

Modelling of ammonia dispersion and deposition from intensive farming

**ADMLC meeting
9 February 2011**

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Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming

Executive summary

A two-stage approach is recommended to model dispersion and deposition of ammonia emitted from intensive farming sources. The proposed empirical approach allows both the concentration dependency of the deposition velocity and the ammonia depletion of the plume to be taken into account.

Ji Ping Shi and Colin Powlesland

Questions

Why do we need this technical guidance?

What is the technical thinking behind the guidance ?

Structure of presentation

Why do we need to model ammonia from intensive farming

What are the problems in the modelling application

How have we dealt with the problem

Application of the recommended method

Legislation

Applications for authorisation under the PPC / EPR regulations will need to be assessed in relation to the requirements of the Habitats Directive and Birds Directive and implementing UK regulations (The Conservation of Habitats and Species Regulations 2010)

Environmental Permitting Regime

To determine applications for permits under the Environmental Permitting Regime information is needed on the potential environmental impact of the installation being considered.

Impacts of Ammonia

Direct damage to sensitive species
(e.g. leaf discoloration)

Changes in species composition - reduced
species richness

Increased sensitivity to other stresses (e.g.
frost)

Acidification of soils and freshwaters

Other effects (e.g. slime)

Damage to lower plants

Lichen



Healthy

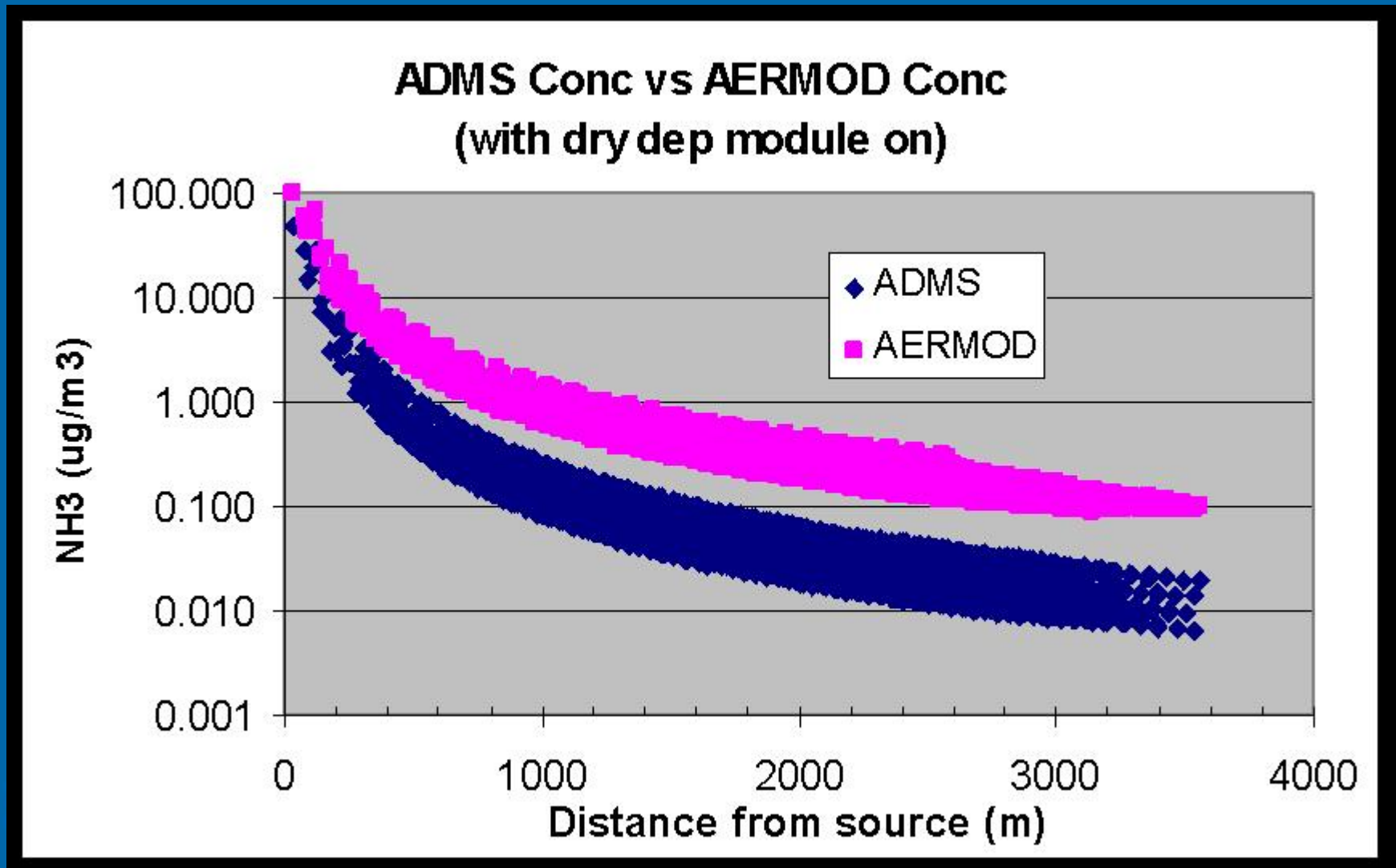


Damaged by ammonia

Moss

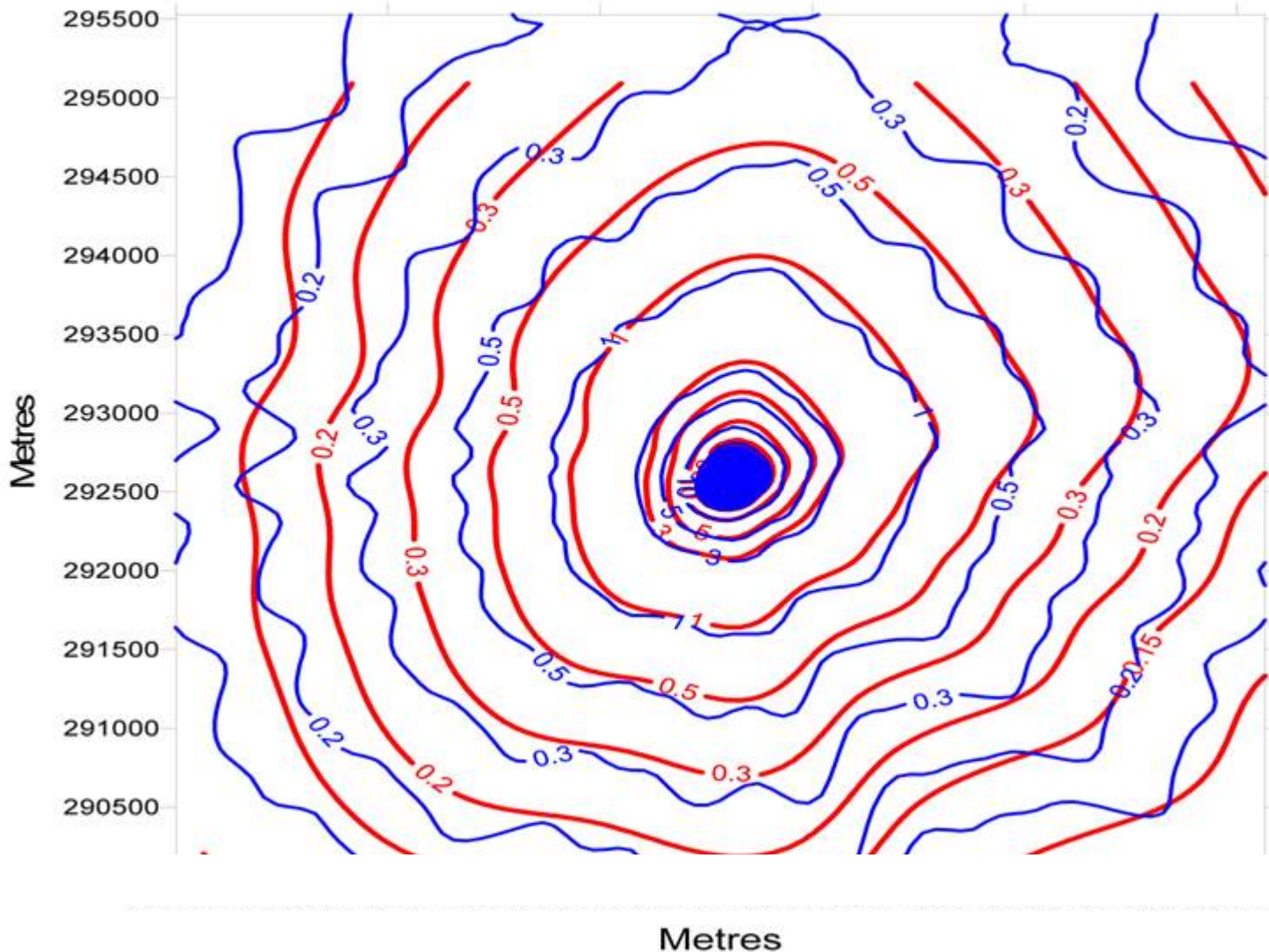


Problems encountered

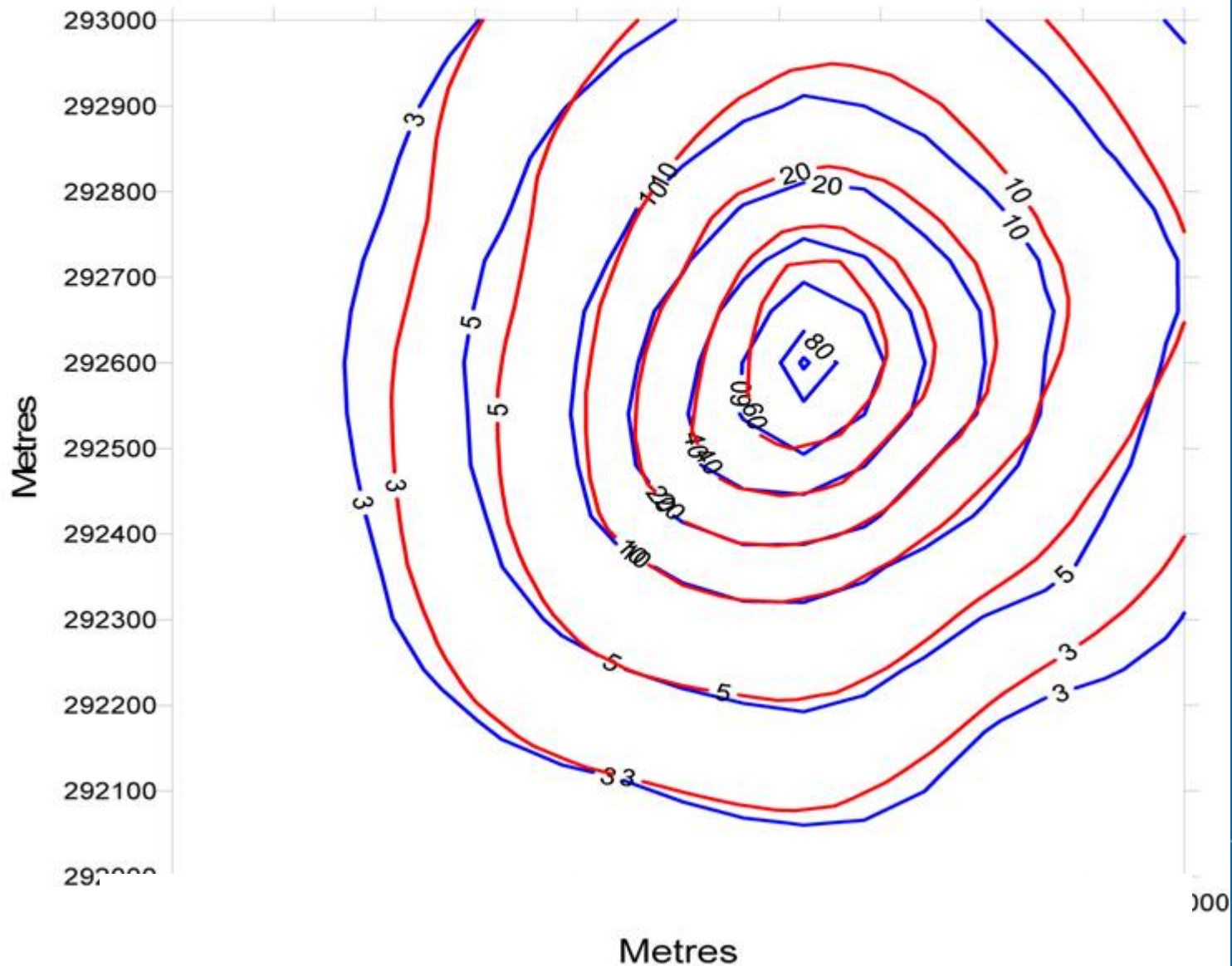


Comparison without deposition

ADMS 4.1 (red) vs AERMOD (blue)
2007 Marham metdata
Annual mean NH₃ (ug/m³)

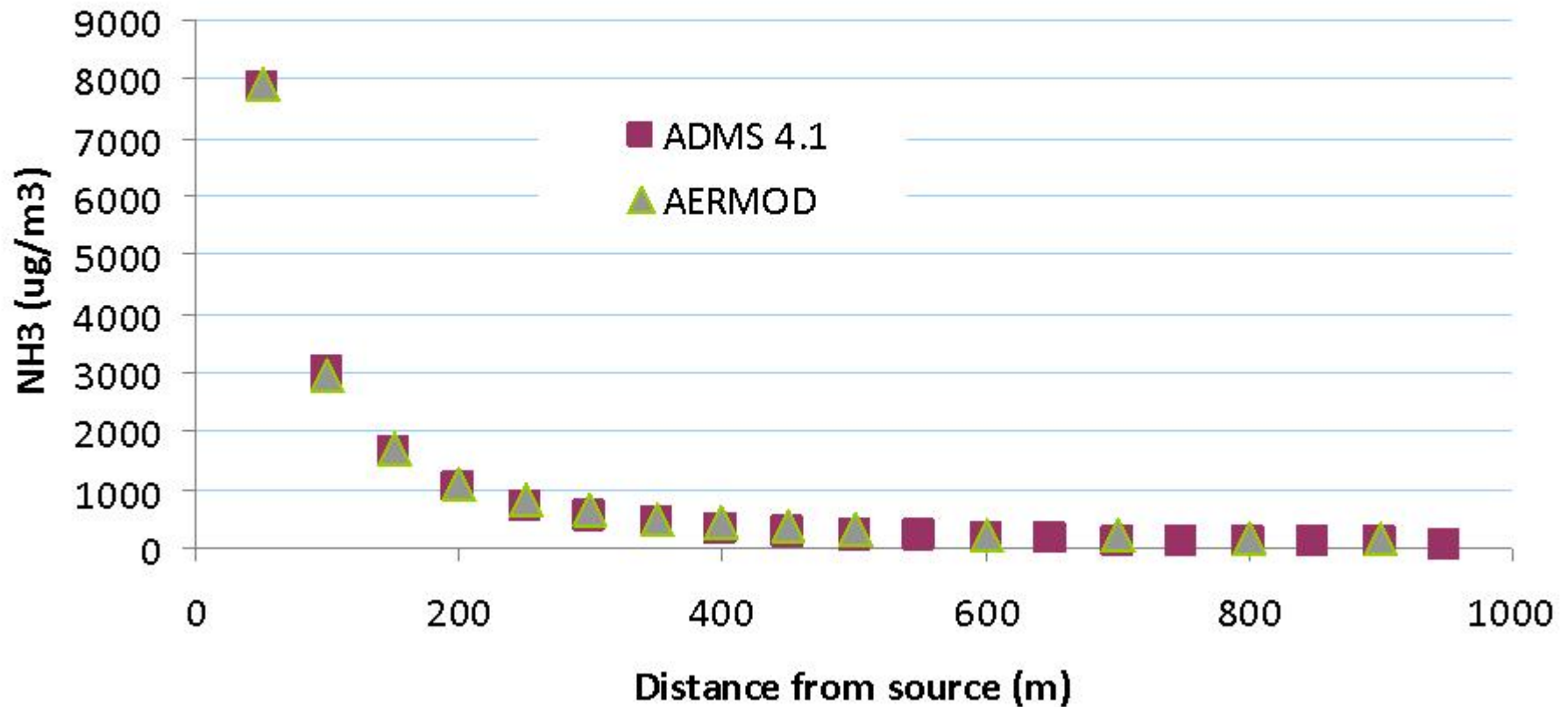


**ADMS 4.1 (red) vs AERMOD (blue)
2007 Marham metdata
Annual mean NH3 (ug/m3)**



Comparison without deposition

ADMS 4.1 VS AERMOD



AERMOD and ADMS deposition modules

AERMOD and ADMS have different deposition algorithms, especially in the surface resistance

But are there any other reasons causing the significant discrepancy in the prediction as shown above?

For example, ammonia deposition velocity?

Review Ammonia deposition velocity

Literature review shows that the reported ammonia dry deposition velocity varied from 0.13 to 4.16 cm/s for grassland and moorland/heathland, from 0.79 to 6.56 cm/s for forest.

J N Cape et. al., presented a paper at Edinburgh UNECE Ammonia Workshop (2006) which set the new critical levels.

The paper suggested 1.6-3.2 cm/s for short vegetation and 3.3 – 4.8 cm/s for tall vegetation. These ranges assumed based on the annual average wind speed dependent data for the UK for each 5 km grid square.

Variation of V_d with ammonia concentration

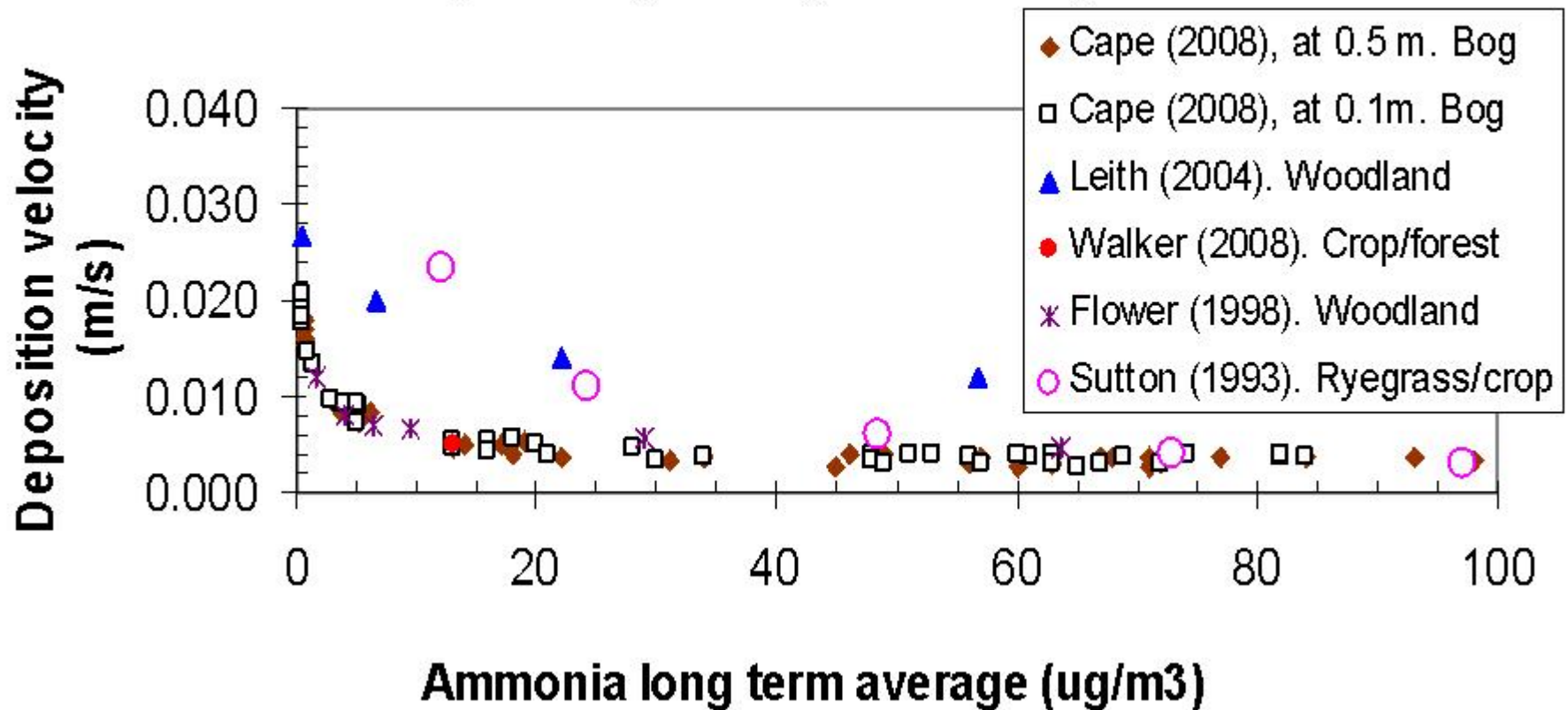
The majority of the above studies were carried out in the ambient ammonia concentration.

However, when close to a pig/poultry farm, the ammonia concentration, annual mean and hourly mean can be very high.

Studies show that ammonia deposition velocity decreases with increase of ammonia concentration

Deposition velocity vs long-term ammonia concentration

Ammonia dep velocity vs long term average concentration



An empirical approach

Recommend ammonia dry deposition velocities at different long term average concentrations to be used in an impact assessment.

	< 10	10 - 20	20 - 30	30 – 80	> 80
NH ₃ conc (µg/m ³)					
Deposition velocity (m/s)	0.02 - 0.03*	0.015	0.01	0.005	0.003

* 0.02 m/s for short vegetation, and 0.03 m/s for tall vegetation.

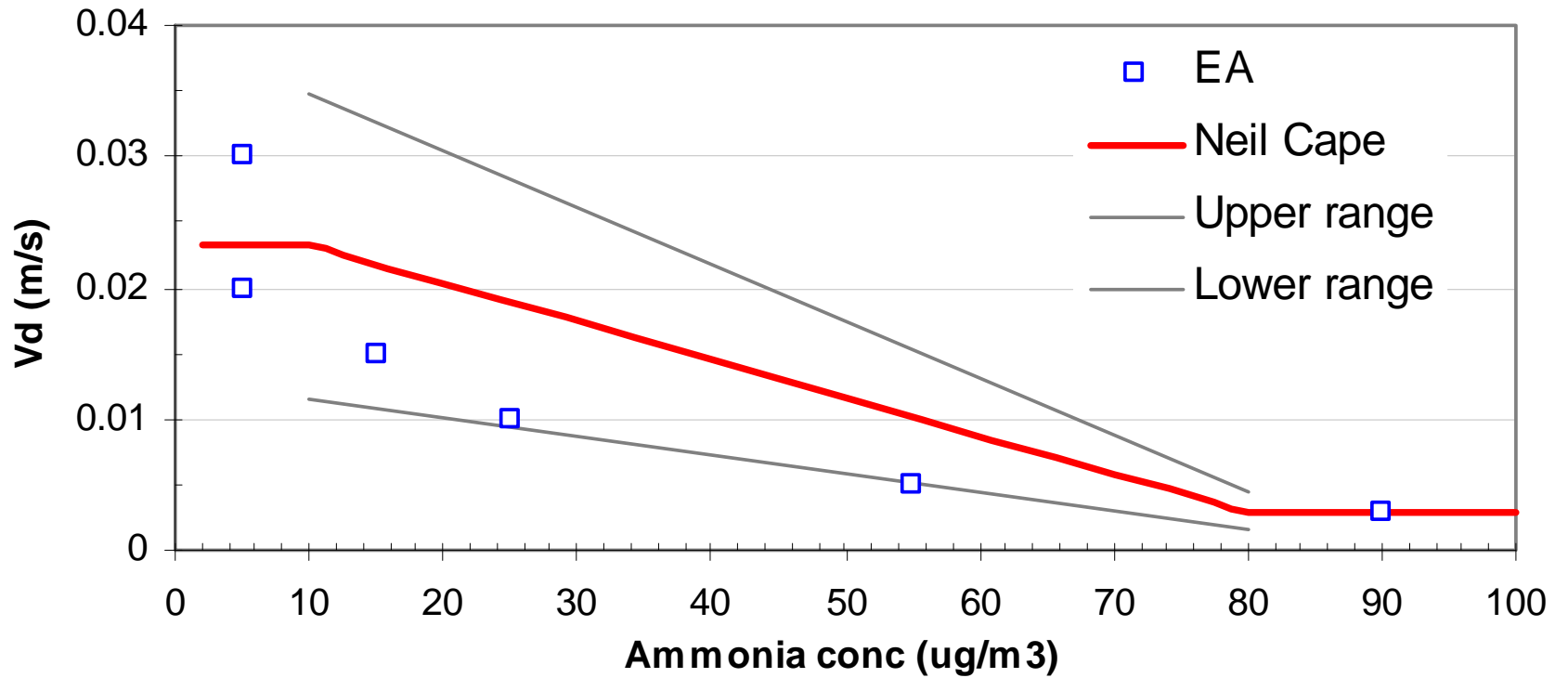
Neil Cape, from CEH, suggested a similar approach, with deposition (g/m²/d) expressed as:

<0.02 for concentrations < 10 ug/m³ [scaled in proportion to concentration]

0.02 +/- 0.01 for 10-80 ug/m³

>0.02 for concentrations > 80 ug/m³ [scaled in proportion to concentration]

Vd vs Conc



Uncertainty

The recommended approach is based on studies into long-term observation of the relation between ammonia deposition and concentration. The use of the long term average concentration avoids the complexity encountered in short term (i.e., hourly) modelling.

The recommended deposition velocities are based on the limited data available. There is currently insufficient information to do an uncertainty analysis.

However, the proposed empirical approach does allow both the concentration dependency of the deposition velocity and the ammonia depletion of the plume to be taken into account.

Application - Deposition modelling with variable deposition velocity

AERMOD ?

ADMS ?

AERMOD Gas Deposition

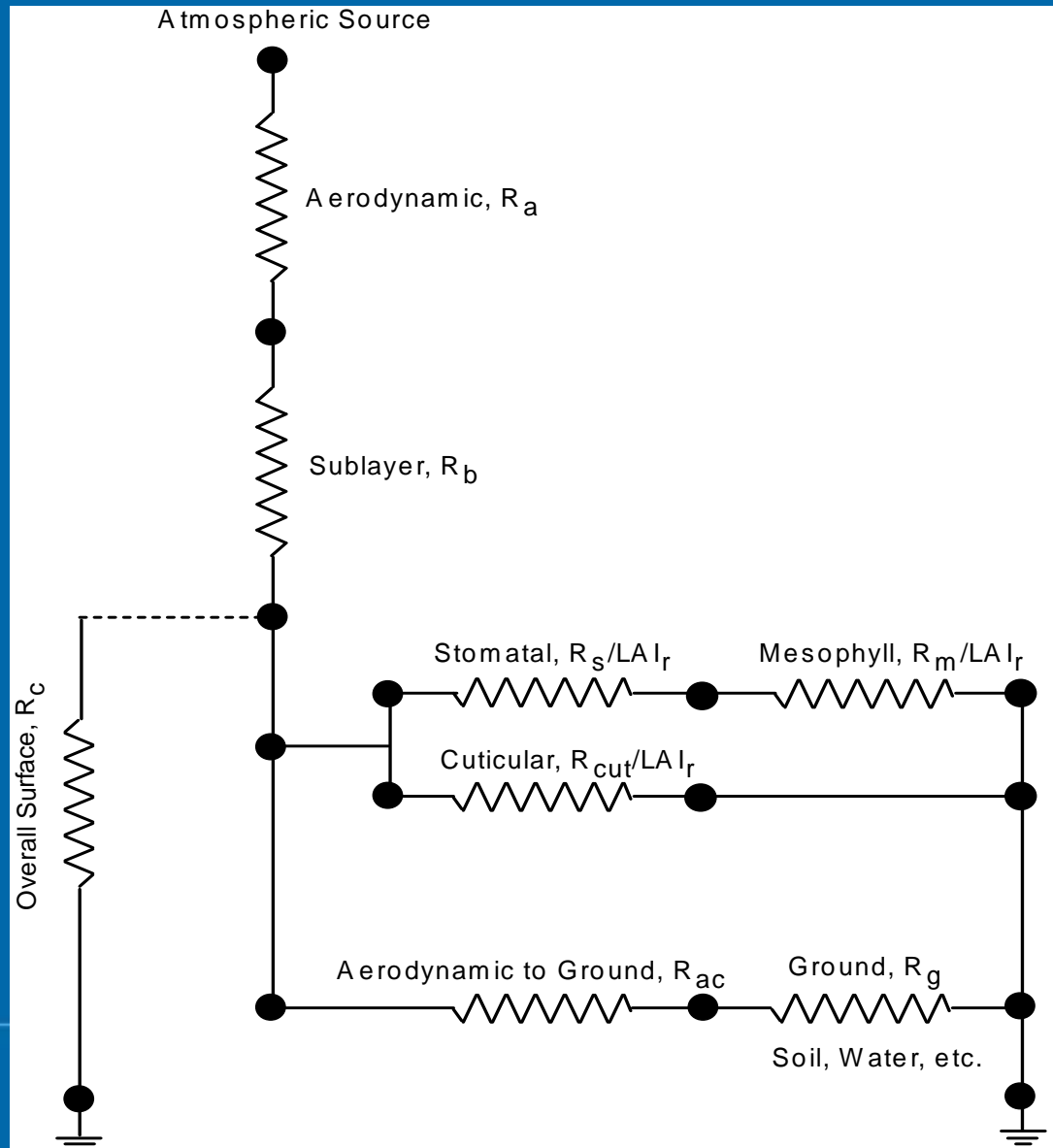
Scheme of major components of resistances used for gaseous dry deposition

$$F_d = V_{dg} C$$

$$V_{dg} = (R_a + R_b + R_c)^{-1}$$

$$R_c = [LAI_r(R_s + R_m)^{-1} + LAI_r R_{cut}^{-1} + (R_{ac} + R_g)^{-1}]^{-1}$$

Where LAI_r = relative leaf area index (unitless).



ADMS deposition module

User defines a V_{dg} ,
 $F_d = V_{dg} C$

When V_d is unknown,

$$r = r_a + r_b + r_s$$

Type	Definition	Examples	R_c ($s\ m^{-1}$)
Reactive gases	Gases expected to undergo significant chemical reaction with the surface	SO_2 , O_3 , NO_x , I_2 , Cl_2 , HF	30
Unreactive gases	Gases not undergoing significant chemical reaction with the surface	CO_2 , CH_3I	1000
Inert gases	Noble gases	He, Ne, Ar, Kr, Xe, Rn	∞

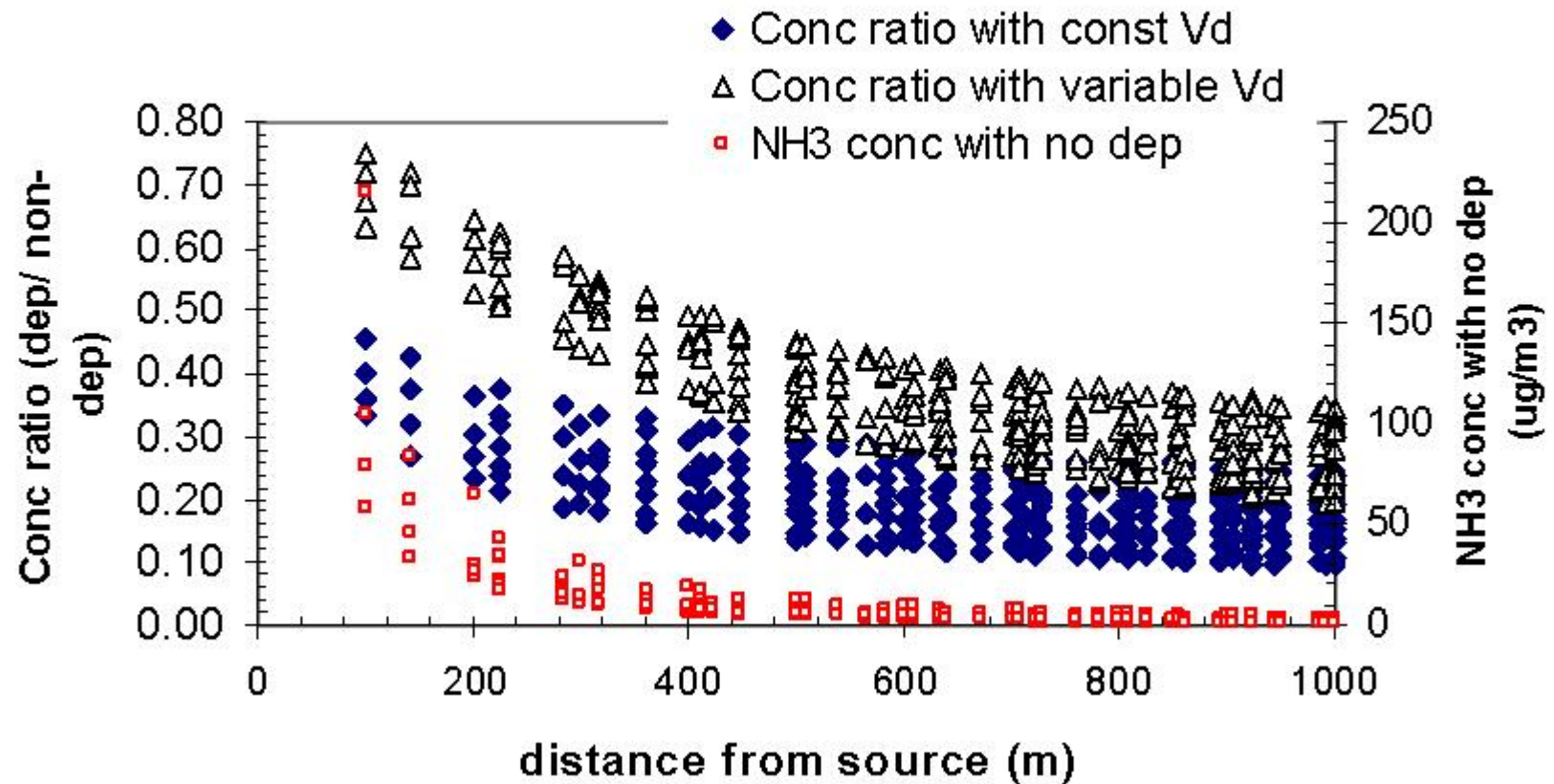
Modelling assessment with deposition velocity varying with concentration

ADMS 4.2 -- Spatially varying deposition

This is not an ideal way for the calculation of deposition varying with concentration, but it makes the assessment possible.

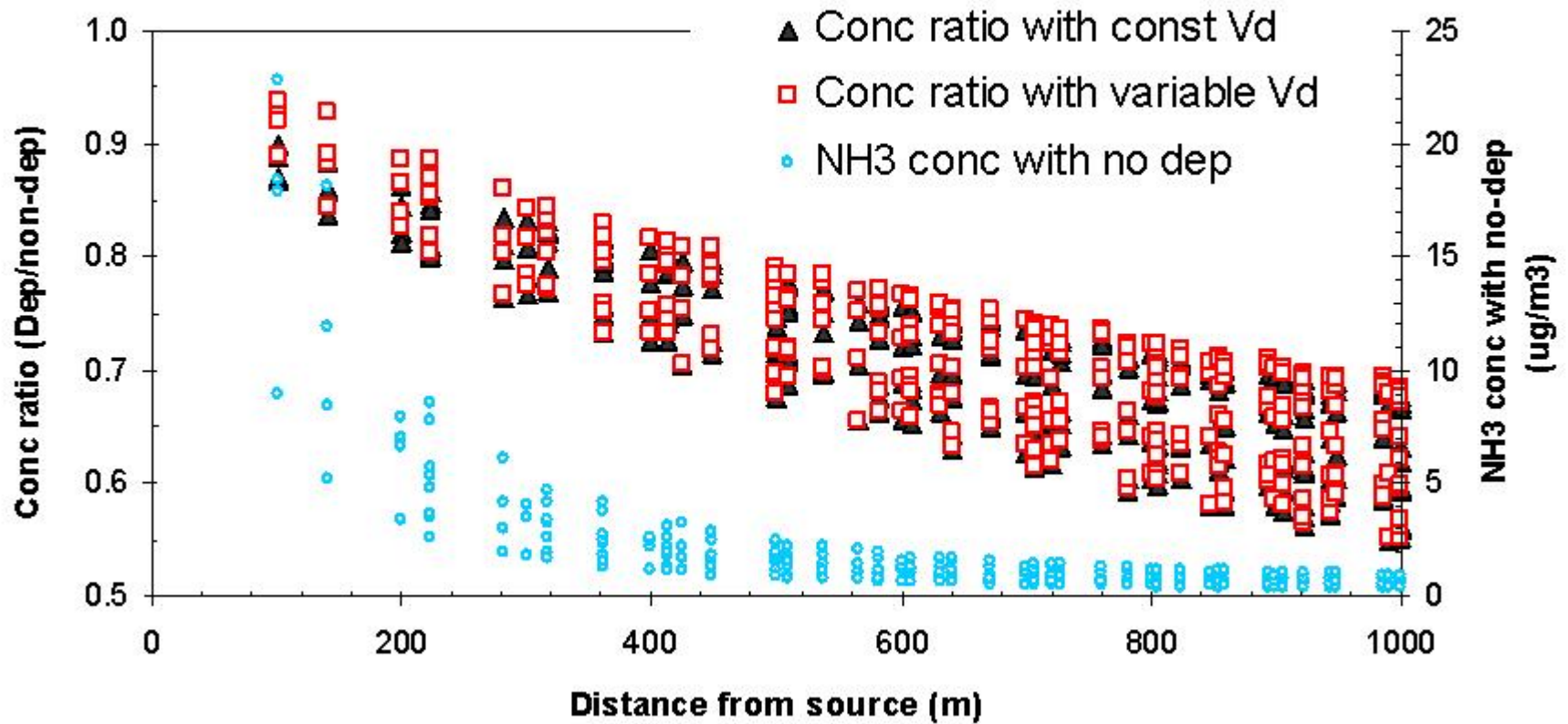
Question to model developers

Concentration ratio



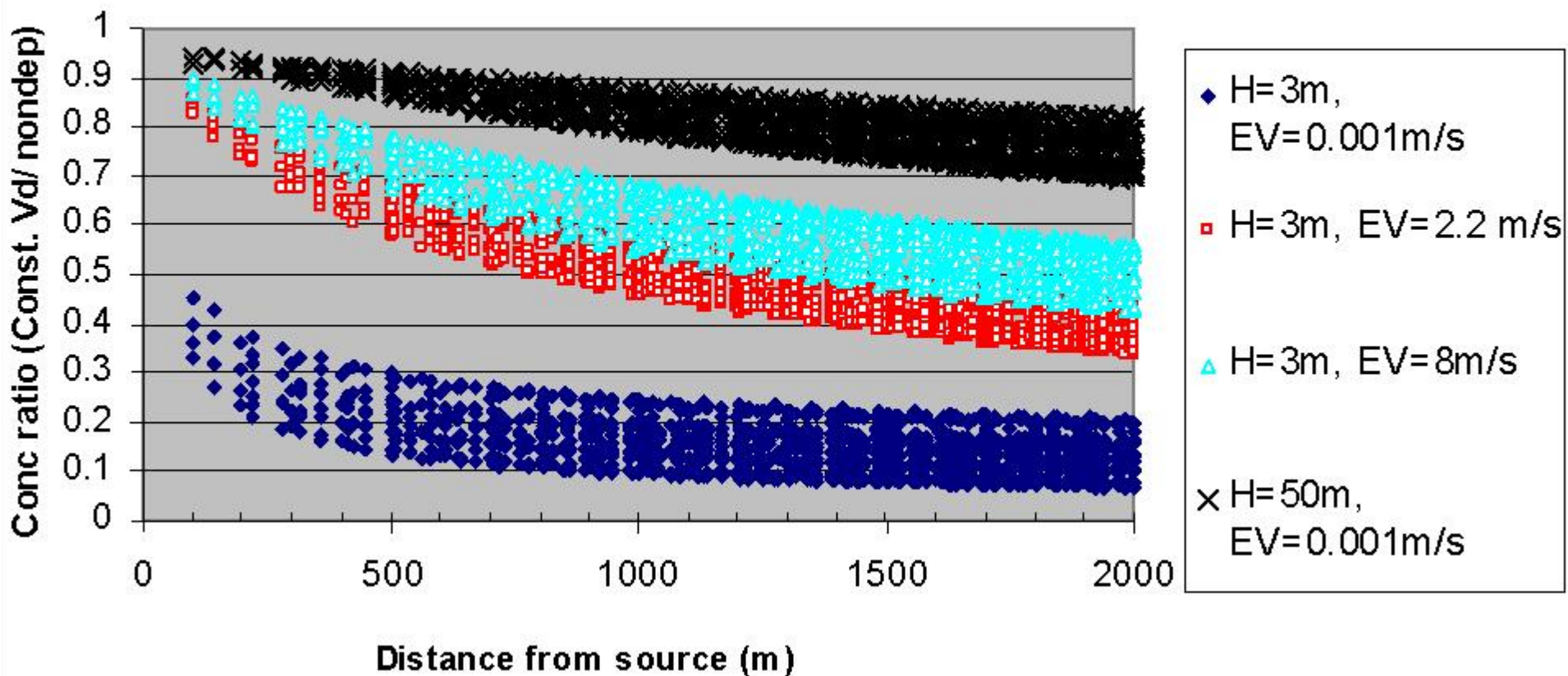
- Single point source (1 g/s)
- H = 3m, exit velocity = 0.001m/s
- Met data: Marham 2007

Concentration ratio



- Point source (1 g/s)
- H = 3m, exit velocity = 8 m/s
- Met data: Marham 2007

Comparison of conc ratio



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Acknowledgement

We would like to thank to following people for their useful discussion and comments during the guidance development:

Malcolm Sharp from SAC Consulting

Steve Smith, Ian Barrie from ADAS

Neil Cape, Ron Smith, Bill Bealey and Mark Theobald from CEH