Meeting Modelling Challenges: ADMS 4 and ADMS-Airport

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Content

ADMS 4

- New features
- Flat terrain validation
- Buildings validation
- Hills & hills with buildings validation

ADMS-Airport

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New scientific features

- Improvements to the buildings module
  - Changes to the effective building
  - Modifications for stable and convective conditions
- Wet deposition of SO2 and HCl improved by use of a “Falling Drop” model of kinetics and chemistry
- Treatment of calm conditions
- Extension to coastline module
- Use of vertical profiles of met parameters

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New scientific features (cont)

- More meteorological parameters (source and met site)
  - Priestley-Taylor parameter, albedo
- Outputs specific or relative humidity and temperature
- Calculates gamma dose due to deposition
- Input of spatially varying flow and turbulence e.g. mesoscale model output
- Offshore boundary layer
- *Many user features.*

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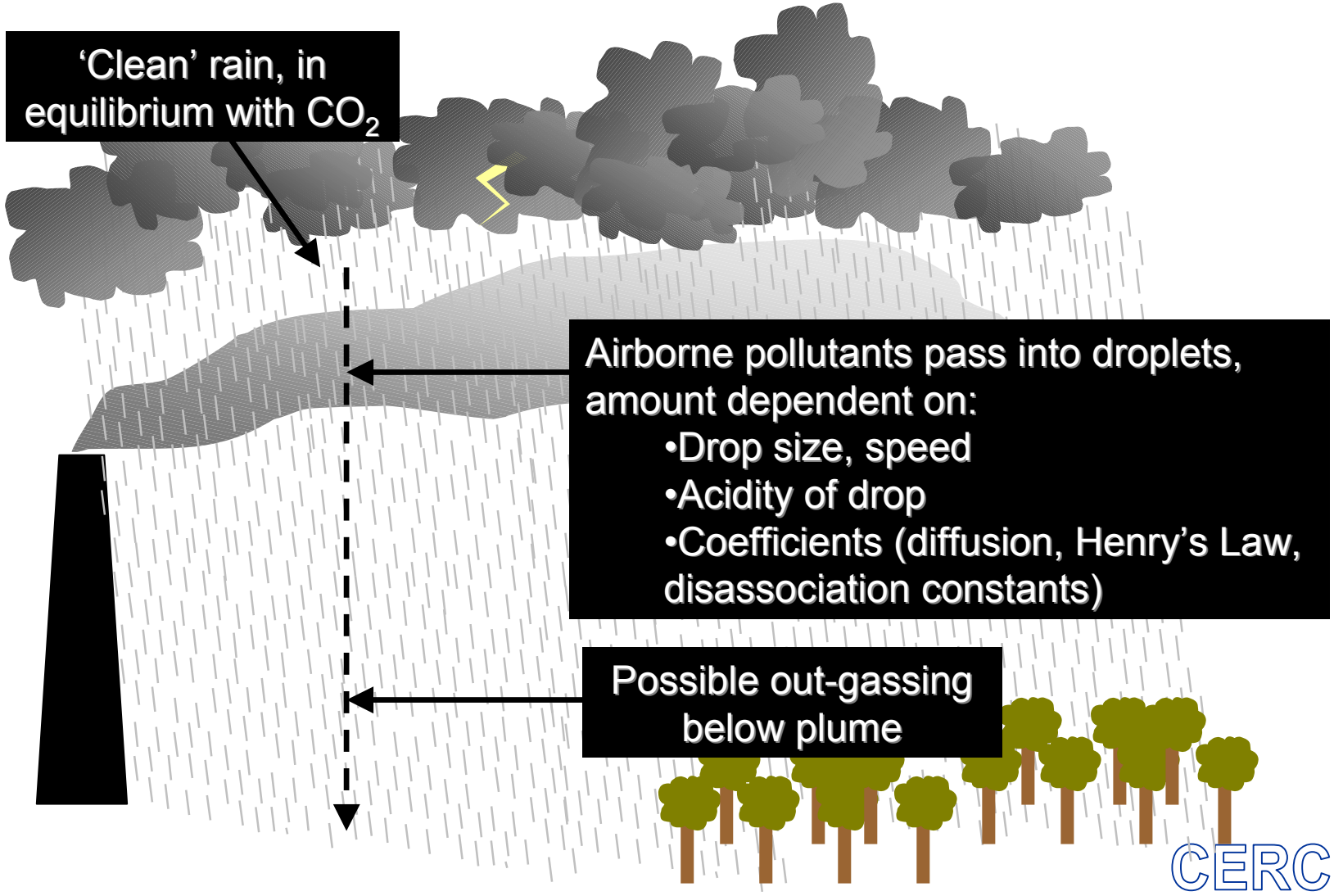
Wet deposition in ADMS 4

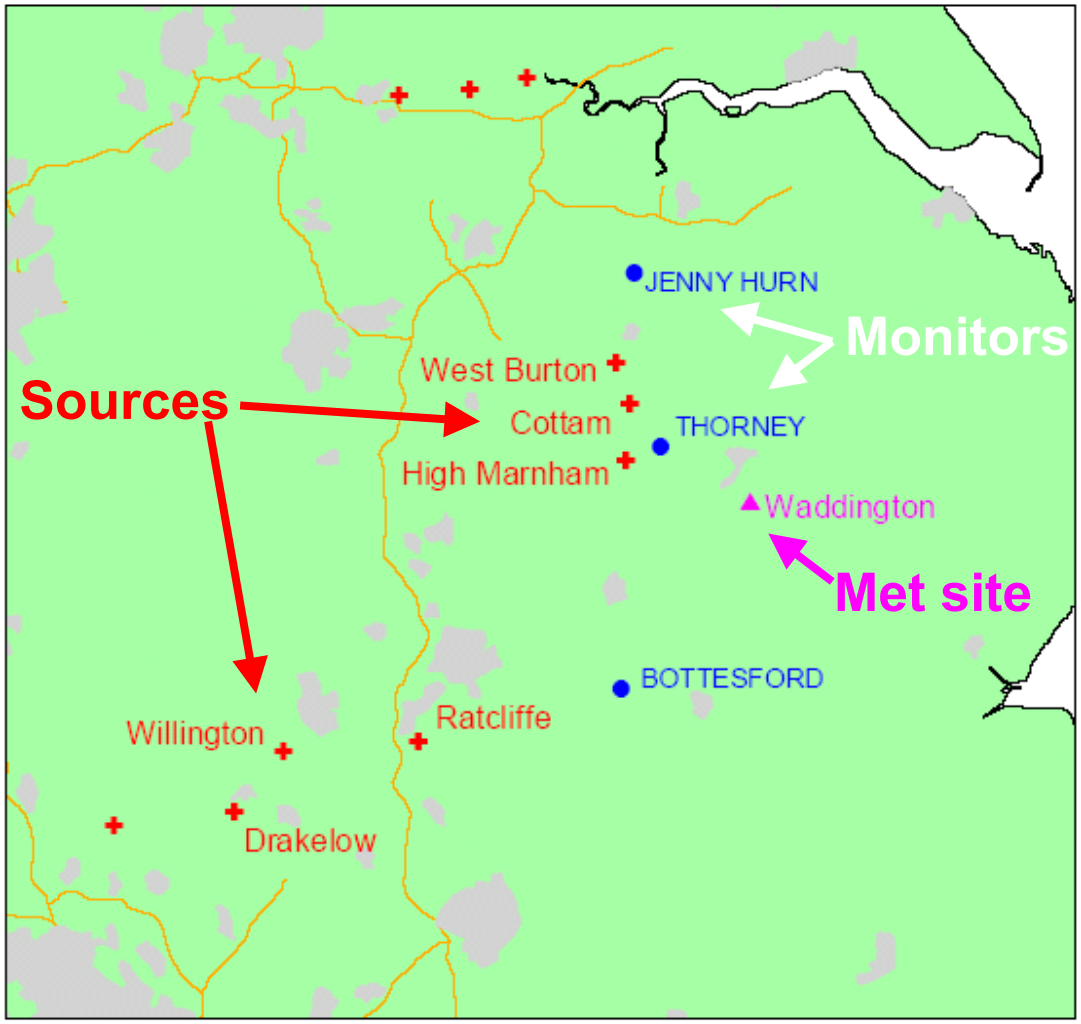
Model Description – Falling Drop



Wet deposition in ADMS 4

Comparison with data

JEP report *'Comparison of ADMS Wet Deposition Against Monitored Data and Assessment of the Relevance of HCl Deposition from Power Stations'*



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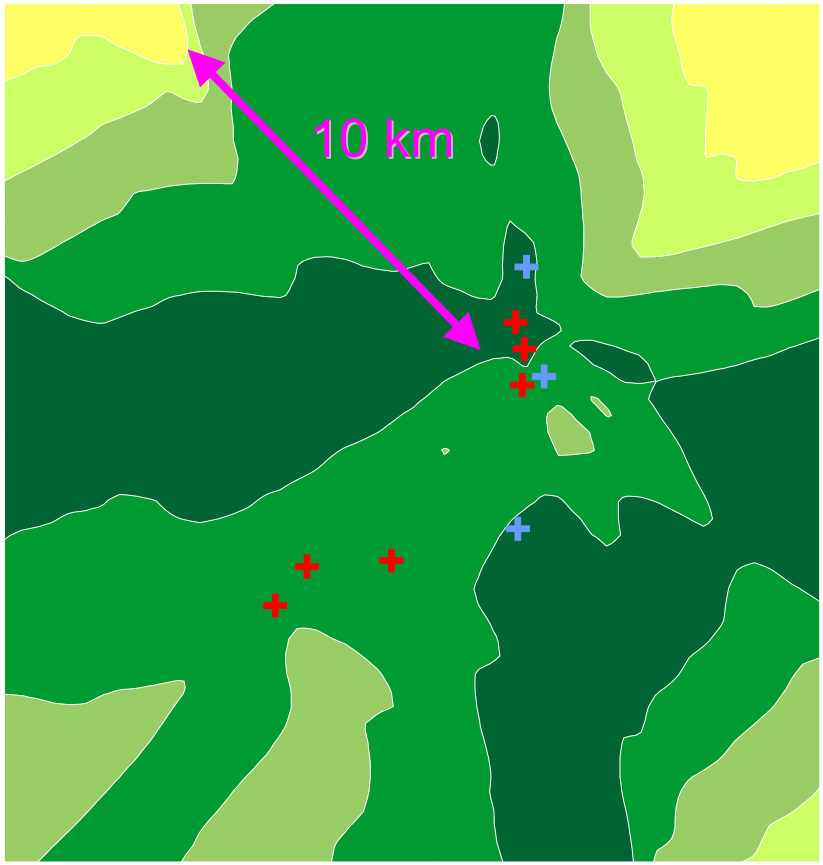
Wet deposition

ADMS 4 predicted wet deposition

Monitors

Sources

SO_2 wet deposition
Falling drop method



High deposition in far field

SO_2 µg/m²/s

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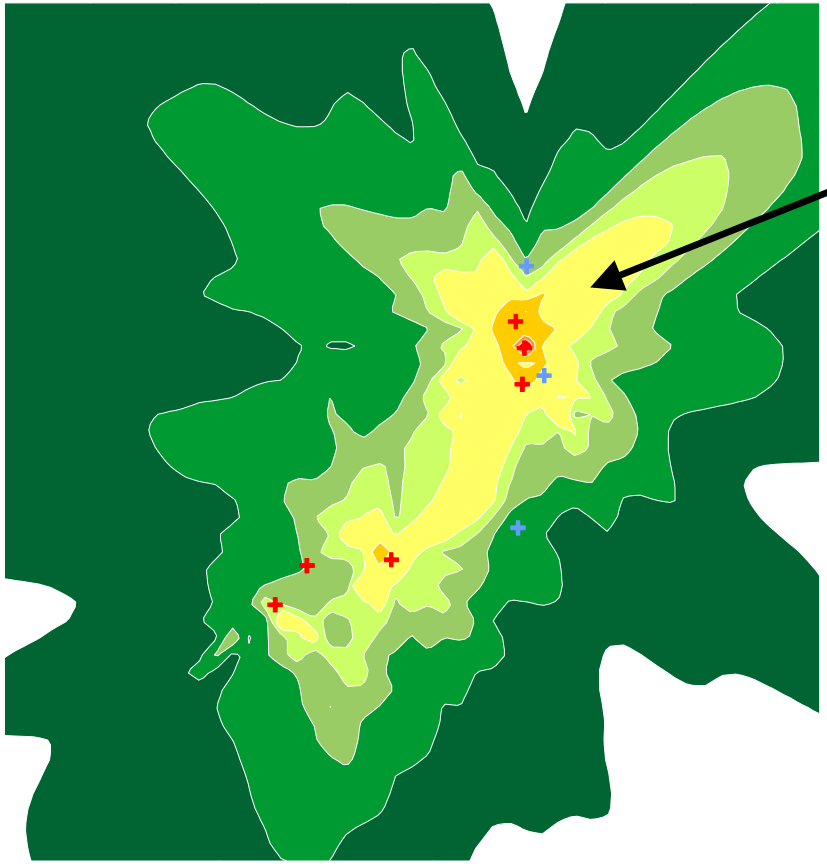
Wet deposition

ADMS 3 predicted wet deposition

Monitors

Sources

SO_2 wet deposition in ADMS 3



High deposition close to source

SO_2 µg/m²/s

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Calm conditions
New approach in ADMS 4

- New ‘hybrid’ approach at low wind speeds:
  - At wind speeds less than or equal to 0.5m/s use a radially symmetric solution assuming equal probability of all wind directions.
  - At wind speeds above approximately 1.2m/s (depends on vertical turbulence, time travelled from source), use standard ADMS calculations.
  - At wind speeds between these limits, interpolate between the radially symmetric and standard ADMS solutions

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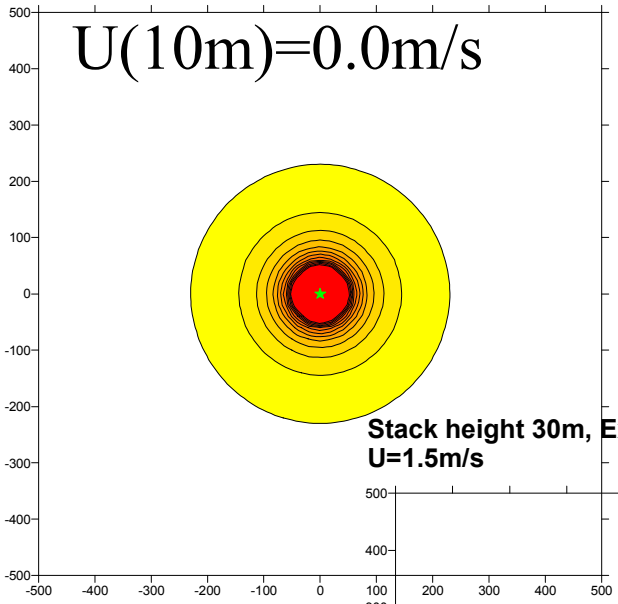
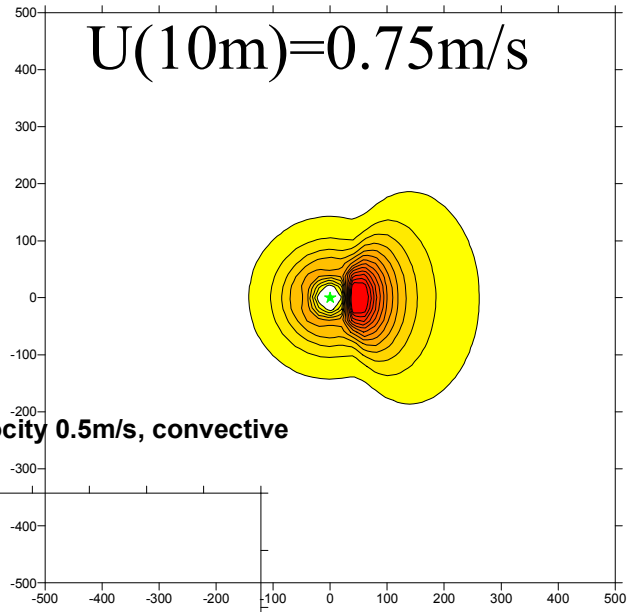
Calm Conditions

30m non-passive source in convective conditions

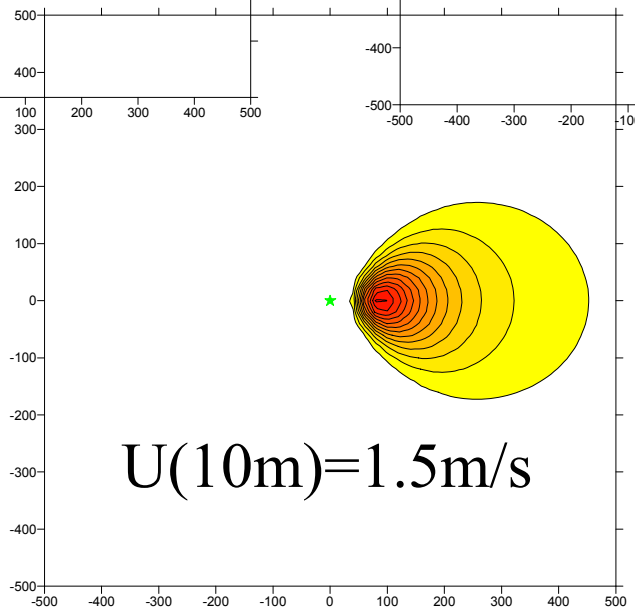
Stack height 30m, Exit velocity 0.5m/s, convective U=0m/s



Stack height 30m, Exit velocity 0.5m/s, convective U=0.75m/s



Stack height 30m, Exit velocity 0.5m/s, convective U=1.5m/s



★ Source location

High

Low

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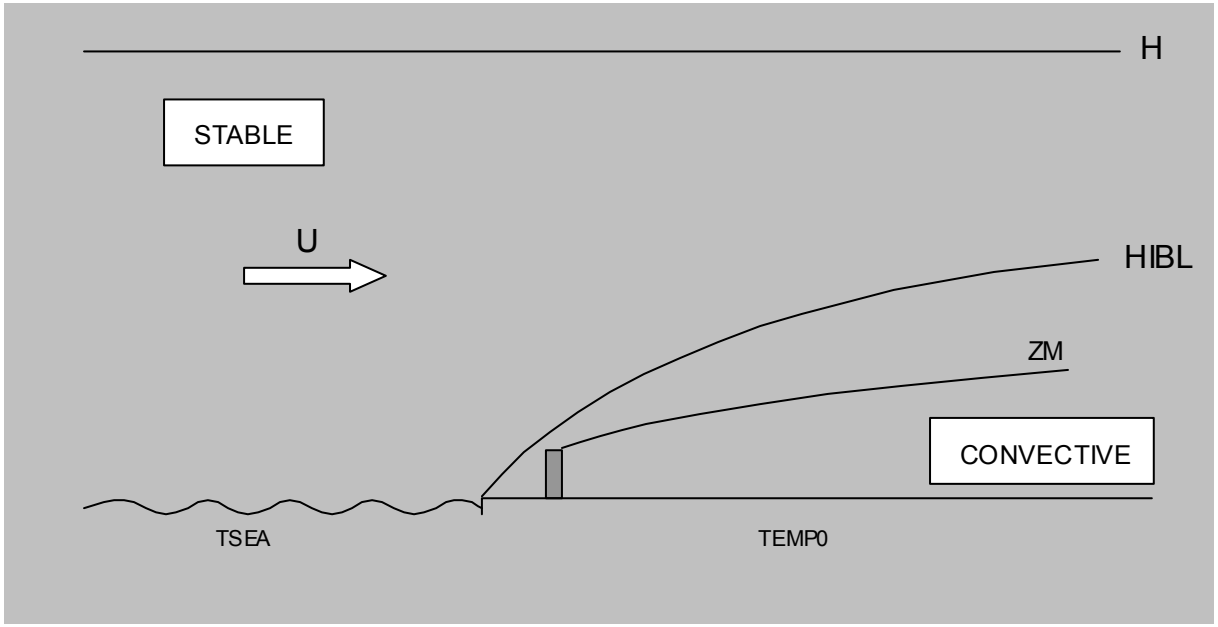
Coastline - extended

- Now include sources starting inside internal boundary layer



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Validation – aims and methods of analysis

ADMS 4 validation:

- 20 studies used
- Model set up:
  - Flat terrain (without buildings)
  - Hills
  - With buildings
  - Met. profile files
- Calculations:
  - Long-term (year)
  - Short-term (few met. lines)
- Monitored data:
  - field campaign
  - wind tunnel experiments

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Validation – aims and methods of analysis

- Results
  - Remove (observed, modelled) if observed or modelled not present
  - Remove (observed, modelled) = (0, 0)
  - Ignore data with a (supplied) low quality index
  - Work with these data or normalised by emission rate (usually)
  - Graphical: scatter plot and quantile-quantile plot
  - Numerical:
    - mean
    - 1-hour, 3-hour, 24-hour maximum values
    - Robust Highest Concentration (RHC)
    - BOOT statistical package from Model Validation Kit
- Issues
  - Behaviour of high values dominate the mean
  - Useful to normalise by the observed concentration
  - Look at other statistics

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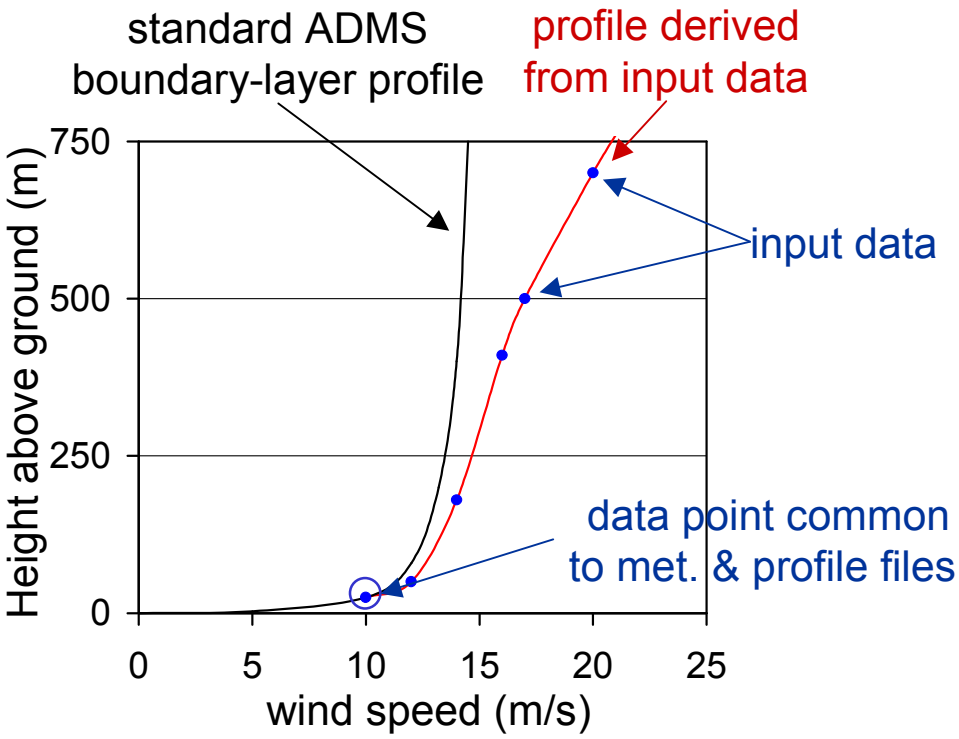
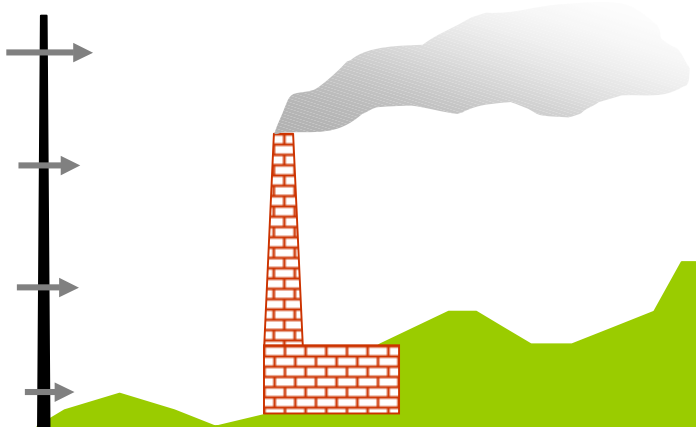
Meteorological profile data

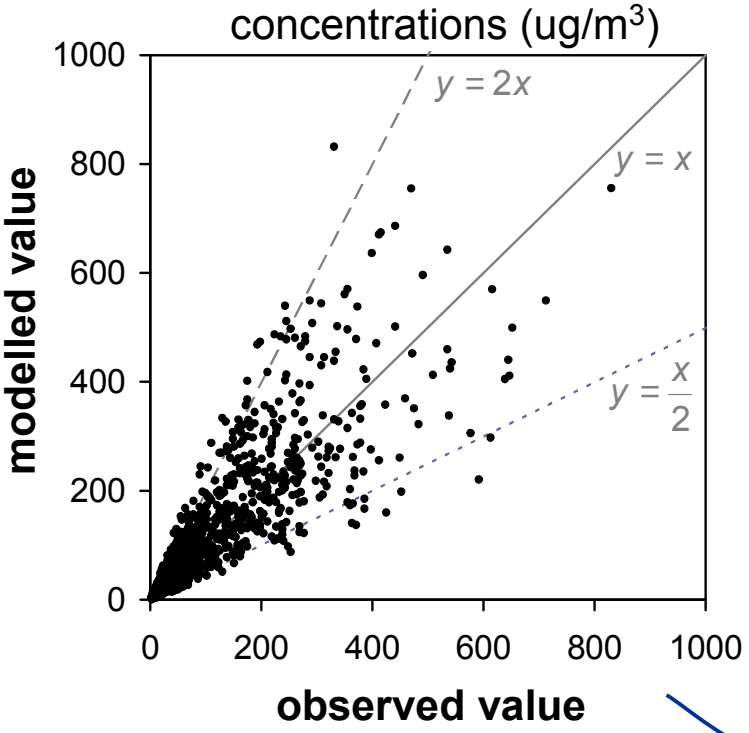
- Met tower: wind speed, temperature, etc., at different heights
- ADMS 4 can use ‘profile’ data to adjust the standard ADMS boundary layer profiles



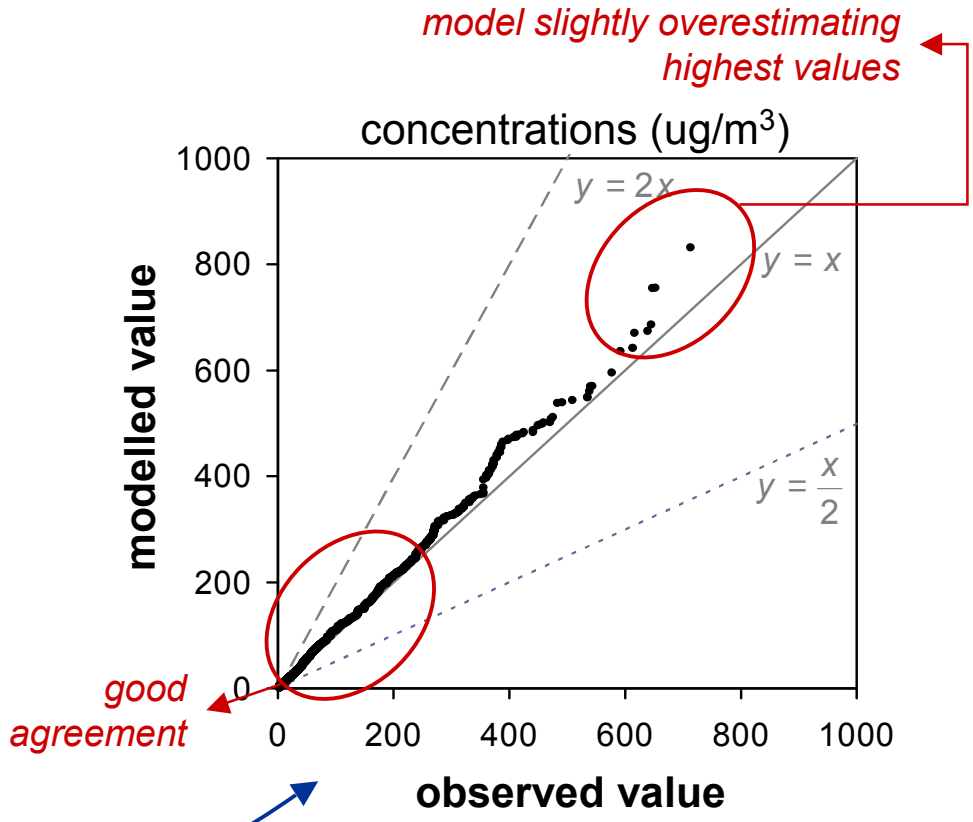


Validation – aims and methods of analysis

Scatter plot of concentrations of the pollutant



Quantile-quantile plot of concentrations of the pollutant



model and observations sorted separately

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Validation – aims and methods of analysis

- BOOT statistical package: range of statistics

  Dimensional measure

  Non-dimensional measure

Data	Mean	σ	Bias	NMSE	Correlation	Factor of 2
Observations	64.83	37.35	0	0	1	1
Model	37.35	25.43	15.99	0.44	0.47	0.68

Measure of spread of values

Values generally higher or lower?

Measure of overall behaviour (normalised mean square error)

Measure of 'pattern' of results

Fraction of values within a factor of 2

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Flat terrain validation

Studies (tracer)	Release	Met.
Kincaid power plant *Illinois, US*	187-m stack	neutral, convective 171 hours
Indianapolis Perry-K power plant *Indiana, US*	84-m stack	all (day & night) 170 hours
Prairie Grass ***Nebraska, US***	ground level passive	all (day & night)

All flat terrain datasets are part of the Model Validation Kit (from *"Harmonisation of Atmospheric Dispersion Modelling for Regulatory Purposes"* conferences)

Key ***Bold italic = better than ADMS 3.3***
Italic = similar to slightly better than ADMS 3.3
No bold or italic = worse versus ADMS 3.3

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Flat terrain validation – summary of results

Data		Mean	σ	Bias	NMSE	Corr	Fac 2
Kincaid	**Observations**	54.3	40.3	0.0	0.0	1.00	1.00
	ADMS 4	48.5	31.5	5.9	0.6	0.45	0.68
Indianapolis	**Observations**	351.5	221.4	0.0	0.0	1.00	1.00
	ADMS 4	348.1	237.4	3.5	0.6	0.26	0.55
Prairie Grass	**Observations**	2.23	3.90	0.00	0.00	1.00	1.00
	ADMS 4	1.56	3.33	0.67	3.01	0.63	0.66

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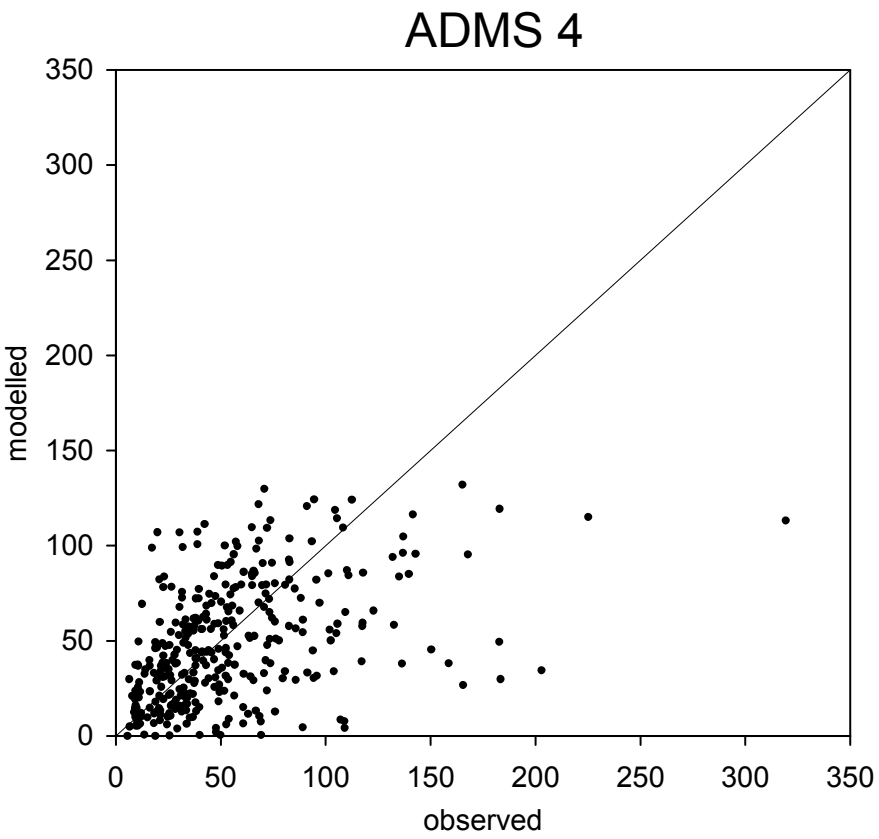
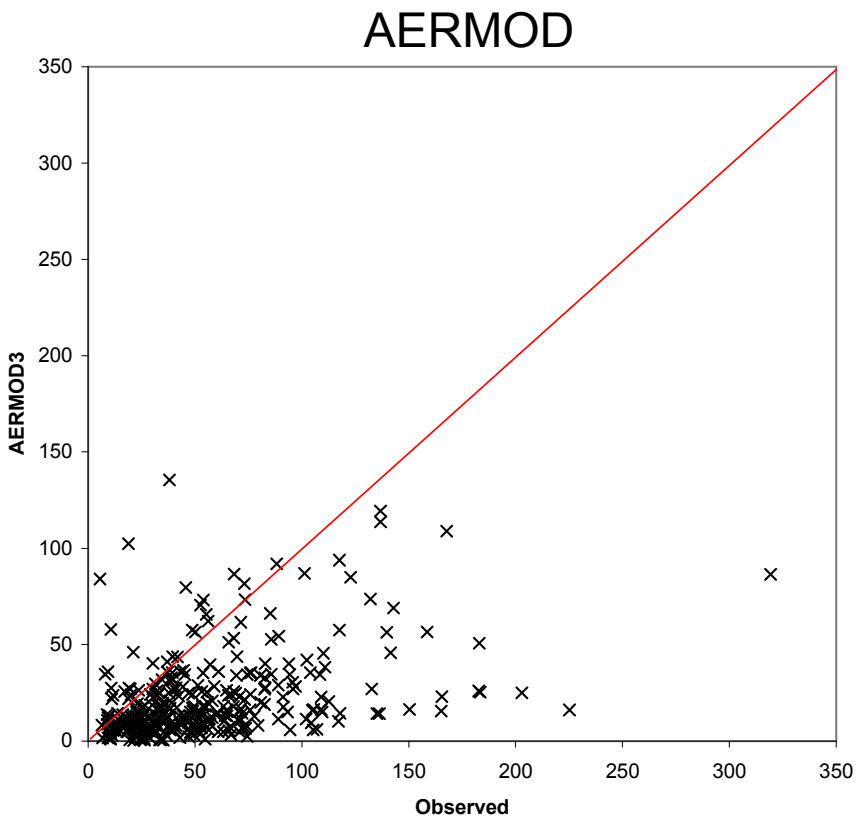
Flat terrain – Kincaid power plant

- Scatter plots (ns/m^3)





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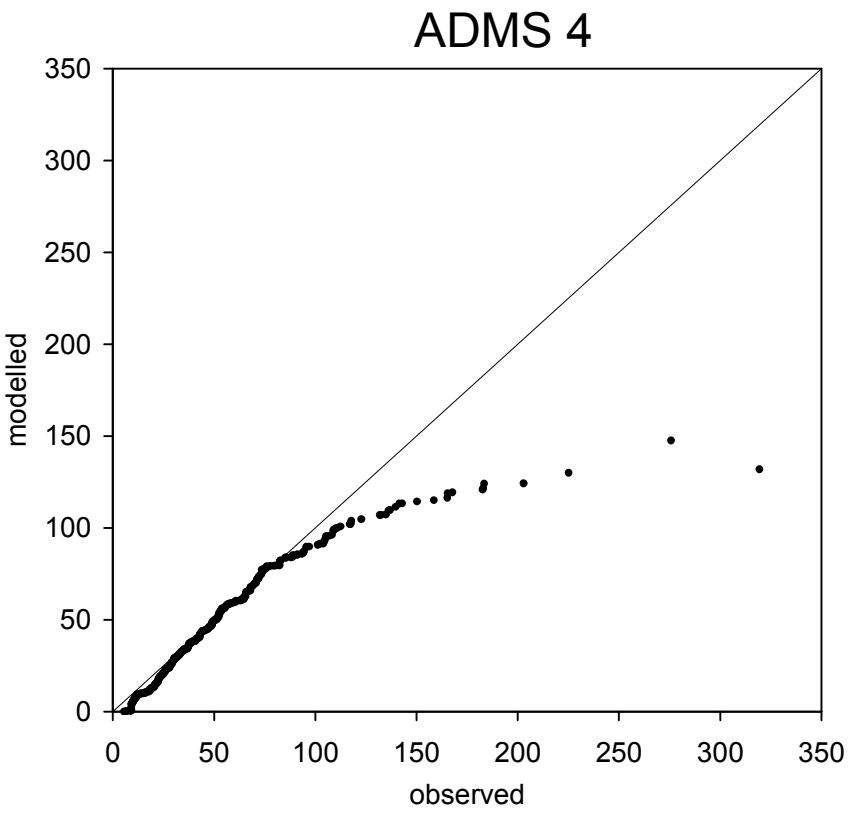
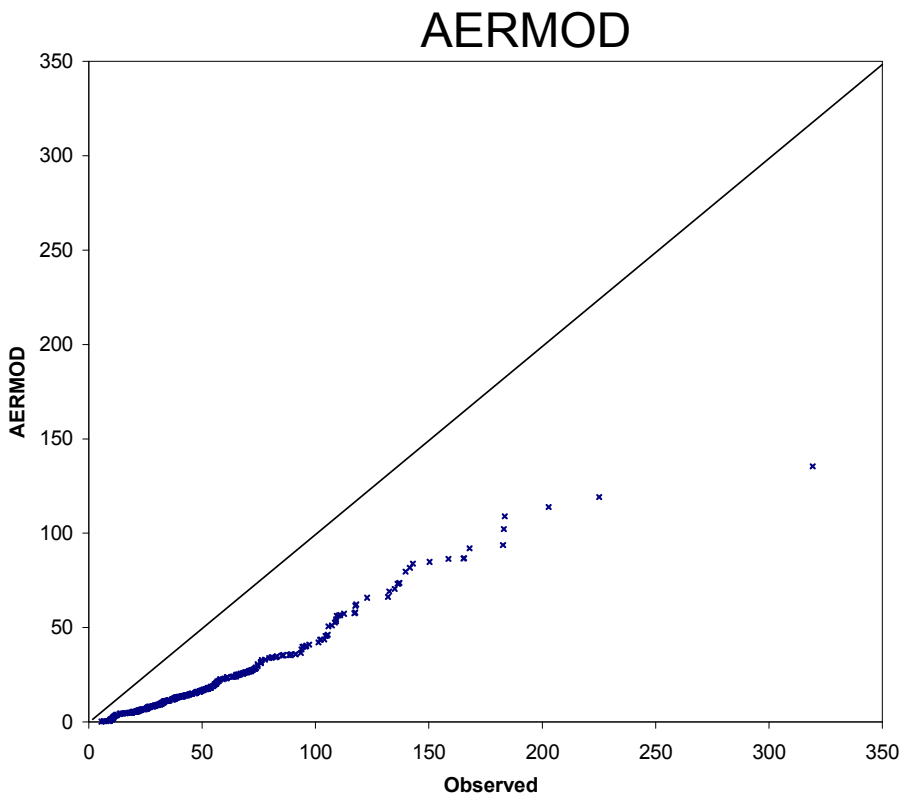
Flat terrain – Kincaid power plant

- Quantile-quantile plots (ns/m^3)





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Buildings validation – field studies

Study	Release	Building(s)	Met.
AGA (tracer) ***Texas, Kansas, US***	10-24 m stacks buoyant	12 m high	convective (41 met. lines)
Alaska (tracer) ***Alaska, US***	39-m stack buoyant	34 m high	stable, neutral (44 met. lines)
Bowline Point site *New York, US*	87-m stack buoyant	30 to 65 m high	mainly stable & conv. (1 year)
EOCR (tracer) ***Idaho, US***	1, 25, 30-m stacks passive	7 and 25 m high	mainly convective (19 met. lines)
Millstone power plant *Connecticut, US*	29 & 48-m stacks buoyant	28-45 m high	mainly stable & neutral (36 met. lines)

Key ***Bold italic = better than ADMS 3.3***
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No bold or italic = worse versus ADMS 3.3

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Buildings validation – summary of field study results

Data		Mean	σ	Bias	NMSE	Corr	Fac 2
AGA	Observations	58.7	54.1	0.0	0.0	1.00	1.00
	ADMS 4	75.9	65.8	17.2	0.9	0.51	0.51
Alaska	Observations	0.8	1.2	0.0	0.0	1.00	1.00
	ADMS 4	2.4	2.4	-1.6	3.7	0.47	0.23
EOCR	Observations	140.9	357.8	0.0	0.0	1.00	1.00
	ADMS 4	248.5	607.9	-107.6	7.2	0.59	0.43
Millstone	Observations	18.6	14.8	0.0	0.0	1.00	1.00
	ADMS 4	11.9	12.2	6.7	1.4	0.28	0.45

modelled/observed ratios

Data		1-h max	3-h max	24-h max	annual mean	1-h RHC	3-h RHC	24-h RHC
Bowline	ADMS 4	1.11	1.22	0.46	0.23	0.75	0.74	0.53
	AERMOD '03	-	-	-	-	-	1.14	1.43

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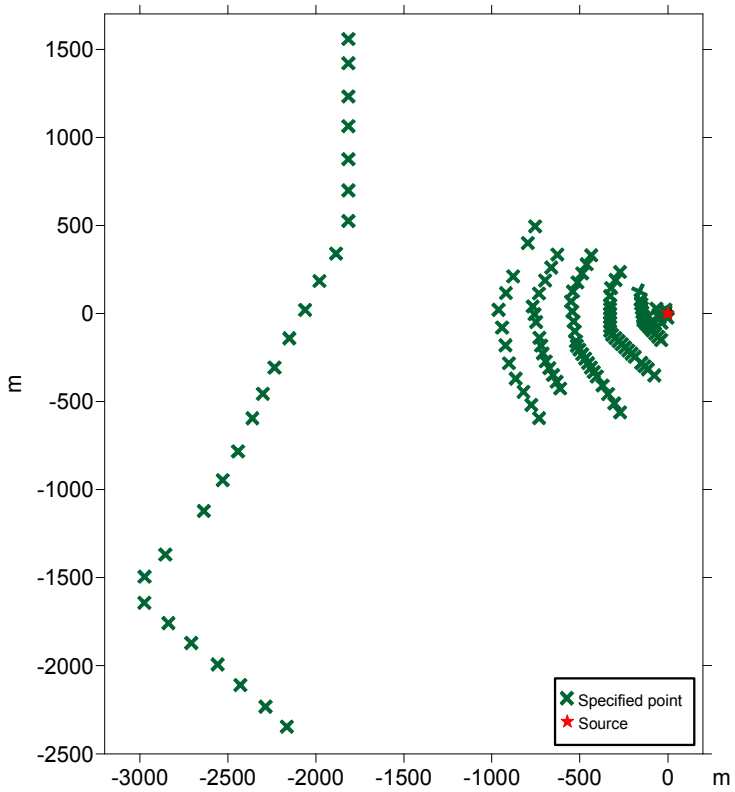
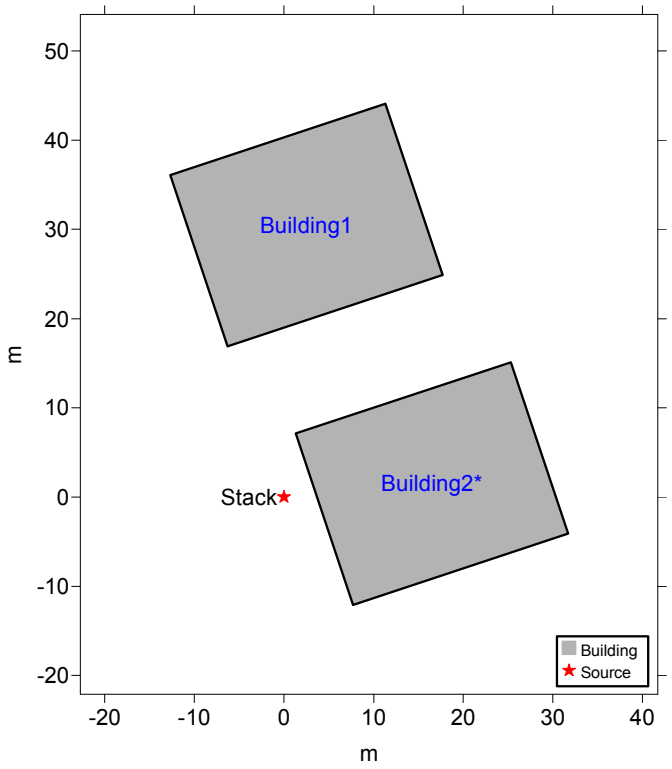
Buildings – Alaska North Slope Tracer Study

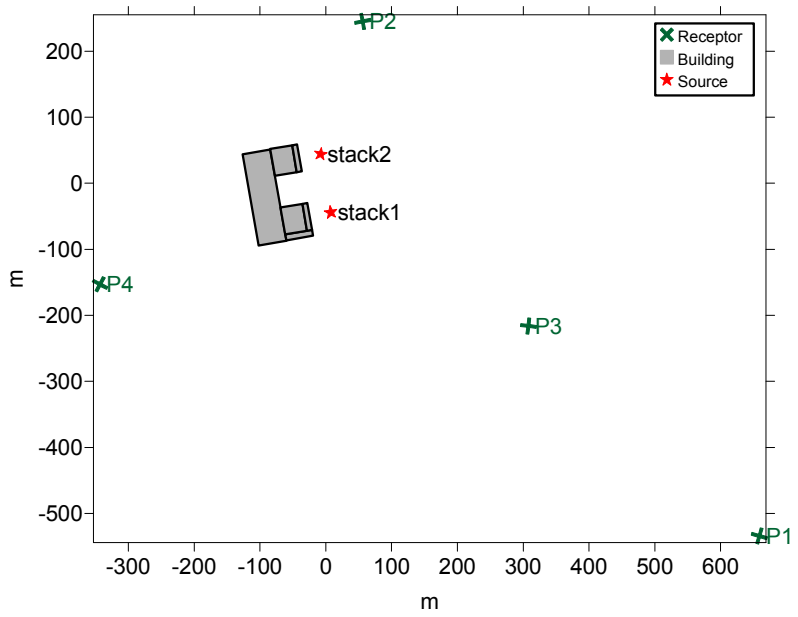
- Site – smooth snow-covered tundra
- Met – 44 hours, neutral or slightly stable
- Release – 39-m high turbine stack, SF_6, buoyant
- Results – us/m^3 (normalised by emission rate)

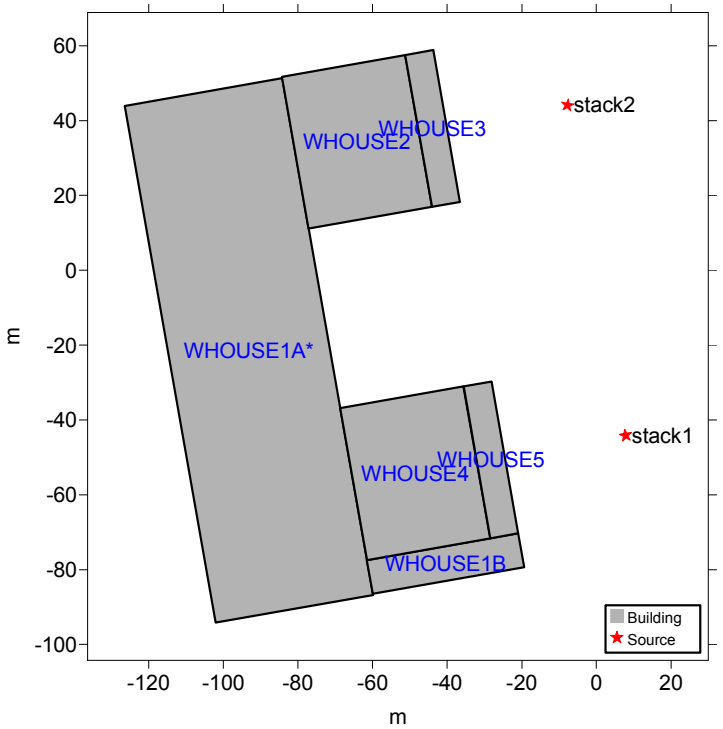




Buildings – Bowline Point site

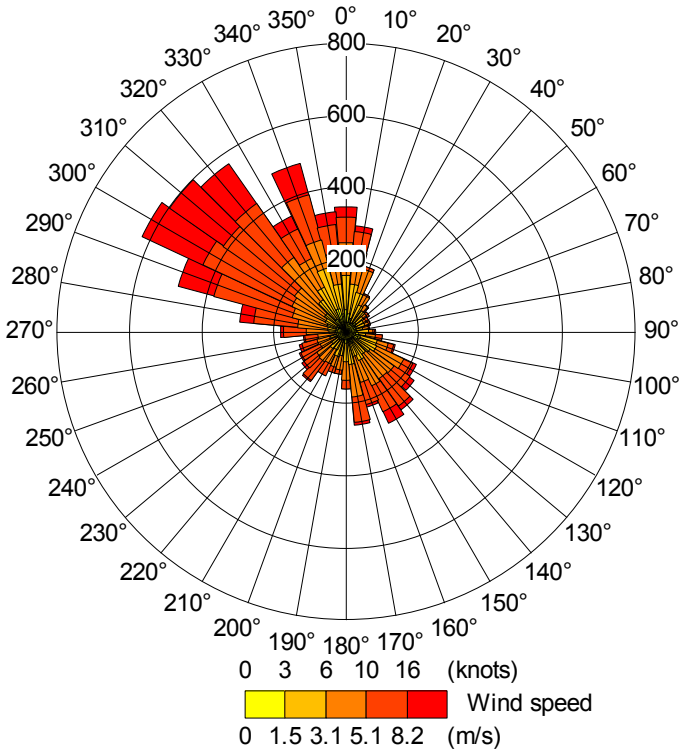
- Site – Hudson River valley, rural and relatively flat terrain, urban area to the west, significant hills to the south-west
- Met – one year, mainly stable or unstable
- Release – 2 stacks, 87 m high, SO_2, buoyant
- Results – $\mu g/m^3$ (! background)

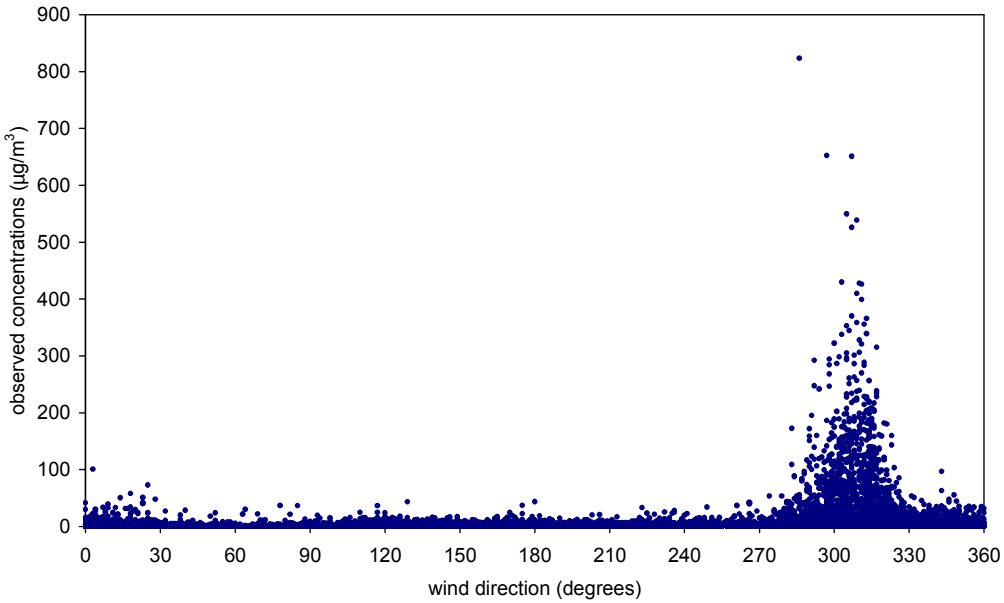




Buildings – Bowline Point site

- Wind rose and observed concentrations at P1 (ug/m^3, versus wind direction)





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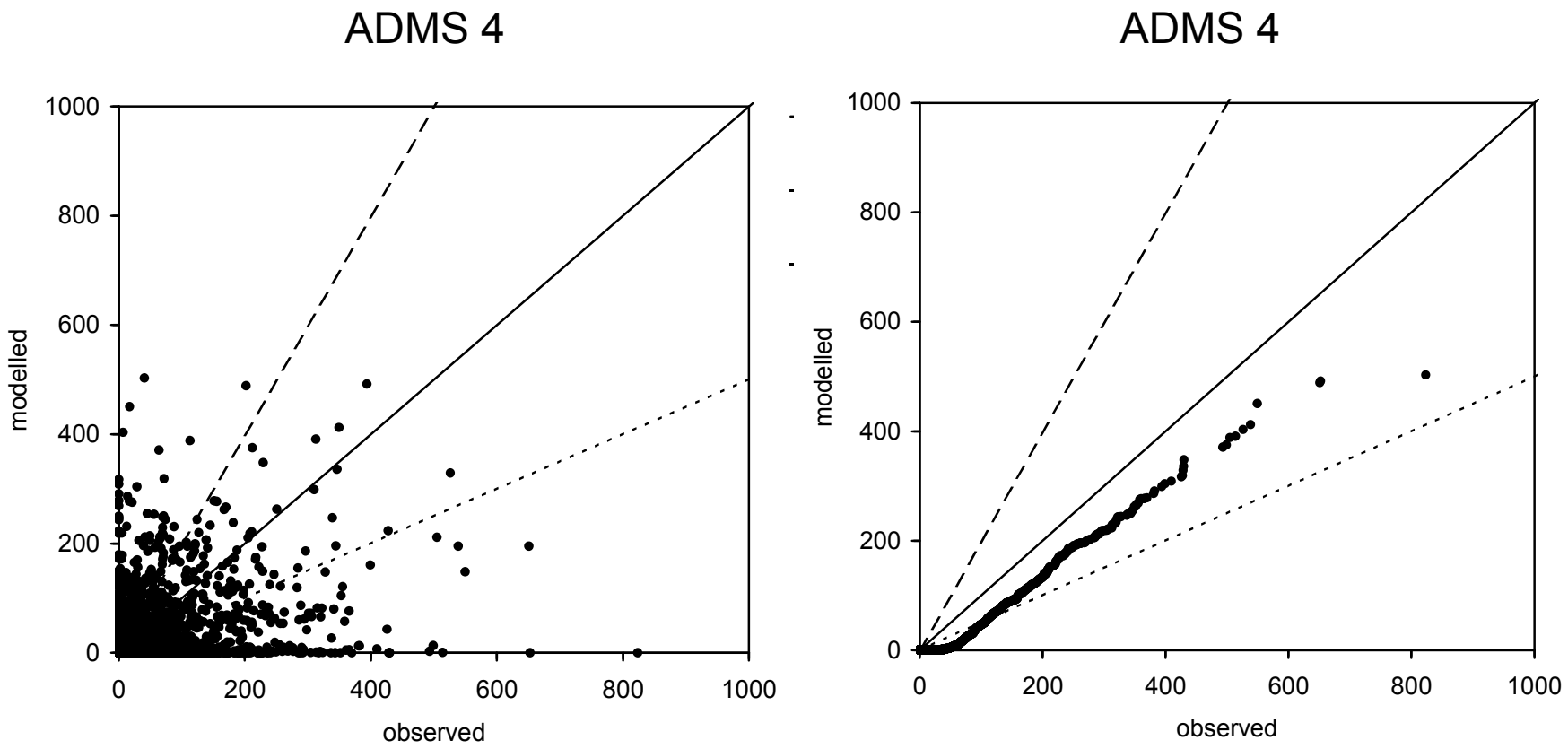
Buildings – Bowline Point site

- Scatter plot (left) and quantile-quantile plot (right) (ug/m^3)



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Buildings validation – wind tunnel studies

Wind tunnel: often a model set up of a real site
(dimensions are equivalent full scale)

Study	Release	Building (s)	Met.
Lee	65-m stack range of buoyancies	rectangular (40 m high)	stable, neutral
Robins & Castro	60 to 150-m stacks range of buoyancies	cubic (60 m high)	neutral
Snyder	12.5, 50, 125-m stack buoyant	rectangular (50 m high)	neutral
Warehouse fires	roof openings range of buoyancies	rectangular (10 m high)	neutral

Key ***Bold italic = better than ADMS 3.3***
Italic = similar to slightly better than ADMS 3.3
No bold or italic = worse versus ADMS 3.3

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Buildings validation – summary of wind tunnel study results

Data		Mean	σ	Bias	NMSE	Corr	Fac 2
Lee	**Observations**	2.77	2.53	0.00	0.00	1.00	1.00
	ADMS 4	2.65	2.26	0.11	0.23	0.86	0.79
Robins & Castro	**Observations**	1.00	0.00	0.00	0.00	1.00	1.00
	ADMS 4	0.96	0.32	0.04	0.11	0.84	0.85
Snyder	**Observations**	1.00	0.00	0.00	0.00	-	1.00
	ADMS 4	1.32	1.50	-0.32	1.77	-	0.86
Warehouse fires	**Observations**	1.00	0.68	0.00	0.00	1.00	1.00
	ADMS 4	0.59	0.89	0.41	1.35	0.52	0.37

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Hills validation

Studies	Release	Terrain	Met.
Cinder Cone Butte (tracer) *Idaho, US*	15-40 m passive	isolated hill	neutral, stable 19 met. lines
Hogback Ridge (tracer) *New Mexico, US*	20-70 m passive	ridge of a hill	stable, convective 7 met. lines
Tracy power plant (tracer) ***Nevada, US***	90 m buoyant	plant in a valley	stable 128 met. lines
Baldwin power plant* Illinois, US	185 m buoyant	plant in a valley	stable, convective (mainly) 1 year
Clifty Creek power plant *Indiana, US*	210 m buoyant	plant in a valley	stable, convective (mainly) 1 year
Martins Creek plant* Pennsylvania, US	65 to 182 m buoyant	plant in a valley	stable, convective (mainly) 1 year
Lovett power plant New-York, US	145-m stack buoyant	plant in a valley	stable, convective (mainly) 1 year
Westvaco plant ***Maryland, US***	190 m buoyant	plant in a valley	stable, convective (mainly) 1 year

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** hills and buildings*

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Hills validation – summary of results

- Short-term studies

Data		Mean	σ	Bias	NMSE	Corr	Fac2
Cinder Cone Butte	**Observations**	5.20	7.49	0.00	0.00	1.00	1.00
	ADMS 4	3.01	4.15	2.18	3.60	0.35	0.29
Tracy	**Observations**	0.22	0.53	0.00	0.00	1.00	1.00
	ADMS 4	0.14	0.50	0.08	16.12	0.09	0.07

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Hills studies – summary of results

- Long-term studies

modelled/observed ratios

Data		1-h max	3-h max	24-h max	annual mean	1-h RHC	3-h RHC	24-h RHC
Baldwin	**ADMS 4**	0.56	0.62	0.69	0.34	0.50	0.63	0.72
	AERMOD '03	-	-	-	-	-	1.24	0.97
Clifty Creek	**ADMS 4**	0.91	1.11	0.79	0.32	0.98	1.15	0.85
	AERMOD '03	-	-	-	-	-	1.05	0.67
Lovett	**ADMS 4**	0.95	0.83	0.67	0.35	0.82	0.70	0.44
	AERMOD '03	-	-	-	-	-	1.03	1.01
Martins Creek	**ADMS 4**	0.65	0.64	0.44	0.22	0.56	0.40	0.34
	AERMOD '03	-	-	-	-	-	1.12	1.78
Westvaco	**ADMS 4**	0.59	0.51	0.56	0.21	0.55	0.59	1.03
	AERMOD '03	-	-	-	-	-	1.06	1.07

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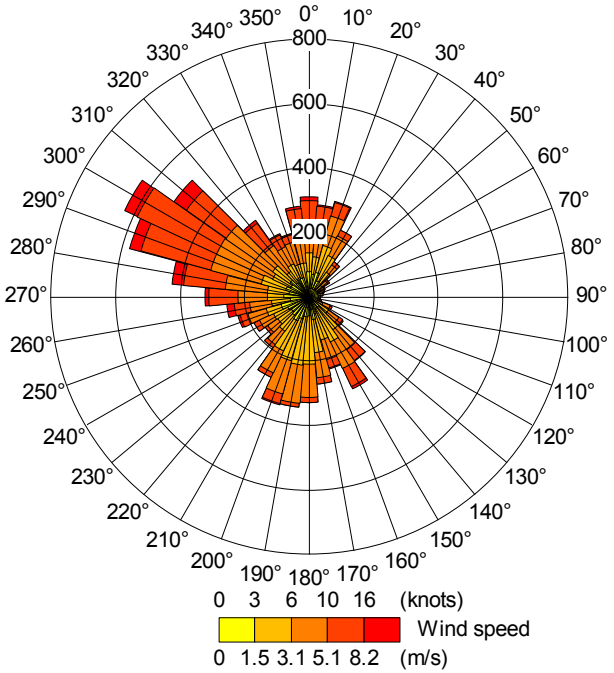
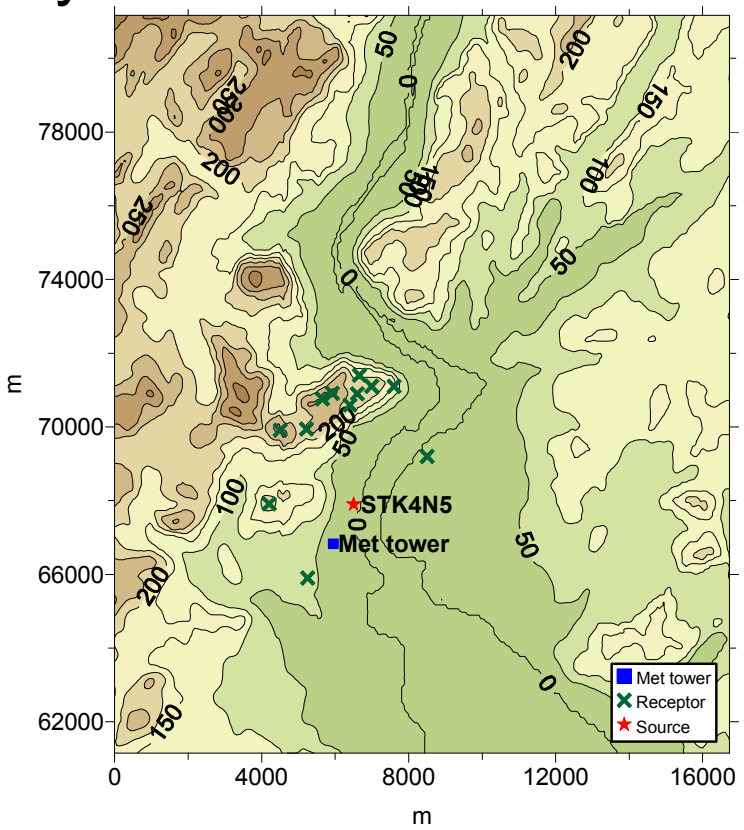
Hills validation – Lovett power plant

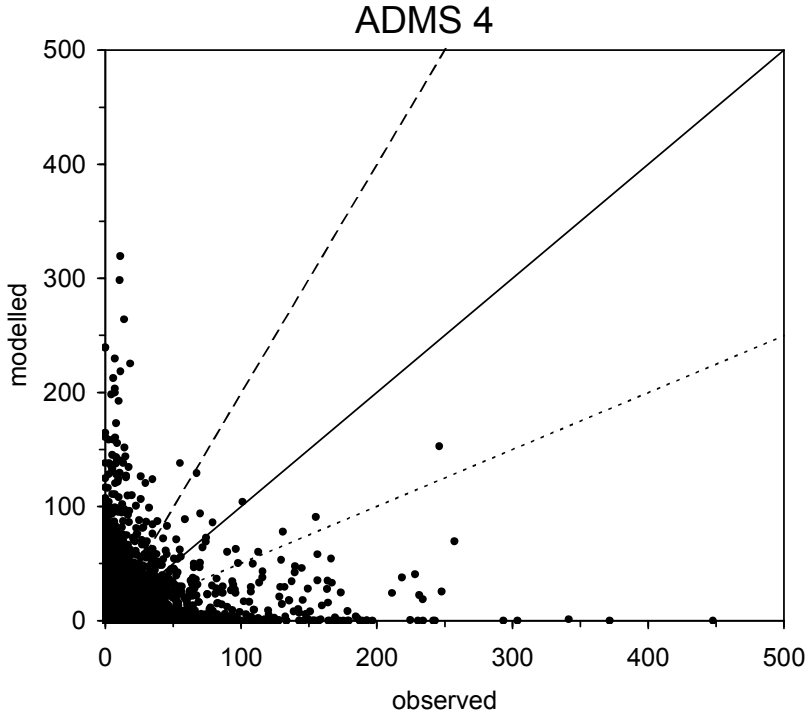
- Site – Hudson river, rural (z_0 = 0.001 to 1.5 m)
- Terrain – complex terrain (river at 0 m, hill tops at 300 m)
- Met – one year, mainly stable or unstable
- Release – 145-m stack, SO_2, buoyant
- Results – µg/m3

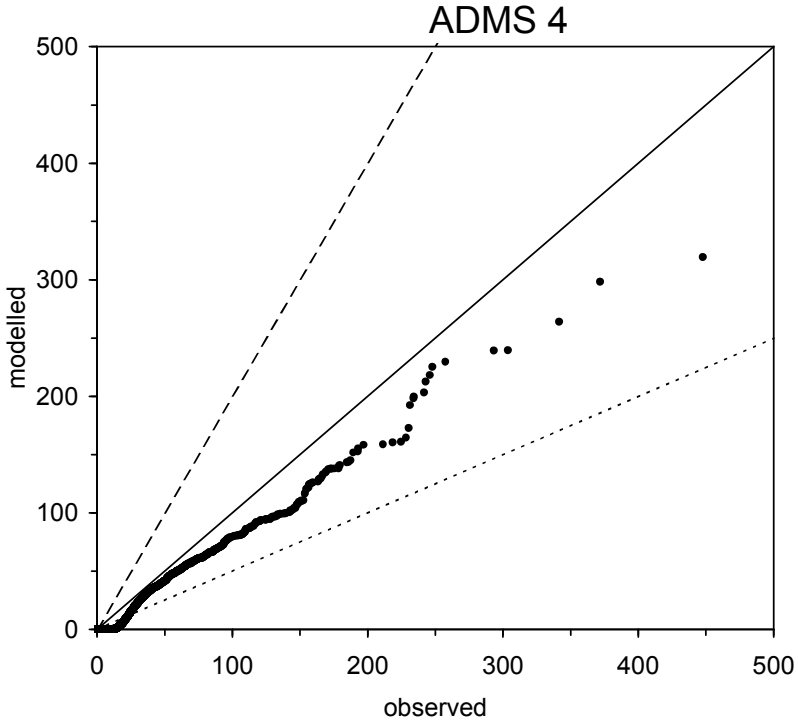




Hills validation – Lovett power plant

- Scatter plot (left) and quantile-quantile plot (right) (µg/m^3)





- Modelled/observed ratios

Data	1-h max	3-h max	24-h max	annual mean	1-h RHC	3-h RHC	24-h RHC
ADMS 4	0.95	0.83	0.67	0.35	0.82	0.70	0.44
AERMOD '03	-	-	-	-	-	1.03	1.01

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Conclusion - ADMS 4

- ADMS 4 was released in June 2007. It includes many new features and model improvements
- ADMS 4 results have been compared with measured data (a wide range of datasets, ADMS 3.3 (and AERMOD/ISC where available)
- ADMS 4 performance against data is improved compared with ADMS 3.3 performance
- The detailed validation documents have been posted on www.cerc.co.uk
- Input and output data are available on request
- Validation is an ongoing activity

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Features of ADMS-Airport

- An extension of ADMS-Urban – Gaussian type model nested in regional trajectory model
- Includes chemical reaction scheme, meteorological preprocessor, Monin-Obukhov and mixed layer scaling for boundary layer structure
- Allowance for up to 6500 sources: road (1500, each with up to 50 vertices), point, line area and volume (1500), grid sources (3000) and up to 500 runway sources (exhaust modelled as moving jets)
- Other airport features
  - Hour by hour time varying data
  - Multi-segment line sources e.g. taxi ways
  - GIS link displays line, volume and runway sources

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Features: Modelling exhausts as moving jets and impact of wake vortices

- Models engine exhausts as moving jet sources
- As the aircraft accelerates
  - buoyancy and emissions increasingly spread along the runway
  - the exhaust jet sees a faster ambient wind speed, this affects the plume rise
- The plume from the faster aircraft rises less than that from a slower aircraft
- Tested for the impact wake vortices may have on jet plume rise – reduce buoyancy

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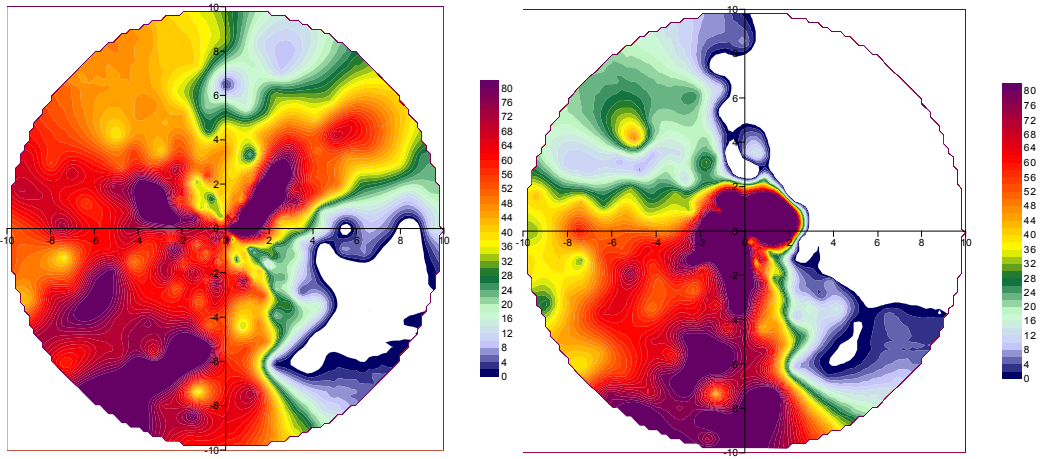
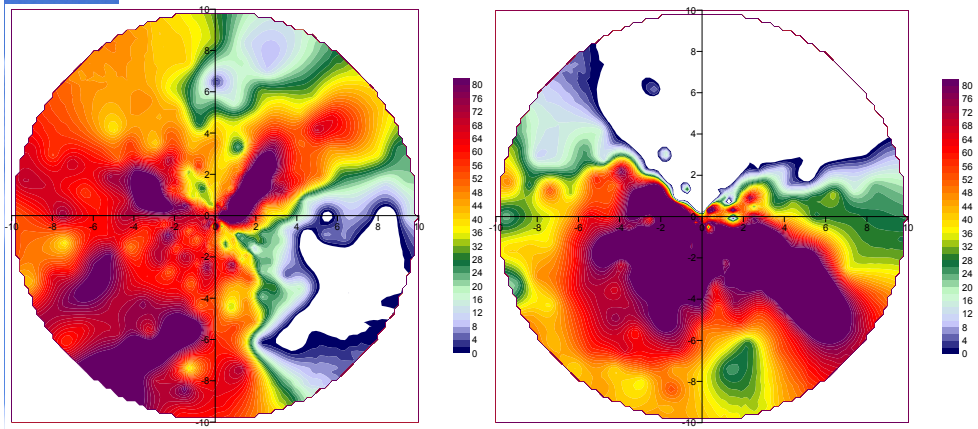
Measured v ADMS modelled



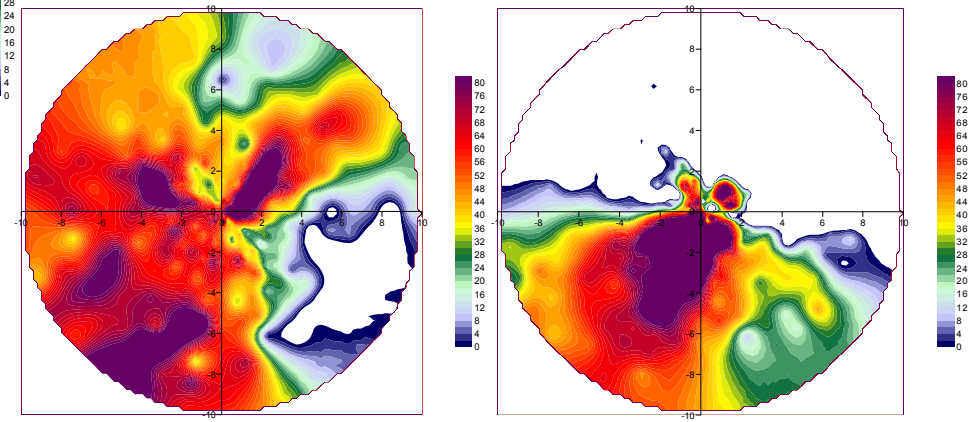
Measured LHR2

CERC predicted

Measured v Model 2



Measured v Model 3



<u>Polar plots</u> of NO_x at LHR2 with background concentrations subtracted. Radius: <u>wind speed</u> in m/s.

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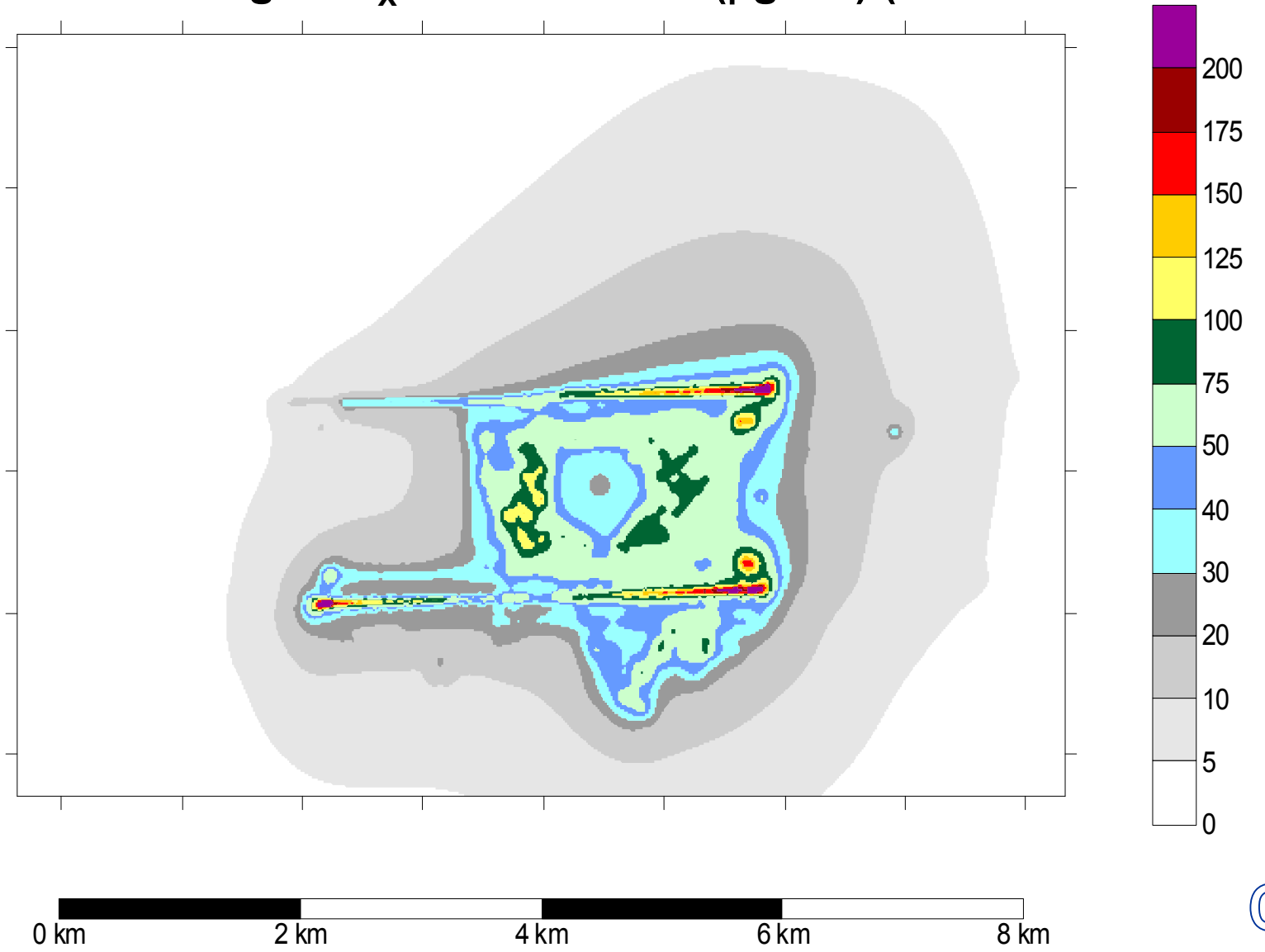
Source apportionment: Aircraft sources

Annual average NO_x concentration (µg/m3) (aircraft sources only)



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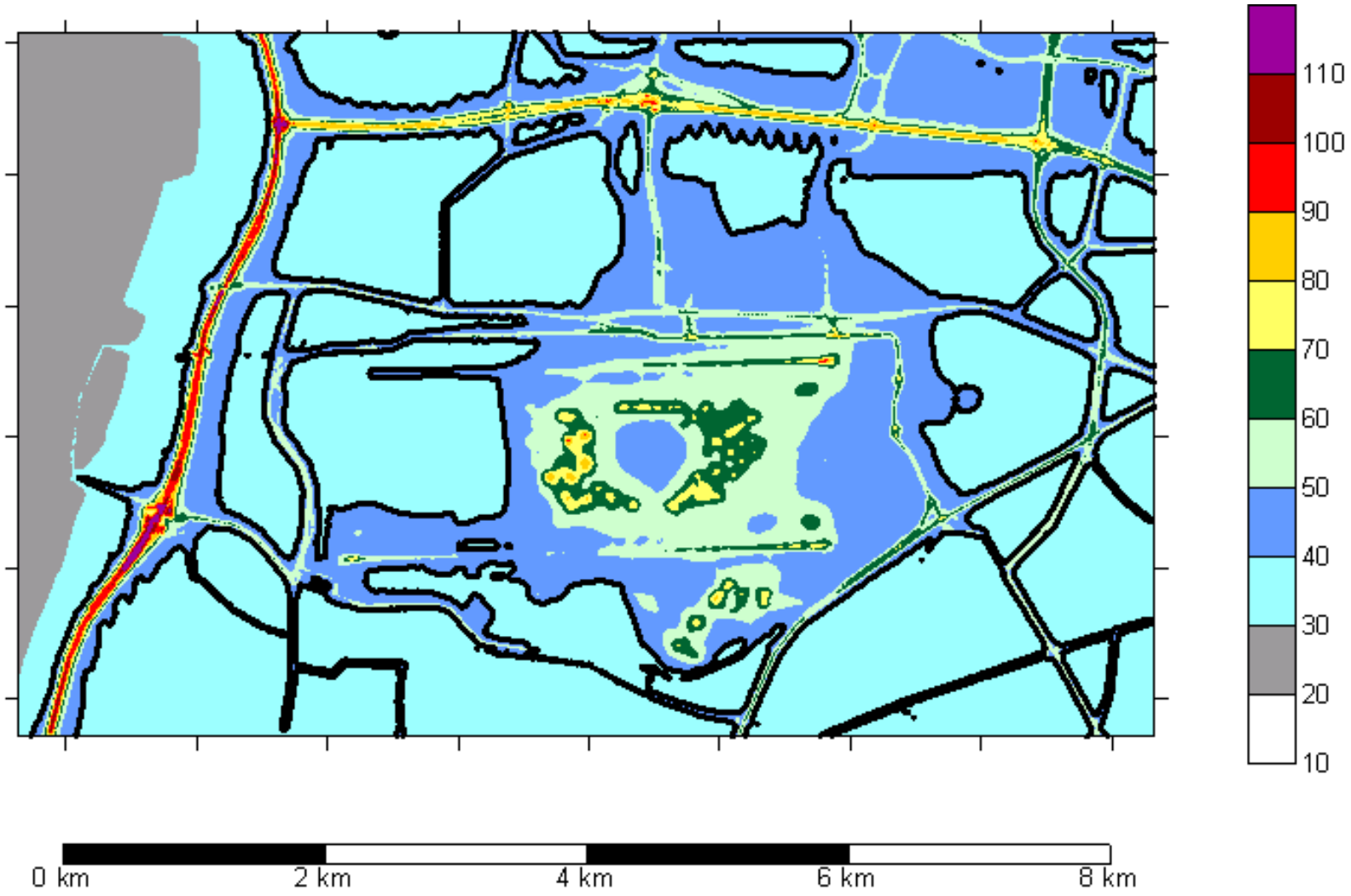
Contours: Annual Average NO_2



40 µg/m³ limit shown in bold

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Conclusion - ADMS-Airports

- ADMS-Airports is to be released this autumn
- The model has undergone extensive comparison with measured data at Heathrow including exacting diagnostic tests
- The model was recommended for future modelling work at Heathrow airport by the PSDH technical panels.

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