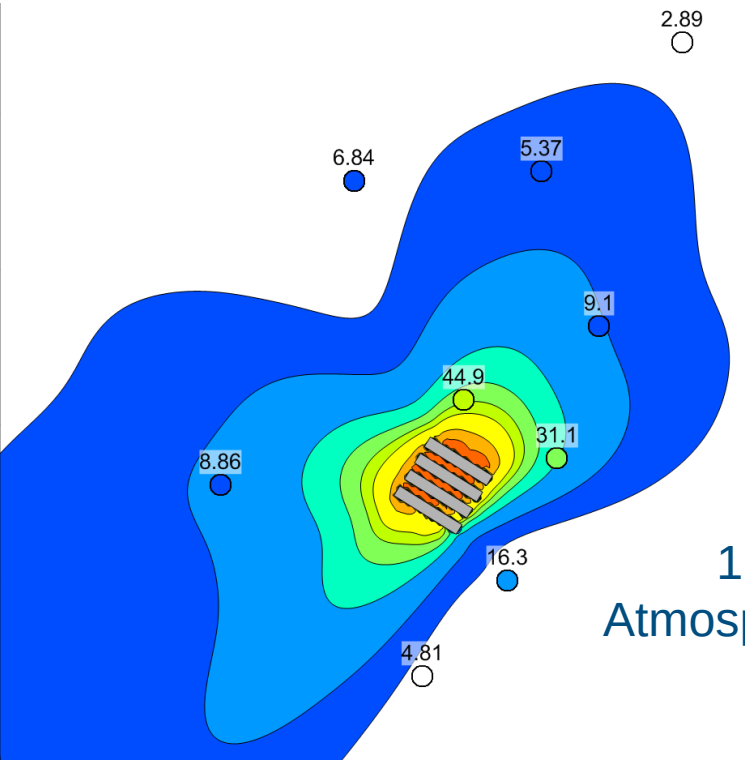
A review of dispersion modelling of agricultural and bioaerosol emissions with non-point sources



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The views expressed in this presentation are those of the authors, and do not necessarily represent the views of ADMLC or of any of the organisations represented on it.

Context

Example agricultural source types

Long, wide sheds with many release points

‘Free range’ sheds

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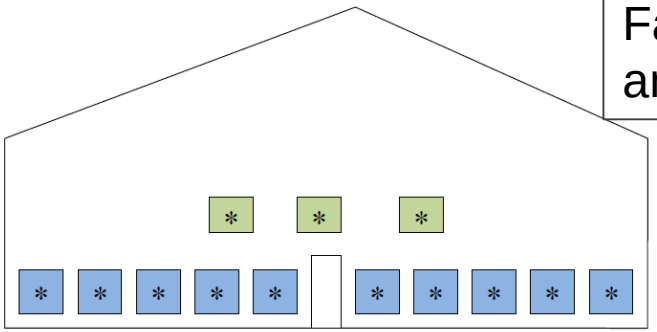

Fan exits on top, side and / or end of sheds

Non-point source types

Table 17 Agricultural source parameter ranges

Example real-world sources	Idealised source type	Source dimensions (m)			
		Height	Length	Width	Depth
Sheds with tunnel ventilation with long line of gable-end fans; wide sheds; naturally-ventilated shed with side inlets and roof exit; side vents which direct the air flow to ground level	Line	0 – 2	60	1	n/a
Slurry lagoon, slurry tank, pig houses.	Area	0 – 2	60	10	n/a
Sheds with tunnel ventilation with long line of gable-end fans; wide sheds; naturally-ventilated sheds; side vents which direct the air flow to ground level; pig houses.	Volume	1.25 – 2.5	60	10	2.5 – 5.0
Sheds with tunnel ventilation with long line of gable-end fans; wide sheds	Jet	1 – 5	-	-	-

Project overview

- **Task 1: Literature review**
  - Review of published studies:
  - Parameter space for idealised modelling
  - Case study selection
  - Model review
  - ADMS & AERMOD formulation comparison
  - Limitations and uncertainties in dispersion modelling
- **Task 2: Generic model behaviour**
  - Individual meteorological conditions
  - Long-term model behaviour (annual and maximum predictions)
- **Task 3: Model validation**
  - **Whitelees farm[a]**
  - Defra poultry datasets[b] (Farm F & G)
  - Defra bioaerosol datasets[c] (Site B)
- **Project findings**
  - Overall conclusions
  - Recommendations for further work

[a]Hill *et al.* (2014)

[b]Demmers (2009) and Demmers *et al.* (2010)

[c]Williams *et al.* (2010)

Case study
Description

- Whitelees Farm (Scotland, UK) study commissioned by Sniffer for validation of the SCAIL-Agriculture tool (used for screening)
- 37 000 birds in eight poultry sheds
- On-site meteorology
- Measurements of total particulates, PM_{10}, $PM_{2.5}$, PM_1, ammonia and odour

Figure 11 Upward pointing cowl at Glendevon Farm; figure taken from Hill *et al.* (2014), reproduced here with permission from Sniffer (private communication, 05/08/15).

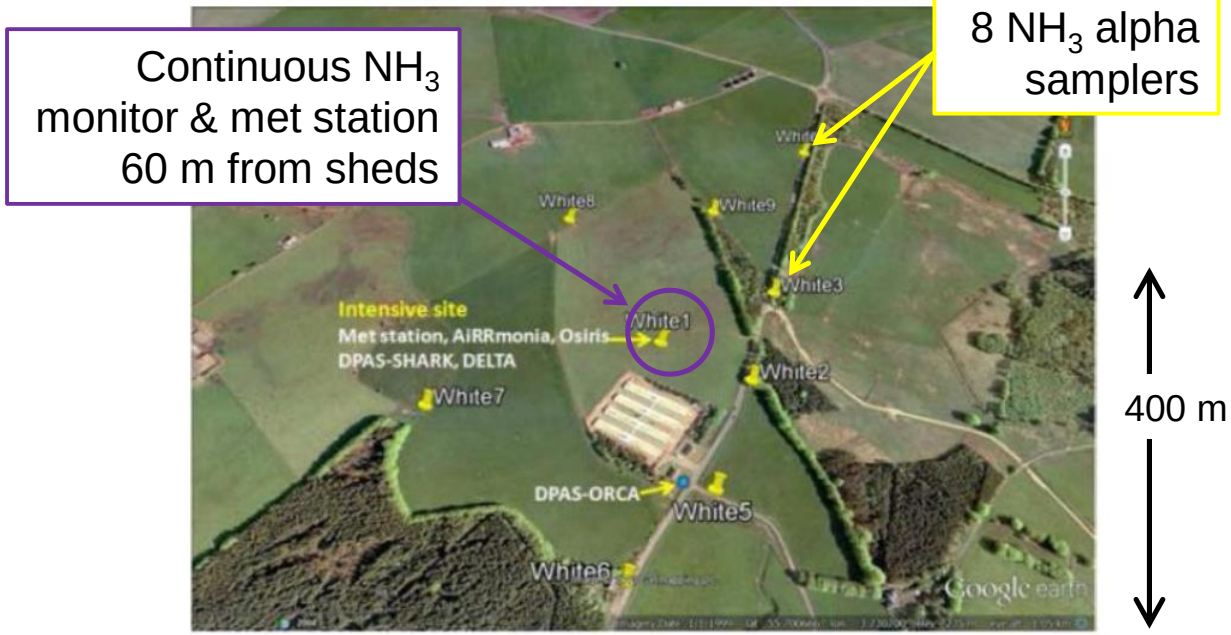

Figure 12 Whitelees Farm study area showing location of the onsite meteorological station (White 1) which is co-located with the continuous ammonia monitoring equipment; White 2 to White 9 indicate the locations of additional ammonia measurements; figure taken from Hill *et al.* (2014), reproduced here with permission from Sniffer (private communication, 05/08/15).

Case study
Description

- Odour measurements along transects
- Data from one day only

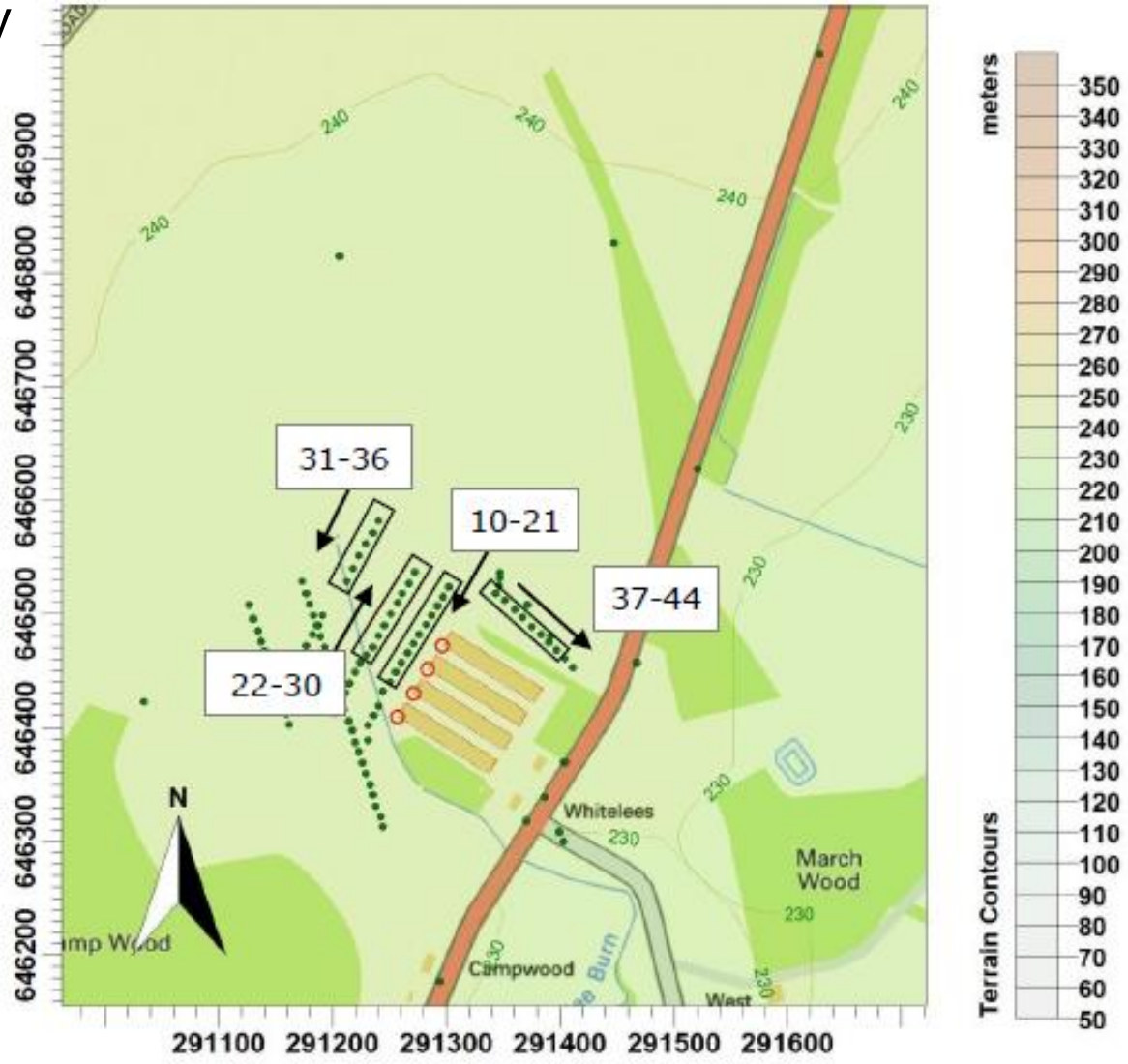

Figure 18 Study set up for Whitelees Farm showing buildings (orange rectangles) and receptors (dark green dots); receptor numbers and arrows show the locations of odour measurements on 19th of September; background map courtesy of © Crown copyright and database rights, 2015.

numbered odour measurement locations

poultry sheds

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Case study
Description of concentration data utilized

- Continuous ammonia measurements:
  - August – November 2013
  - ~ 60 m from sheds

- Period-average ammonia (alpha samplers):
  - 5/9/13- 2/10/13 (27 days)
  - 8 samplers
  - Up to 600 m from sheds

- Odour transects
  - Transect of 35 sites
  - 10-minute measurements on 19/9/13
  - Up to 150 m from sheds

Case study
Model configurations

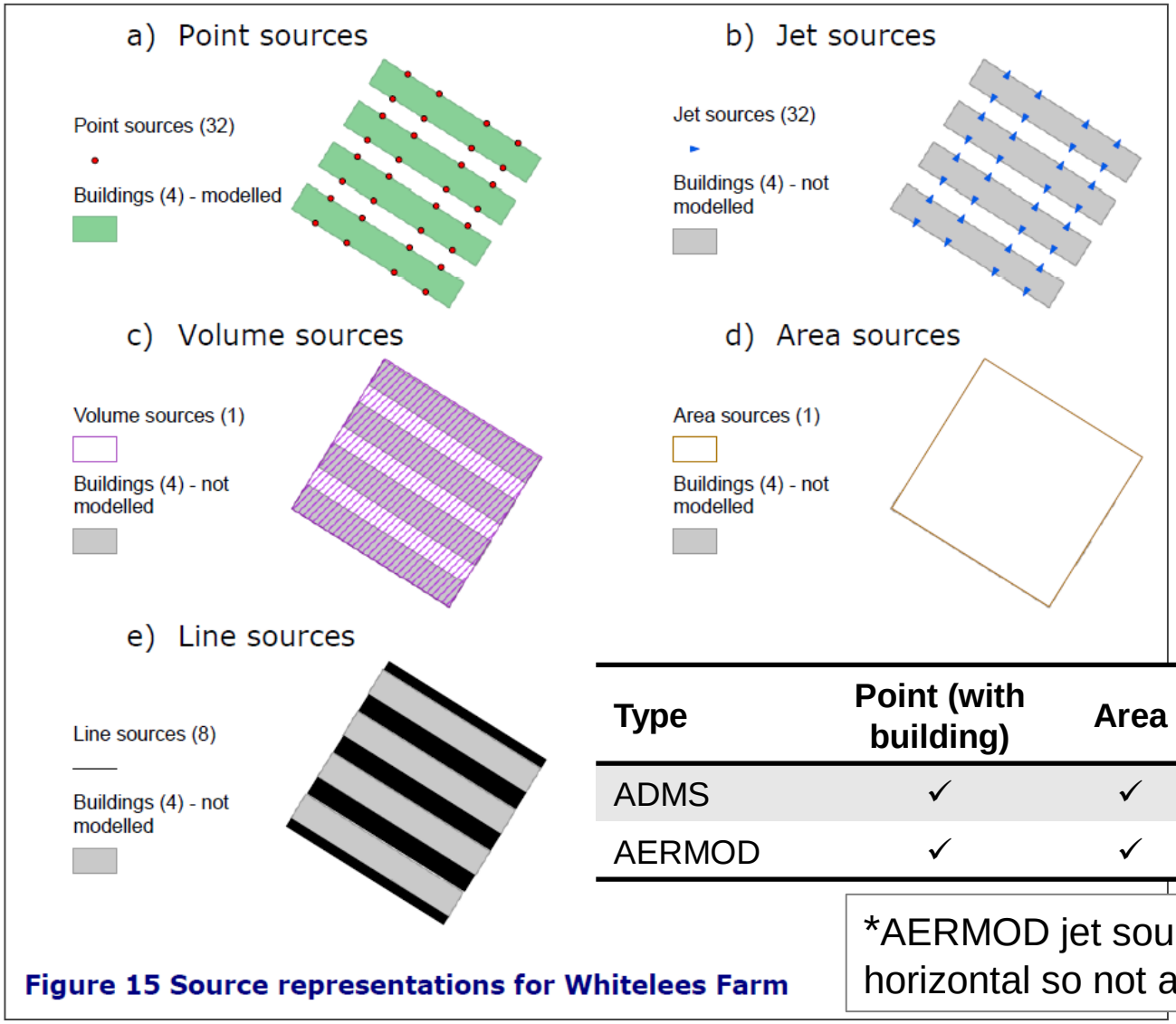


Figure 15 Source representations for Whitelees Farm

Source configurations

Type	Point (with building)	Area	Line	Volume	Jet
ADMS	✓	✓	✓	✓	✓
AERMOD	✓	✓	✓	✓	*

*AERMOD jet sources are wind-aligned and horizontal so not appropriate for this study

Source types & Emissions

- Plume momentum and buoyancy effects included in different source types

Idealised source type	*Buoyancy and momentum effects included?*	
	ADMS	**AERMOD**
Area	✓	x
Jet	✓	n/a
Line	✓	✓ (non-default only)
Point	✓	✓
Volume	*x*	x

- Emissions : measured volume flow rates, ammonia and odour concentrations at cowl exits used to estimate emission rates;
- Variability across vents and with time – averages taken
- Temperature at exit 17.4°C

Case study
Results

- Continuous ammonia modelling (60 m) – statistics of hourly concentrations
  Bold source types indicate buoyant releases

ADMS Idealised source type	Obs. Mean (µg/m³)	Mod. mean (µg/m³)	NMSE	R	Fac2	IoA§§
Area	119	67	0.97	**0.66**	0.41	0.61
Jet	119	96	**0.60**	0.63	**0.53**	**0.65**
Line	119	**104**	0.90	0.52	0.52	0.60
Point	119	87	1.07	0.47	0.41	0.57
Volume	119	163	7.54	0.18	0.48	0.26

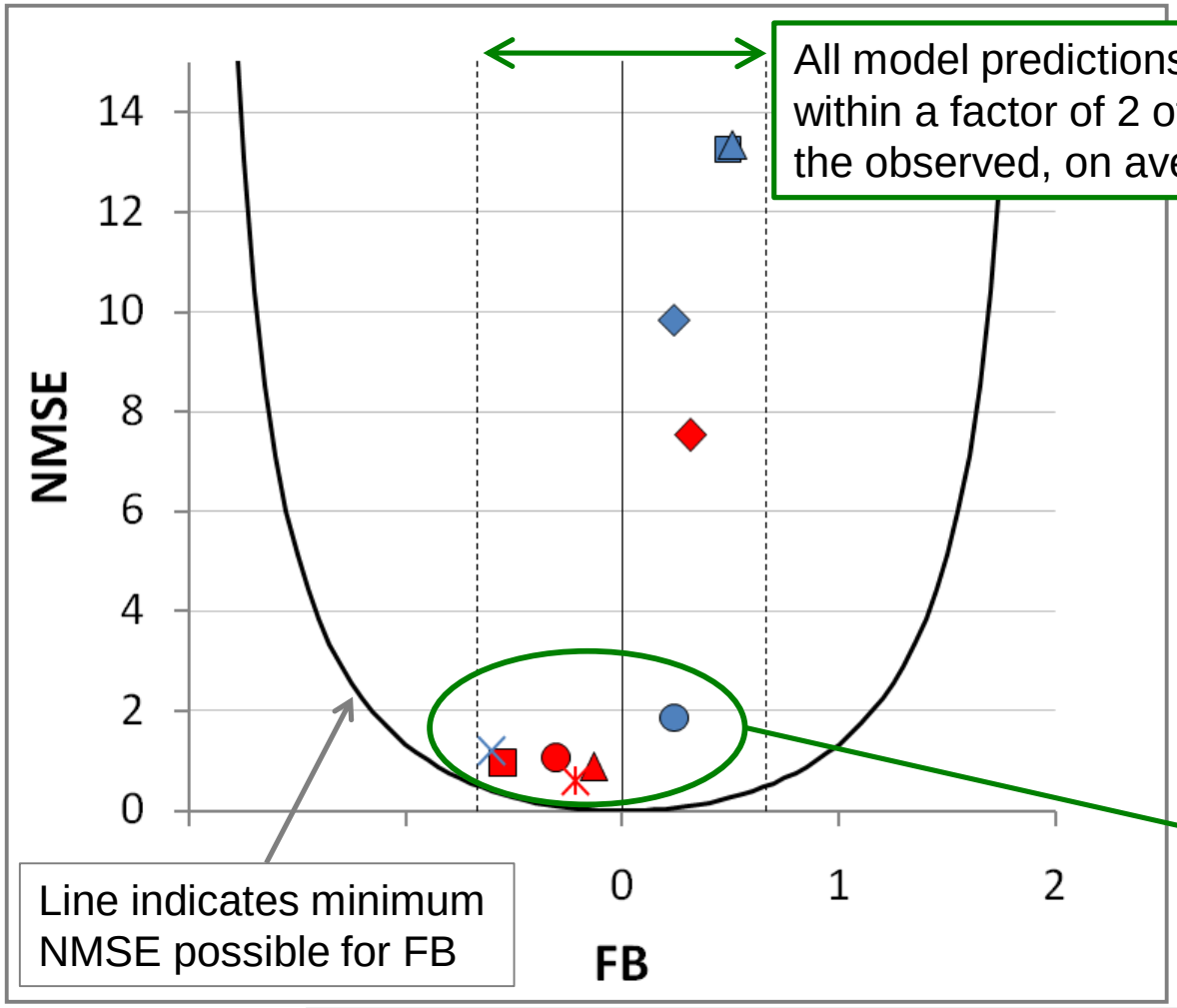
AERMOD Idealised source type	Obs. Mean (µg/m³)	Mod. mean (µg/m³)	NMSE	R	Fac2	IoA§§
Area	119	196	13.3	0.14	**0.44**	0.04
Line (default)	119	200	13.3	0.14	**0.44**	0.02
Line (buoyant)^^	*119*	*64*	***1.2***	***0.60***	*0.33*	***0.58***
Point	119	**151**	1.9	0.48	0.43	0.46
Volume	119	**151**	9.8	0.15	0.35	0.19

^^'Line (buoyant)' results from the inclusion of BLP (for modelling aluminium reduction plants) in AERMOD; ***ERROR in the AERMOD User Guide states emissions units are g/m²/s, whereas they should be g/s***

§§ The Index Of Agreement (IOA) spans between -1 and +1, with values approaching +1 representing better model performance.

Case study
Results

- Continuous ammonia modelling (60 m) - trends



All model predictions within a factor of 2 of the the observed, on average

- Area (ADMS)
- Jet (ADMS)
- Line (ADMS)
- Point (ADMS)
- Volume (ADMS)
- Area (AERMOD)
- Line (default) (AERMOD)
- Line (buoyant) (AERMOD)
- Point (AERMOD)
- Volume (AERMOD)

Line indicates minimum NMSE possible for FB

Buoyant sources much closer to (0,0), the point which indicates a perfect model

Chang & Hanna, Air quality model performance evaluation. *Meteorol. Atmos. Phys.* **87**, 167–196 (2004)

Case study
Results

- Continuous ammonia modelling (60 m) – statistics of max concentrations
  Bold source types indicate buoyant releases

ADMS Idealised source type	Obs. Maximum (µg/m³)	Mod. Maximum (µg/m³)	Obs. RHC*** (µg/m³)	Mod. RHC*** (µg/m³)
Area	*362*	**388**	*367*	**390**
Jet	*362*	445	*367*	479
Line	*362*	961	*367*	808
Point	*362*	872	*367*	808
Volume	*362*	3997	*367*	4274

AERMOD Idealised source type	Obs. Maximum (µg/m³)	Mod. Maximum (µg/m³)	Obs. RHC*** (µg/m³)	Mod. RHC*** (µg/m³)
Area	*362*	5736	*367*	6161
Line (default)	*362*	5750	*367*	6286
Line (buoyant)^^	*362*	**198**	*367*	**202**
Point	*362*	1789	*367*	1644
Volume	*362*	4860	*367*	4512

^^'Line (buoyant)' results from the inclusion of BLP (for modelling aluminium reduction plants) in AERMOD; ***ERROR in the AERMOD User Guide states emissions units are g/m²/s, whereas they should be g/s***

*** Taken to be $\chi(n) + (\chi - \chi(n))\ln\left(\frac{3n-1}{2}\right)$ where n is the number of values used to characterise the upper end of the concentration distribution, χ is the average of the $n-1$ largest values, and $\chi(n)$ is the n^{th} largest value; n is taken to be 26.

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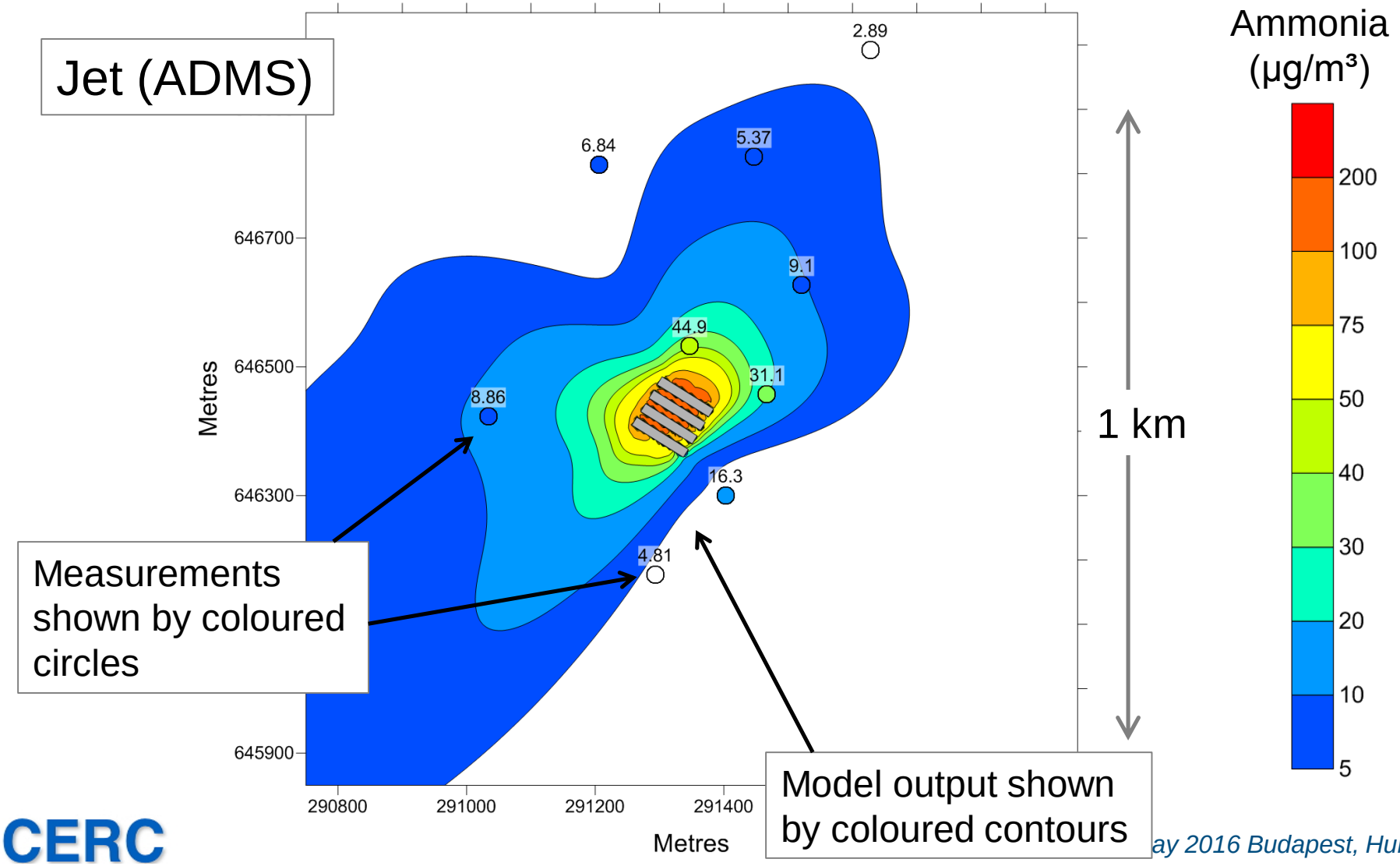
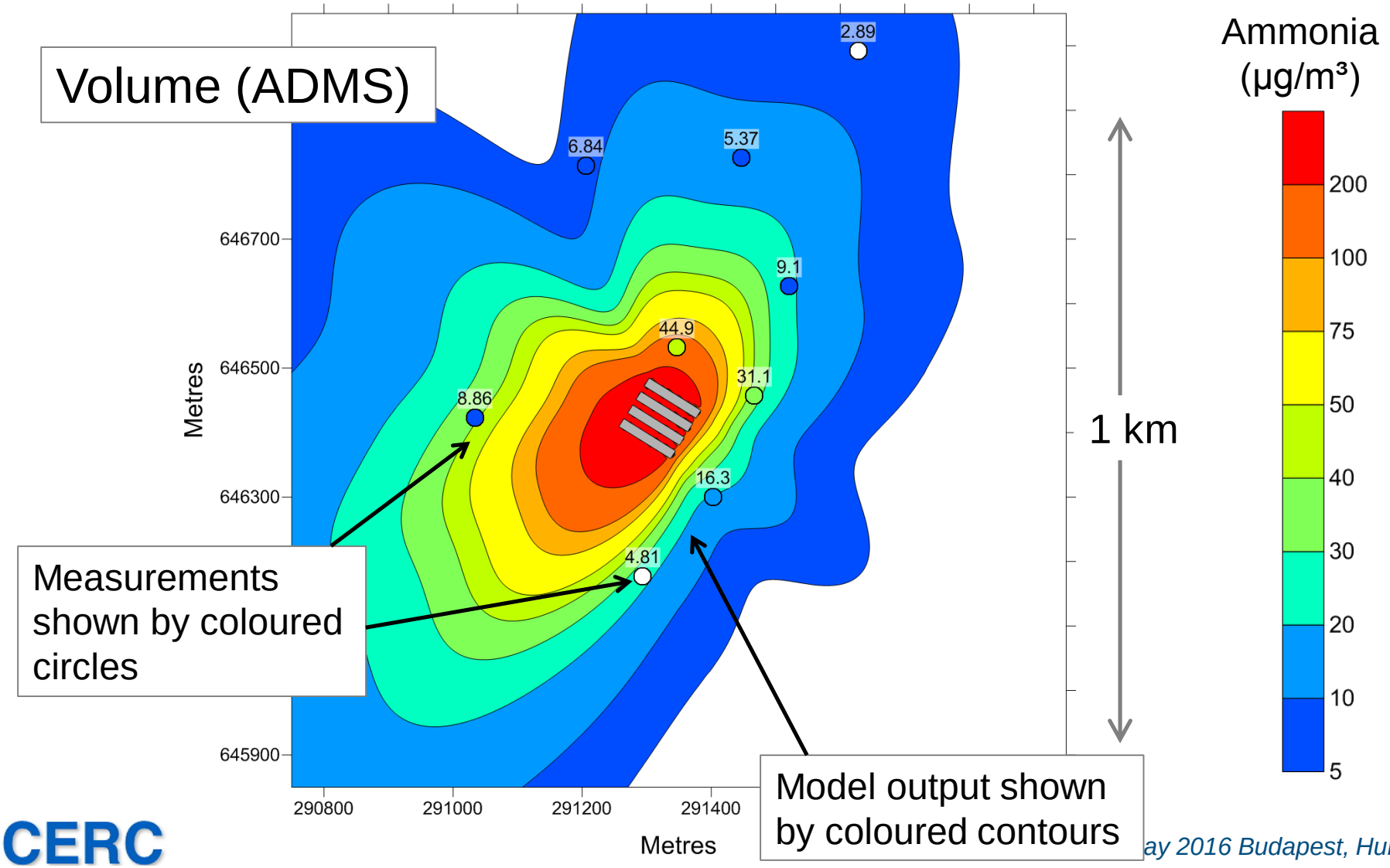
Case study
Results

- Period-average ammonia (alpha samplers); 5/9-2/10



Case study
Results

- Period-average ammonia (alpha samplers); 5/9-2/10



Case study
Results

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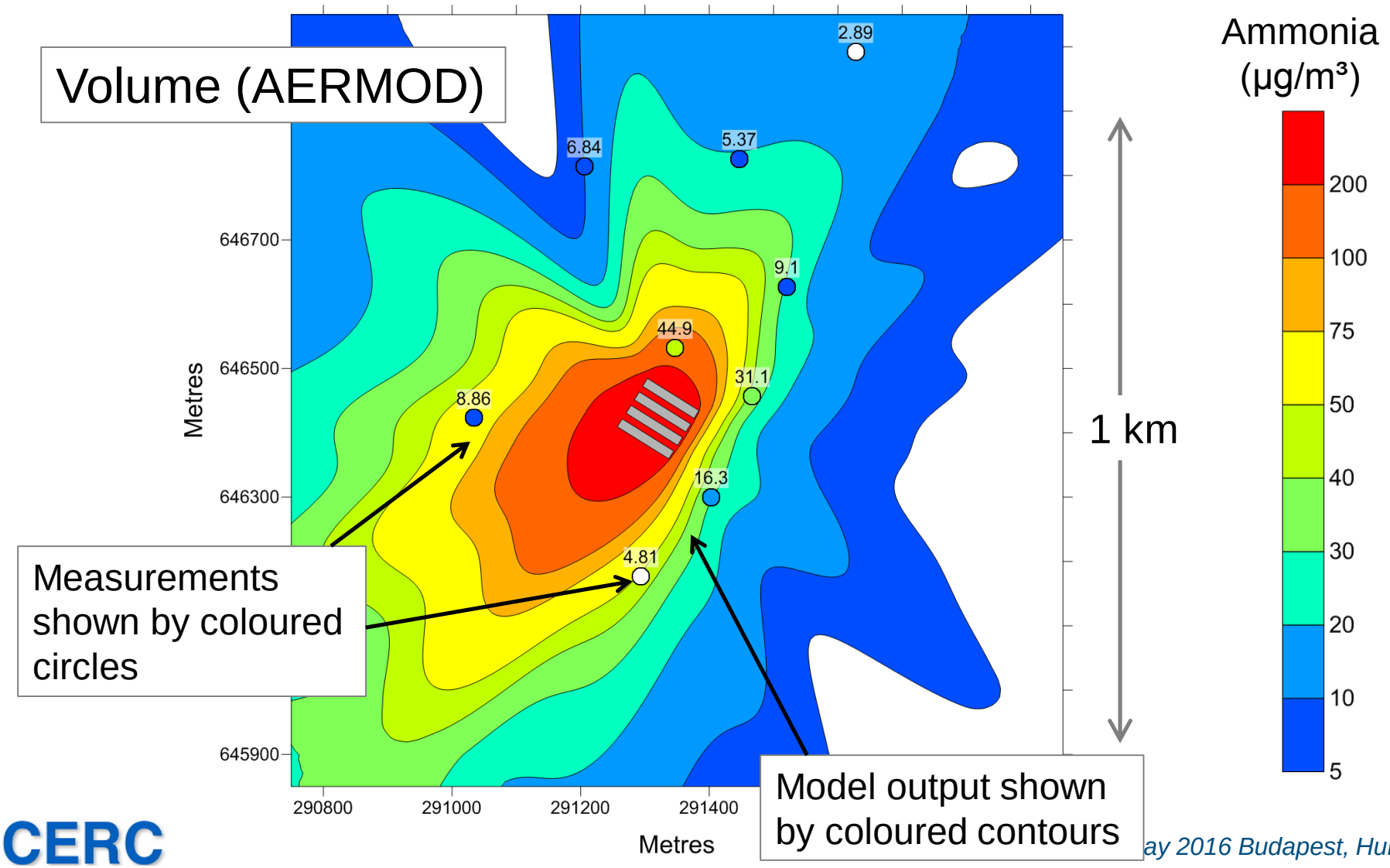

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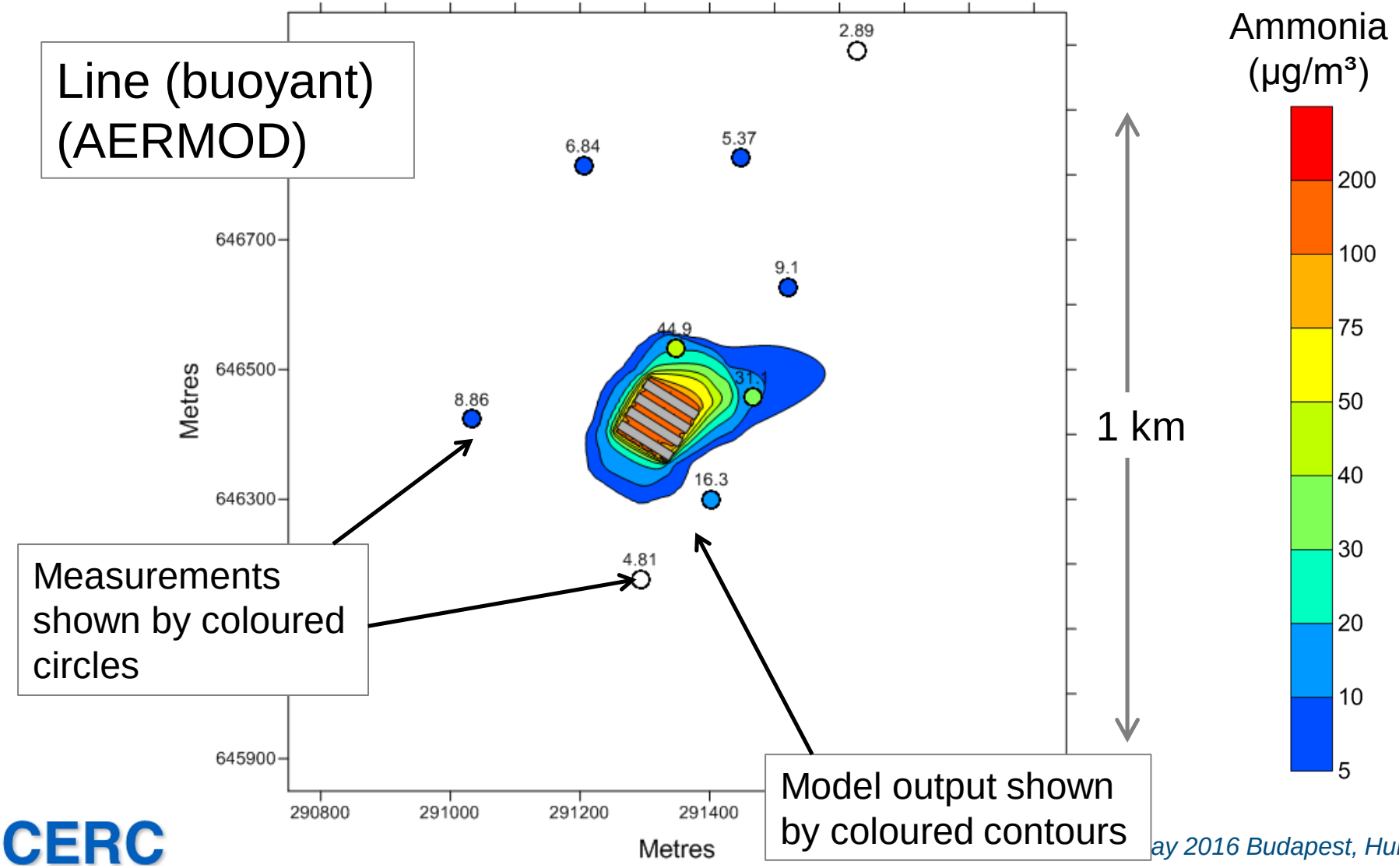
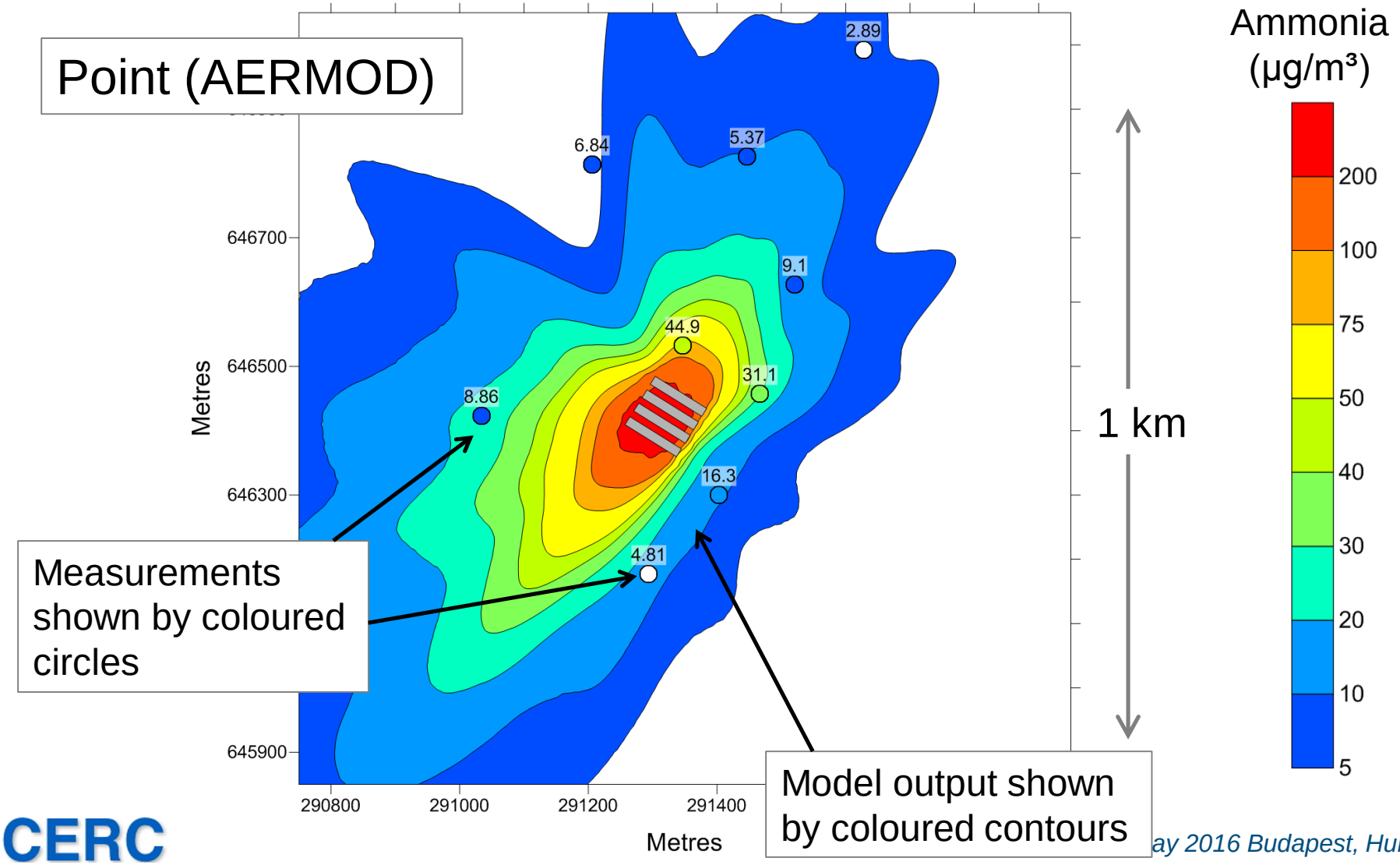


Case study
Results

- Period-average ammonia (alpha samplers); 5/9-2/10

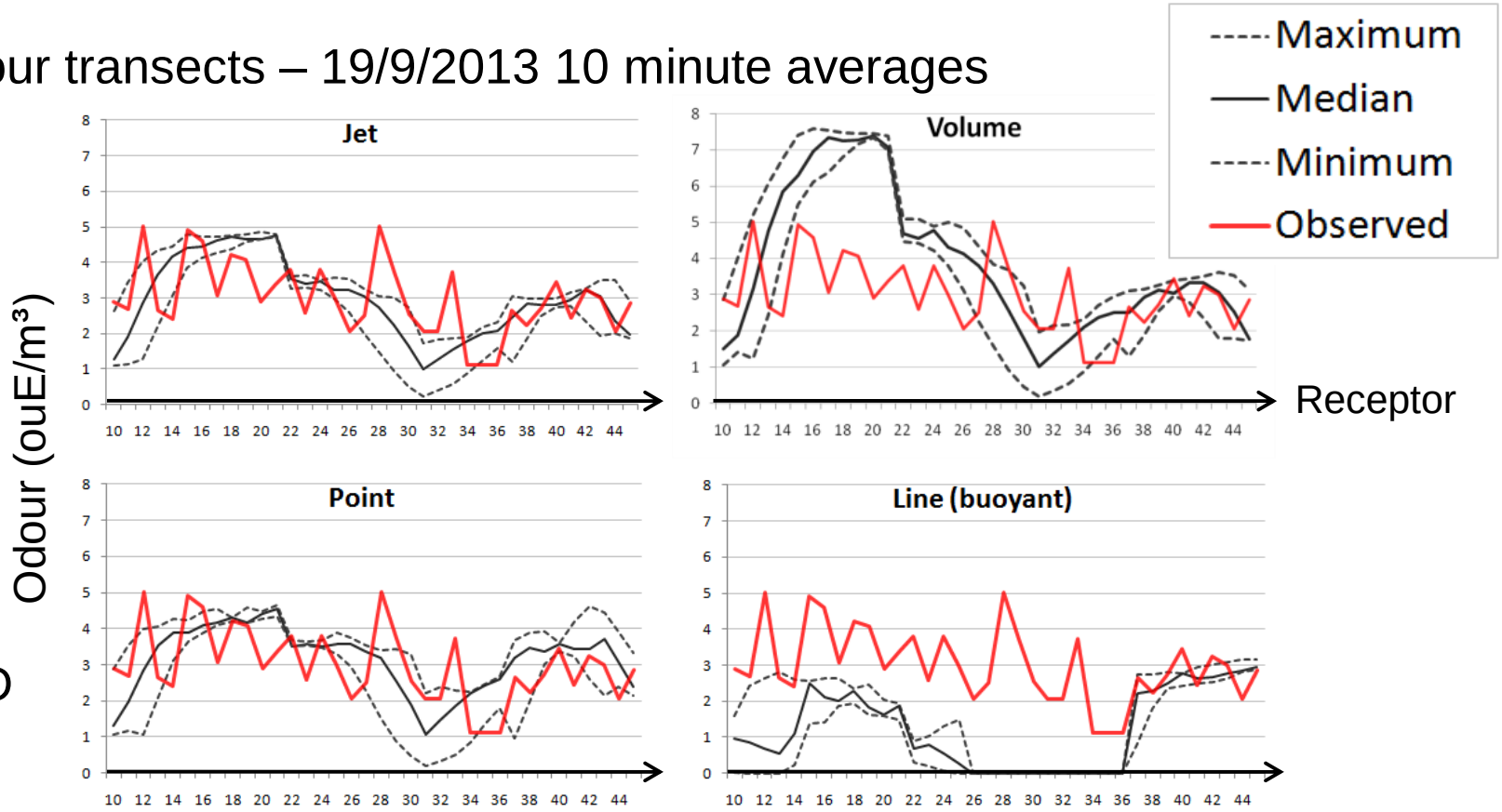


Case study
Results

- Odour transects – 19/9/2013 10 minute averages

ADMS 5

AERMOD



- Buoyant sources better represent odour variations, in general, although some under-prediction for AERMOD line (buoyant)
- Non-buoyant sources may over-predict

Conclusions
Case study: modelling Whitelees Farm

- Model configurations including the effects of buoyancy and momentum show much better performance than those without: specifically ADMS jet, area, line and point sources and AERMOD buoyant line and point sources;

- The ADMS jet source gives the best statistics overall; we might anticipate this as jet sources are able to model initial direction of exhaust flow (45°) from cowls;

- The AERMOD line (buoyant) source shows good statistics, however both mean and maximum concentrations are under-predicted.

Project conclusions

- For agricultural sheds it is important to model the effects of plume momentum and buoyancy unless momentum of sources is small.
- For near-field (<100 m) concentrations use all available information relating to the source dimensions and exit conditions in modelling releases from agricultural sheds.
- For distances >100 m, source dimensions are less important. Efflux conditions may be important, depending on the buoyancy and momentum of the release.
- The effects on dispersion of low-level agricultural sheds and buildings may not be important when multiple sources are modelled: - They are low so building downwash is minimal and the increased turbulence caused by the building has little effect because the sources are already spread out.

Final version of the report is now available

https://admlc.wordpress.com/publications/