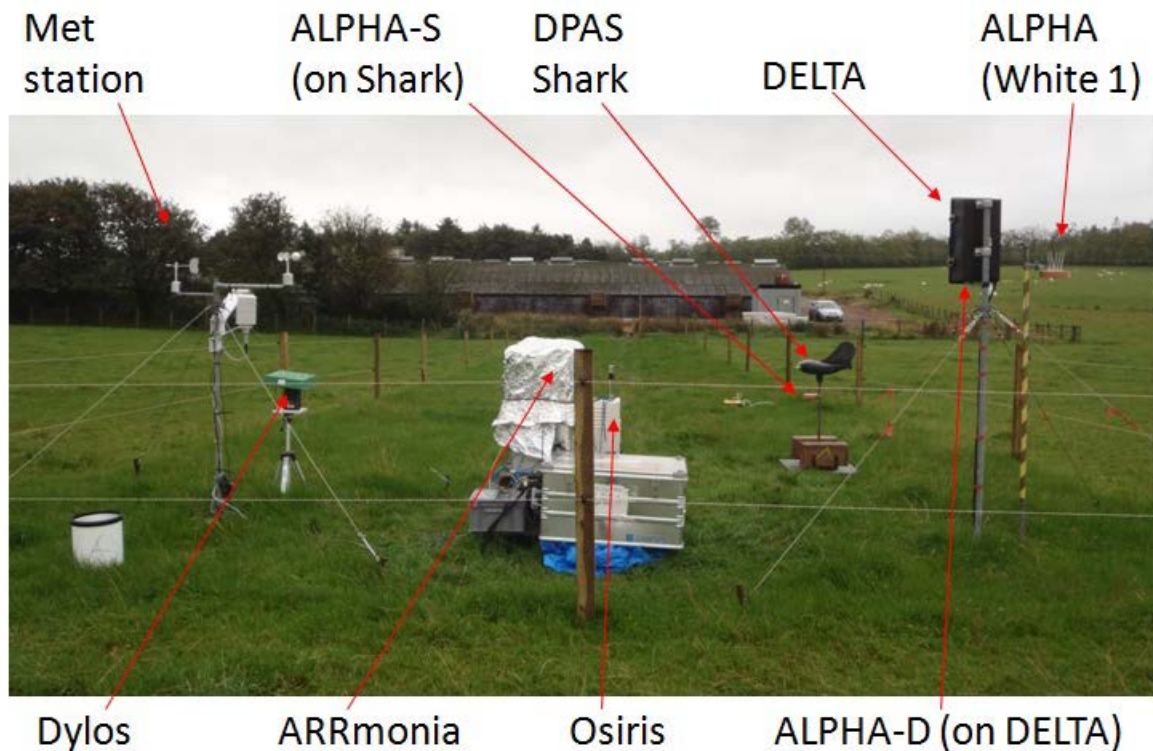
Wind rose showing prevailing wind direction comes from SW



Poultry Farm study area, showing the locations of NH₃ monitoring sites.
White 1 = meteorological and intensive measurement site.

Hill et al. (2014) Final Report - SNIFFER ER26: Model validation using monitored data from Scottish poultry farms.

Quantifying NH₃ emissions: SCAL validation



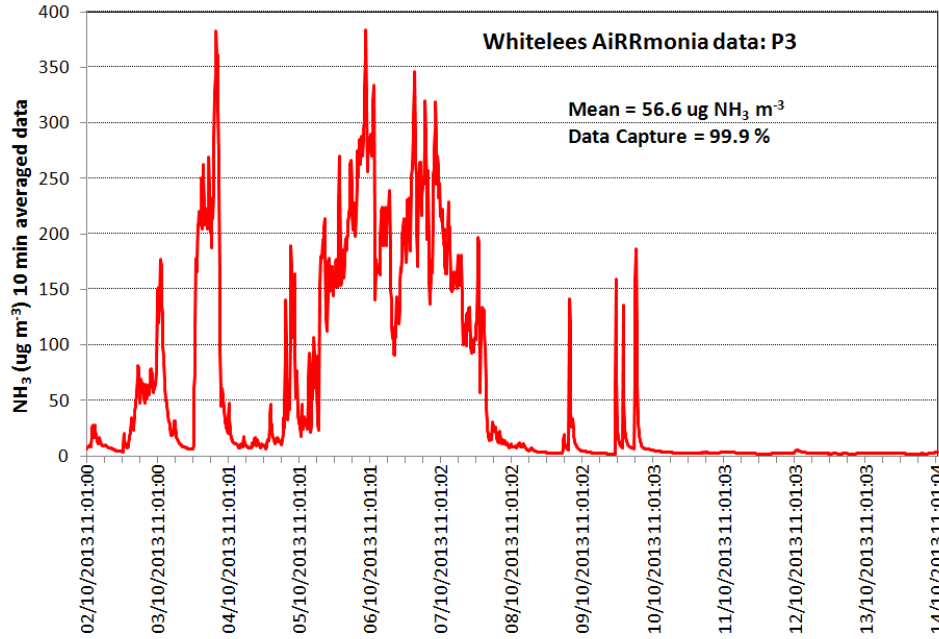
AiRRmonia

- 0.05 $\mu\text{g m}^{-3}$ to $\geq 300 \mu\text{g m}^{-3}$
- Time resolution 10 minutes.



Intensive site ~ 55 m NE of the farm

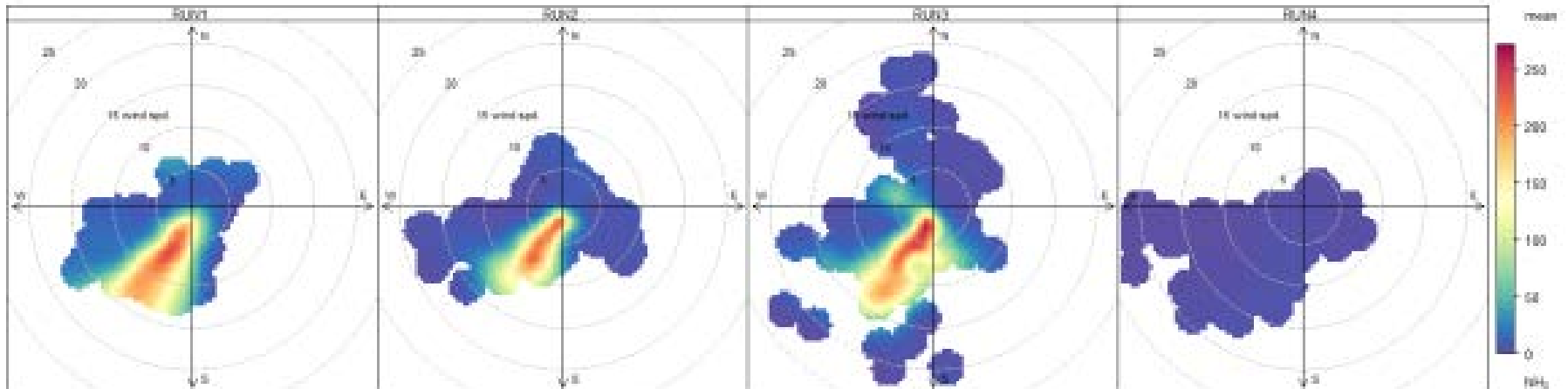
Quantifying NH₃ emissions: SCAL validation



RUN 3

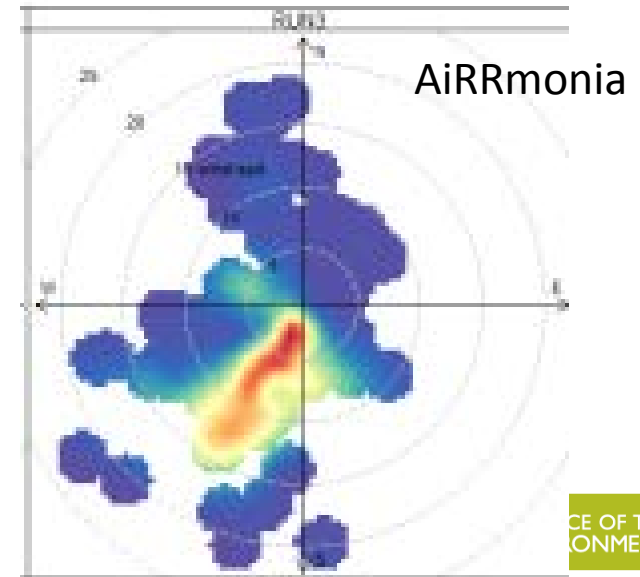
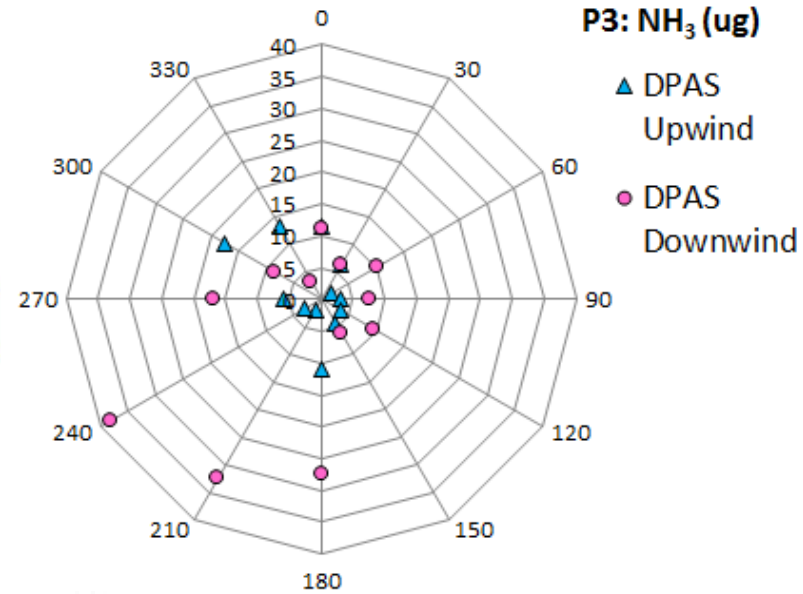
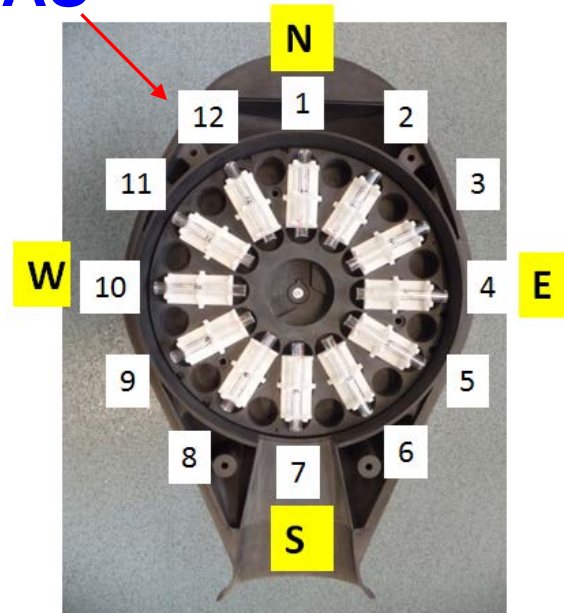
Co-located measurements:
ALPHA: mean = 51.2 ug m⁻³
DELTA: mean = 51.7 ug m⁻³

Polar plots of AiRRmonia [NH₃] by wind direction and wind speed for the 4 sample runs



Quantifying NH₃ emissions: SCAL validation

DPAS

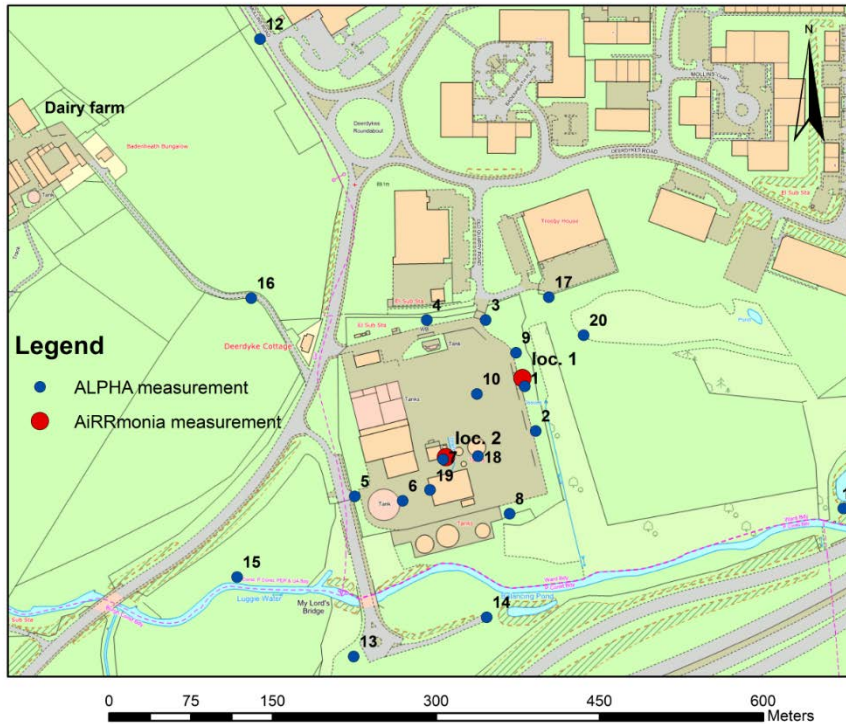


EA / Lancaster University: Patented

Ferranti et al. (2014) *Field-testing a new directional passive air sampler for fugitive dust in a complex industrial source environment*. *Env. Sci: Processes Impacts*. 16, 159-168

Braban et al. (2014). *Directional Ammonia Final Report*.

Quantifying NH₃ emissions: AD plant



AD plant + surrounding areas, showing locations of passive ALPHA and continuous AiRRmonia NH₃ measurement points



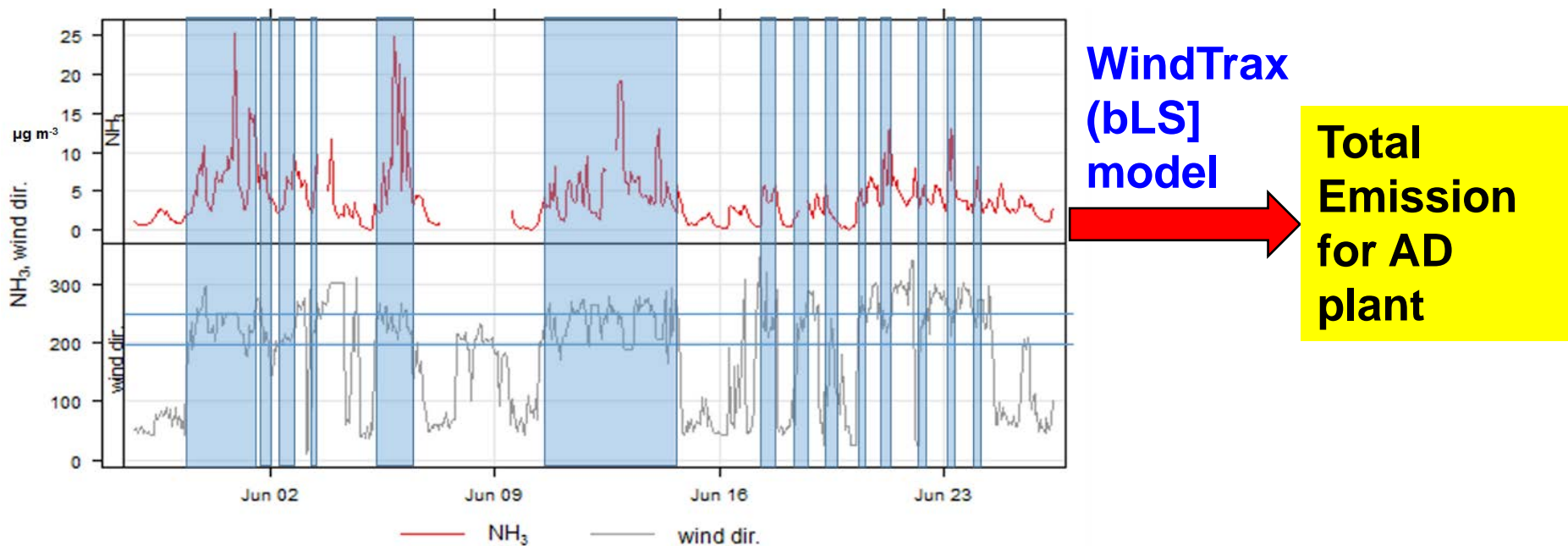
AiRRmonia + ALPHA samplers opposite digestate store

Bell M. (2014) *Measurement and modelling of ammonia emissions from an anaerobic digestion plant*. MSc dissertation. University of Edinburgh.

Bell M. et al. (2015) *Quantifying ammonia emissions from an anaerobic digestion plant through atmospheric measurements and inverse dispersion modelling*, in prep

Quantifying NH₃ emissions: AD plant

Time series of AiRRmonia NH₃ measurements against wind direction



Shaded blue areas = where the AiRRmonia NH₃ is downwind of the AD plant (wind direction 200 - 250°)

Quantifying NH₃ emissions: AD plant

AiRRmonia [NH₃]



WindTrax (bLS) model

Total Emission rate



Emission factors for individual sources

ADMS forward



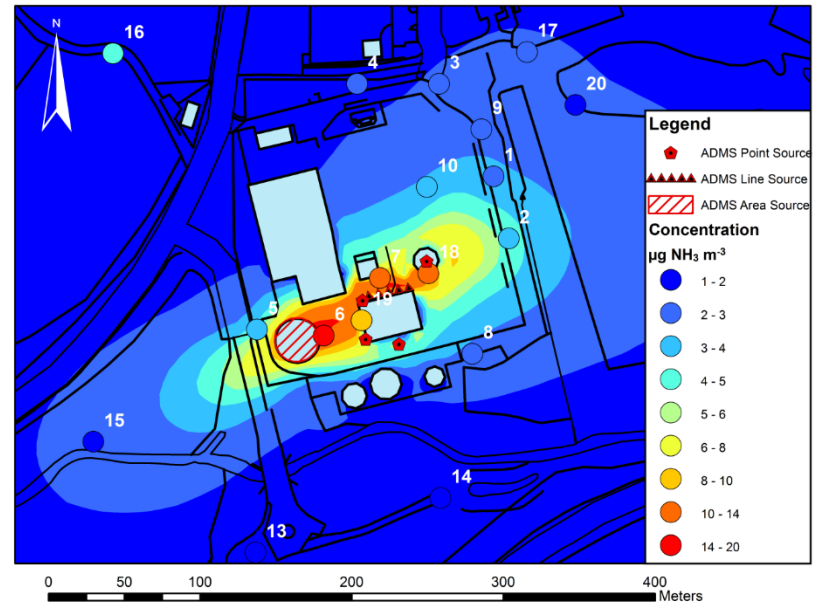
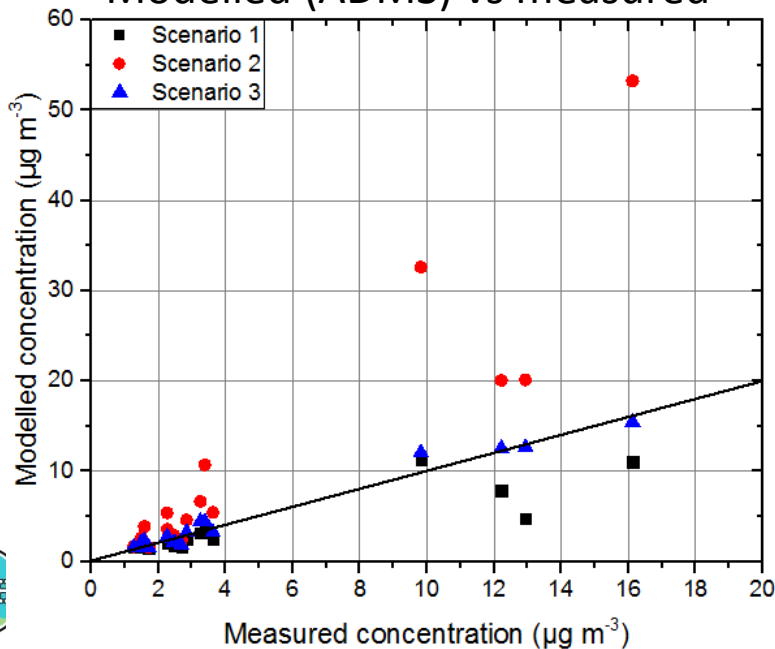
dispersion model

Predicted [NH₃] spatial concentration field



Scale modelled to measured [NH₃]

Modelled (ADMS) vs measured



Contour map of Scenario 3 predicted [NH₃]



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Continuous high time-resolution methods

Wet Chemistry	Manufacturer	Range	Resolution
MARGA: Rotating annular denuder + SJAC with on-line detection (IC)	Metrohm-Applikon	Ambient	hourly
AMANDA: Rotating annular denuder with on-line detection (conductivity)	ECN	0.02 – 500 ppb	7.5 mins
AMOR: Rotating annular denuder with on-line detection (conductivity)	ECN	0.1 – 500 ppb	hourly
AiRRmonia: membrane “stripping” with on-line detection (conductivity)	Mechatronics	0.04 – 500 ppb	10 mins
Spectroscopic and optical	Manufacturer	Range	Resolution
DOAS (Differential Optical Absorption Spectrometry)	various		
Chemiluminescence NO _x monitor with NH ₃ converter	Teledyne	0 – 2000 ppb	40 s
TDLAS (Tunable Diode Laser Absorption Spectrometry)	various		
Photoacoustic, e.g. Nitrolux™	Pranalytica	1 – 2000 ppb	2 mins
QCLAS (Quantum Cascade Laser Spectrometry)	Los Gatos	0.5 ppb – 100 ppm	5 Hz
CRDS (Cavity Ring-Down Spectroscopy)	Picarro, Los Gatos	0 – 50 ppm	3 s
PTR-MS, CIMS	various		1 s

Simple, manual time-integrated methods

Type

Passive Diffusion Samplers:

e.g. ALPHA, Ferm, Gradko, Ogawa, Palmes, Passam, Radiello, Willems

Denuders:

- Annular Denuder Systems, e.g. URG, Italian ADS systems
- Ferm Denuder System (IVL, Sweden)
- DELTA Denuder System, (CEH, UK)

Passive Flux Denuders:

- Simple denuders
- Recurved denuders
- DPAS (deployed with mini annular denuders)

Filter Packs

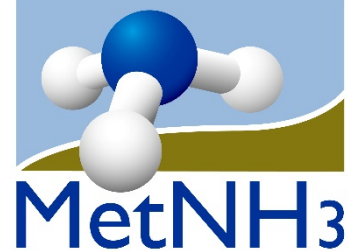


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MetNH₃



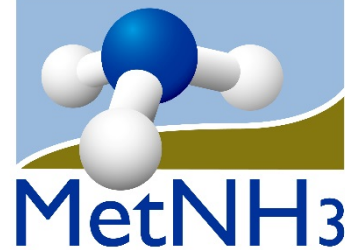
Metrology for Ammonia in Ambient Air

<http://www.metnh3.eu/typo3/>

Joint Research Project (JRP) ENV55 under European Metrology Research project (EMRP) 3 years, started 01/06/14

- WP 1: develop improved reference gas mixtures by static & dynamic gravimetric generation methods.
- WP 2: develop & characterise laser based optical spectrometric standards
- WP 3: establish the transfer from high-accuracy standards to field applicable methods

MetNH₃



AMMONIA FIELD INTERCOMPARISON

- 15 – 21/08/16: Setup and comparison with portable standards
- 22/08 – 02/09/16: Intensive measurements including a urea application in the field
- 2 – 11/09/16: flux measurement intercomparisons

Easter Bush



AMMONIA PASSIVE SAMPLER INTERCOMPARISON

- 2016, Date tbc

Whim bog



ACKNOWLEDGEMENTS

- **Defra for funding SAMBA project**
- **NERC for supporting funds**
- **Birmingham University and Cranfield University staff (wind tunnel study)**
- **Forestry commission (Forest of Ae field site)**
- **Wytham FAI farm staff (NH₃ measurements)**
- **Din Moss + Freuchie Mills farm staff (NH₃ measurements)**