Implications for UK power stations of a move to a particulate matter standard based on $PM_{2.5}$

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Background to study

- Power Technology work on behalf of UK power generator's Joint Environmental Programme (the JEP)
- Eight companies – cover majority of the UK coal and oil-fired generation

- Investigate environmental issues of relevance to the power industry
- Air quality, acid deposition, particulate matter formation
- Selected CMAQ in 1999 to address regional scale issues

Updates to PM guidelines

- Mounting evidence of link between PM exposure and health effect
- Fine particles primarily responsible
- No threshold

- **WHO Air Quality Guidelines global update**

  $PM_{2.5}$ 10 μgm^{-3} annual mean and 25 μgm^{-3} 24-hour mean

- **New EU Air Quality Directive (currently under discussion)**

  PM_{10} 40 μgm^{-3} annual mean, 50μgm^{-3} 24-hour mean

  $PM_{2.5}$ 25 μgm^{-3} annual mean (binding from 2015)

  $PM_{2.5}$ 20% reduction in urban background annual mean (2020)

Important issues for the JEP/ESI

Power stations contribute to PM concentrations:

- 5.5% of primary UK PM_{10} emissions (NAEI., 2004)
- Secondary – 60% of SO_2 and 22% of NO_x emissions

Mass based metric

- Uncertainty regarding fraction responsible for adverse health effects
- Toxicology studies suggest primary combustion particles have high toxic potency
- Other components are thought to have a lower toxic potency e.g. ammonium salts, chlorides, sulphates, nitrates

Need to understand the effect of our emissions on primary and secondary $PM_{2.5}$ concentrations

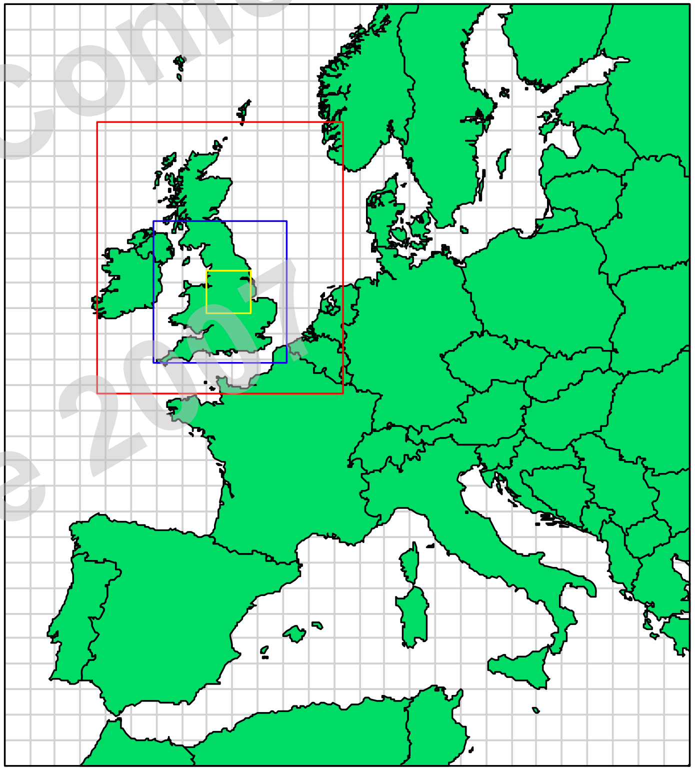
Local scale modelling of primary $PM_{2.5}$ emissions

- Used ADMS Atmospheric Dispersion Modelling System (CERC)
- Based on 2000 MW coal station on full load (ESP, no FGD)
- 30km x 30km grid at 1km resolution
- $PM_{2.5}$ emissions are 50% of PM_{10} emissions
- Operating at dust emissions limit of 50 $mgNm^3$
- 1.3 ktonnes $PM_{2.5}$ per year (much lower in practice)
- 5 years of meteorology
- “Worst-case” scenario

- Max annual mean = 0.041 μgm^{-3}
- Max 90th percentile = 0.157 μgm^{-3}
- Max 100th percentile = 0.888 μgm^{-3}
- <1% of proposed standards

CMAQ

- 3-D gridded Eulerian model
- Set up to run on three nested grids (108, 36, and 12km resolution)
- 21 vertical layers (15km)
- Requires hourly gridded emissions and meteorology
- Plus land-use, initial conditions, boundary conditions
- Chemical Scheme: RADM2+aerosols+aqueous chemistry



Modelling Particulate in CMAQ (v4.3)

- Based on USEPA particulate model / Regional Acid Deposition Model
- Time-dependent size distribution & size specific chemical composition
- Modal approach – Coarse, accumulation & nucleation
- Described by particle number concentration, total surface area & total mass

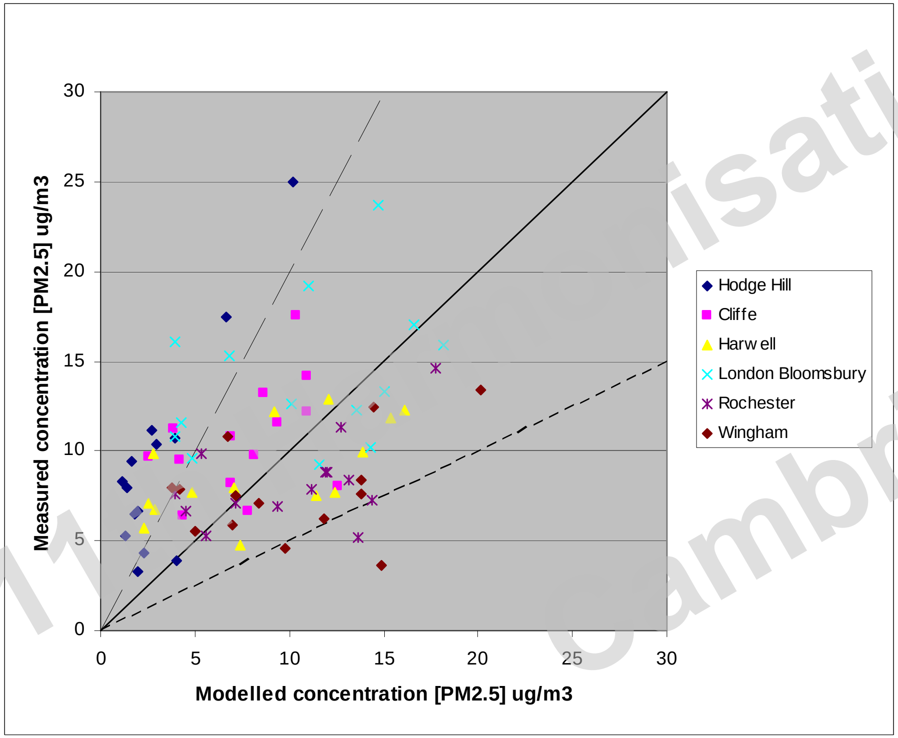
Species:

- Sulphate, Nitrate, Ammonium
- Elemental Carbon
- Primary organic species
- Anthropogenic secondary organic species
- Biogenic secondary species
- Unspecified anthropogenic species
- Can also include aerosol water

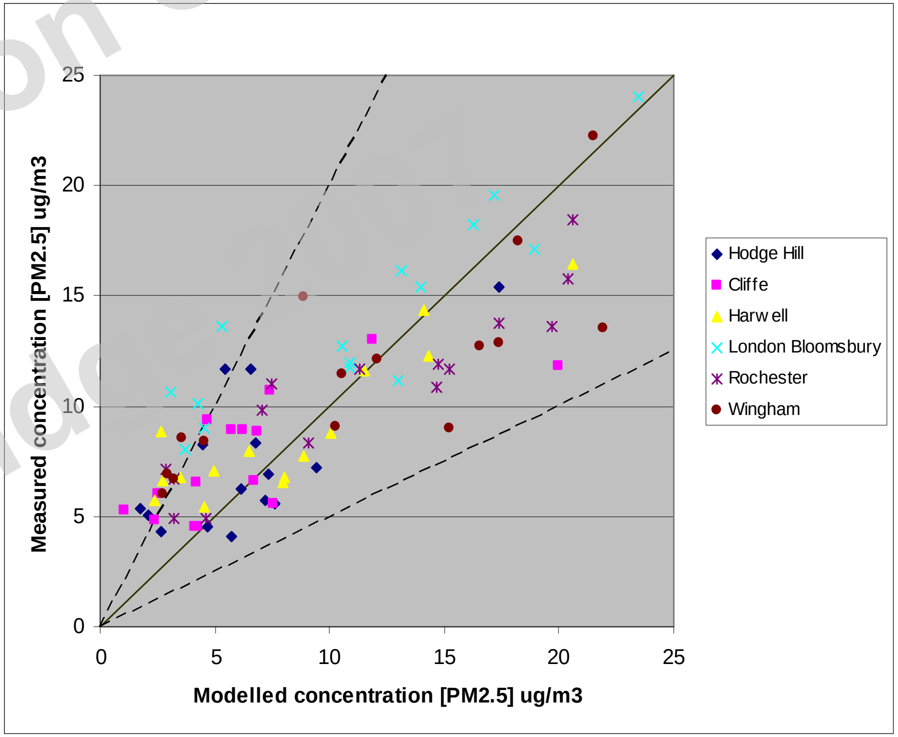
Modelling study

- Ran model for two weeks in January 1999 & two weeks in July 1999
- $PM_{2.5}$ emissions inventory from EMEP
- Used NAEI PM_{10} emissions for 1999 scaled using CEPMEIP source sector $PM_{2.5}$ to PM_{10} ratios
- **C**o-ordinated **E**uropean Programme on **P**articulate **M**atter **E**mission **I**nventories, **P**rojections and Guidance (CEPMEIP)
- Ran model with and without JEP sources (coal & oil-fired plant)
- Derived JEP contribution from difference between the two runs
- Validate against monitored results
- Assess JEP contribution to primary and secondary concentrations
  - Against target values
  - Against ambient concentrations

Models-3 PM simulation validation – UK sites (12km)
Comparison with measured data – 24 hour averages

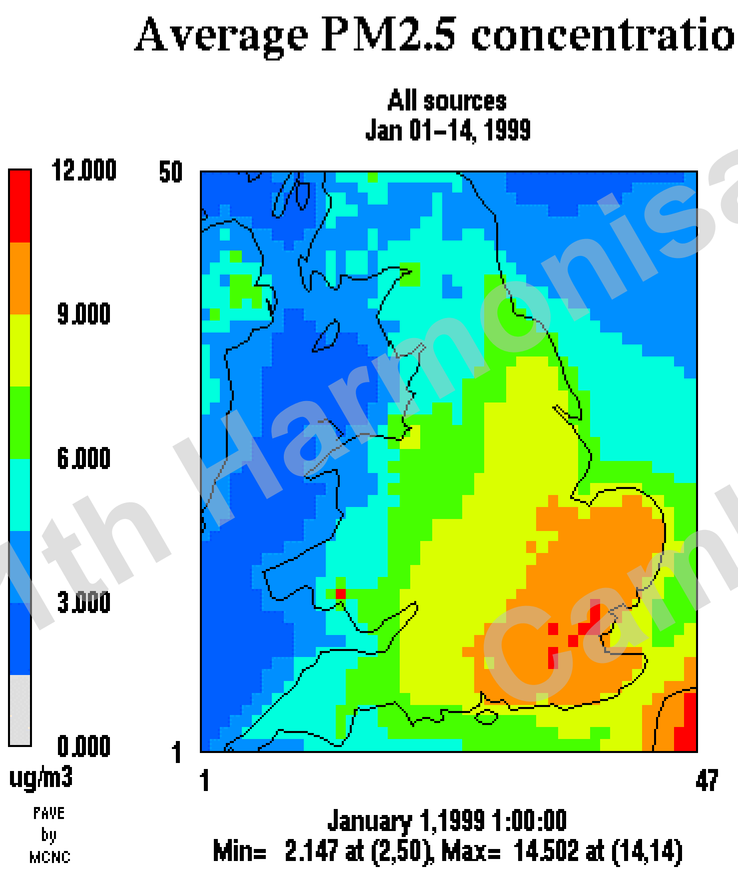


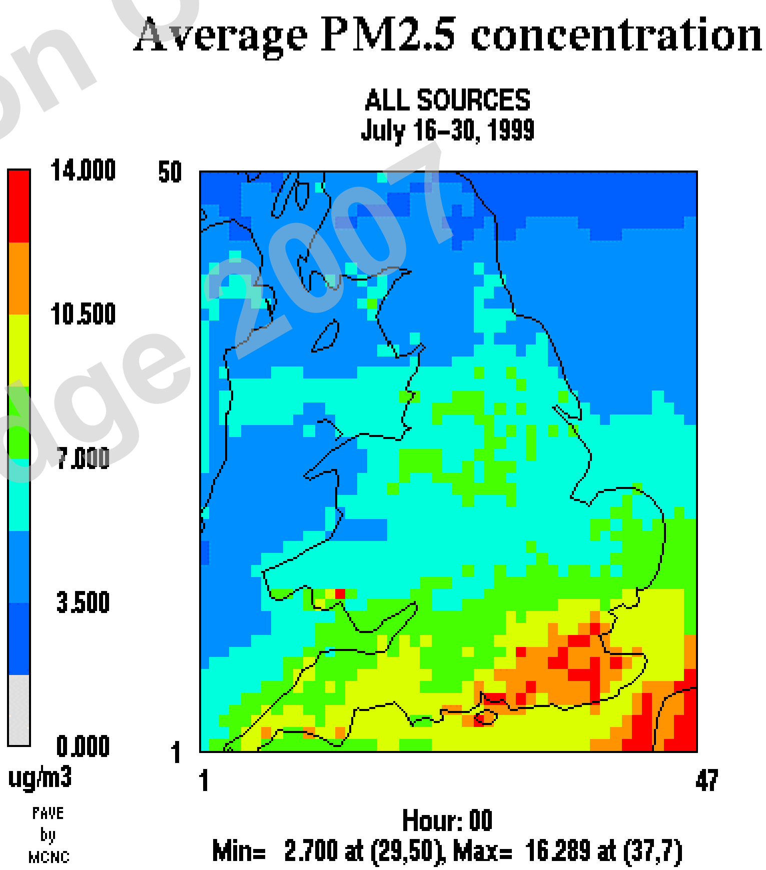
January 1999



July 1999

All-source concentrations

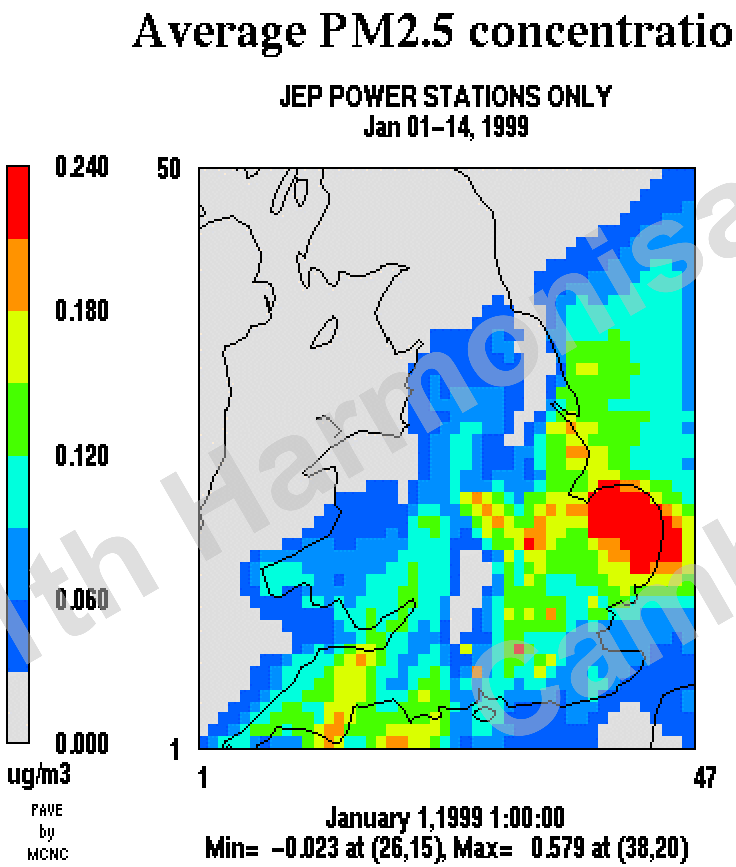


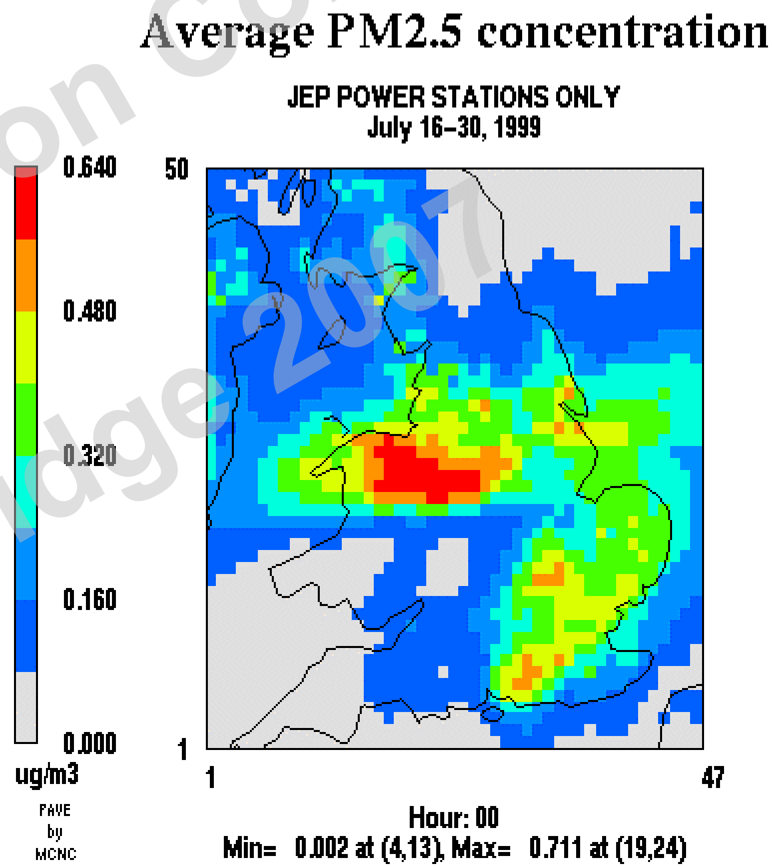


Maximum grid concentrations – all sources

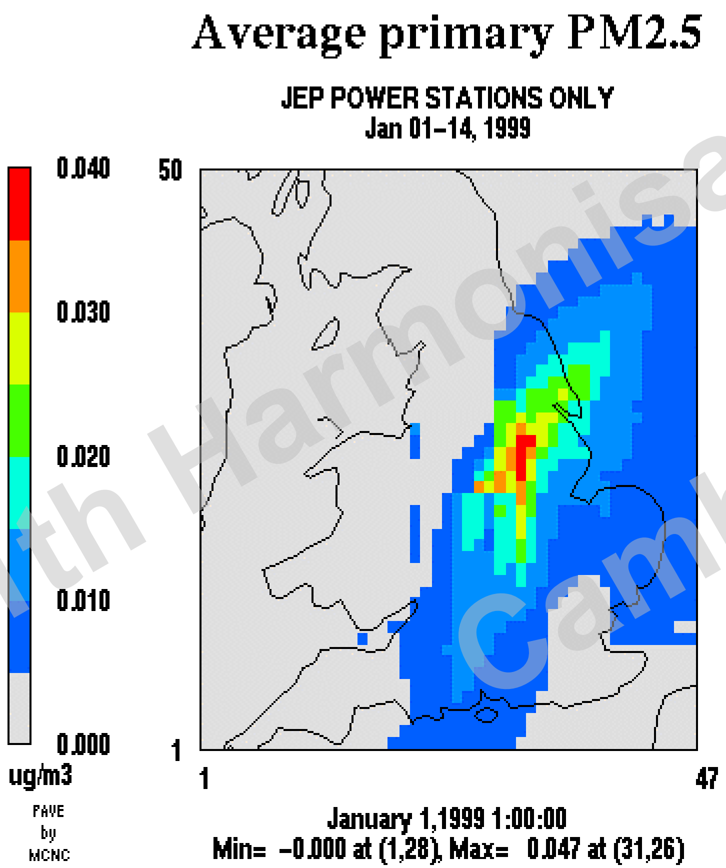
	Winter Period	Summer Period
Maximum (all-source) μgm^{-3}	14.5	16.3
Power stations contribution μgm^{-3}	0.09	0.33
% power stations contribution	0.6%	2.0%
All sources as % of 25 μgm^{-3} cap	58%	65%
Power stations as % of 25 μgm^{-3} cap	0.4%	1.3%

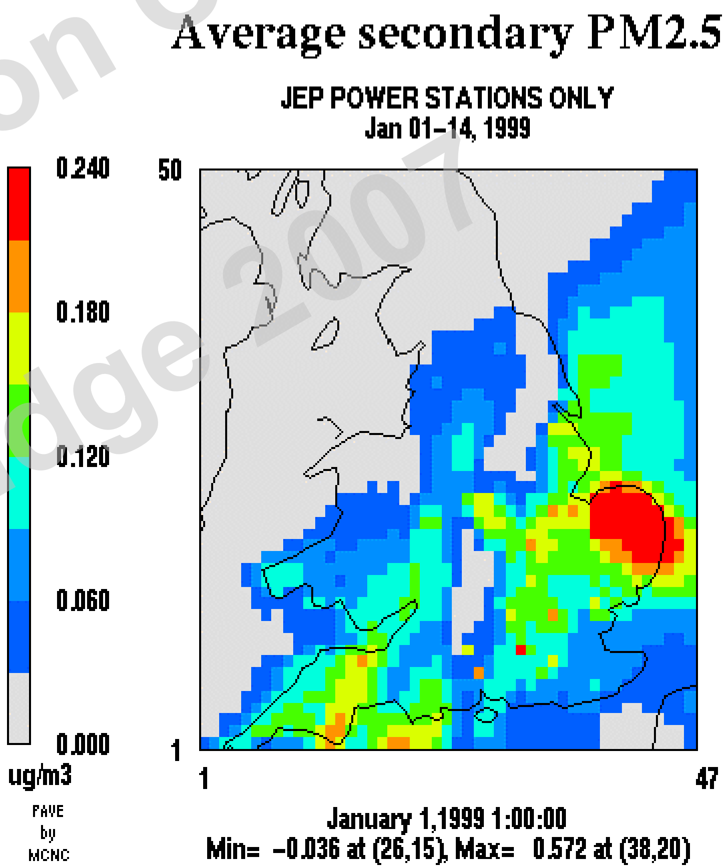
JEP only concentrations



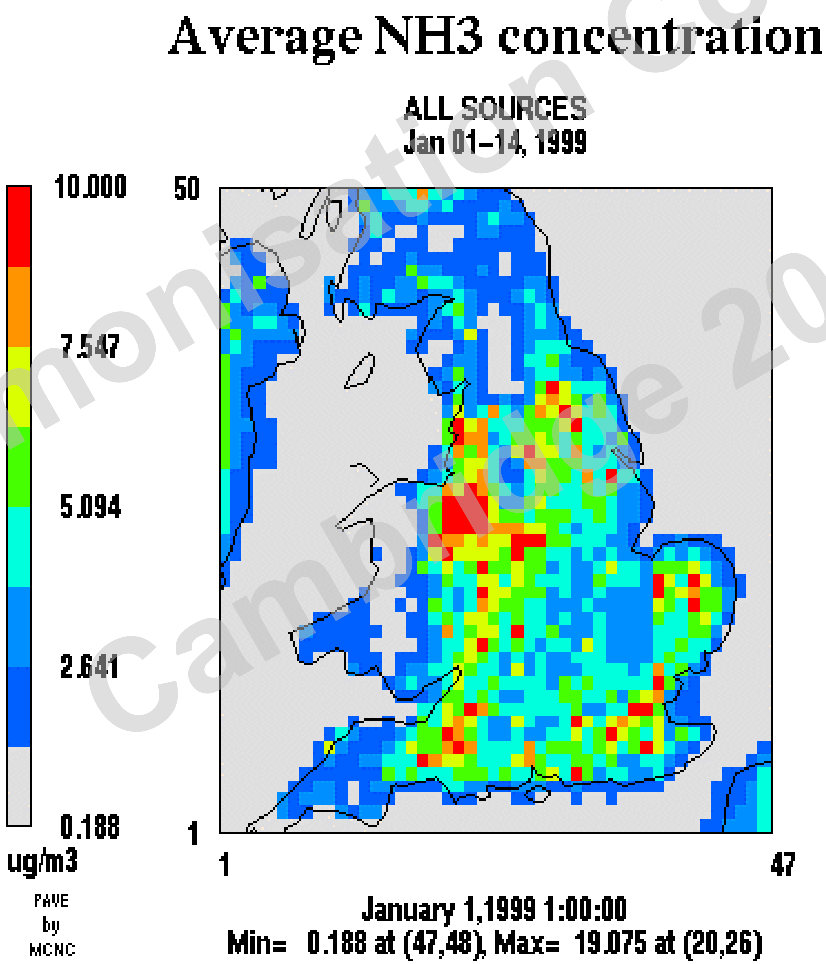


JEP primary & secondary concentrations





Ammonia concentration

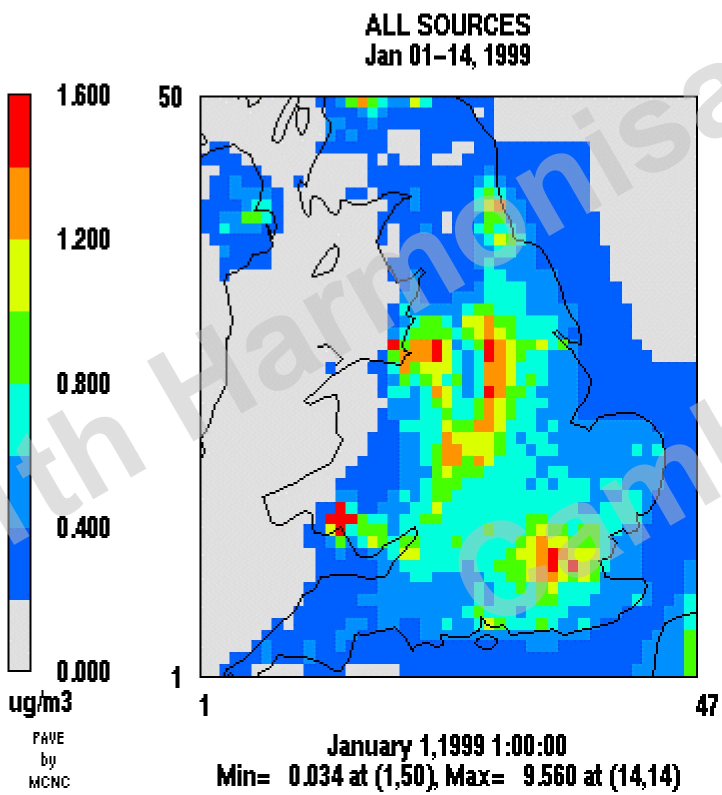


Maximum grid concentrations power stations only

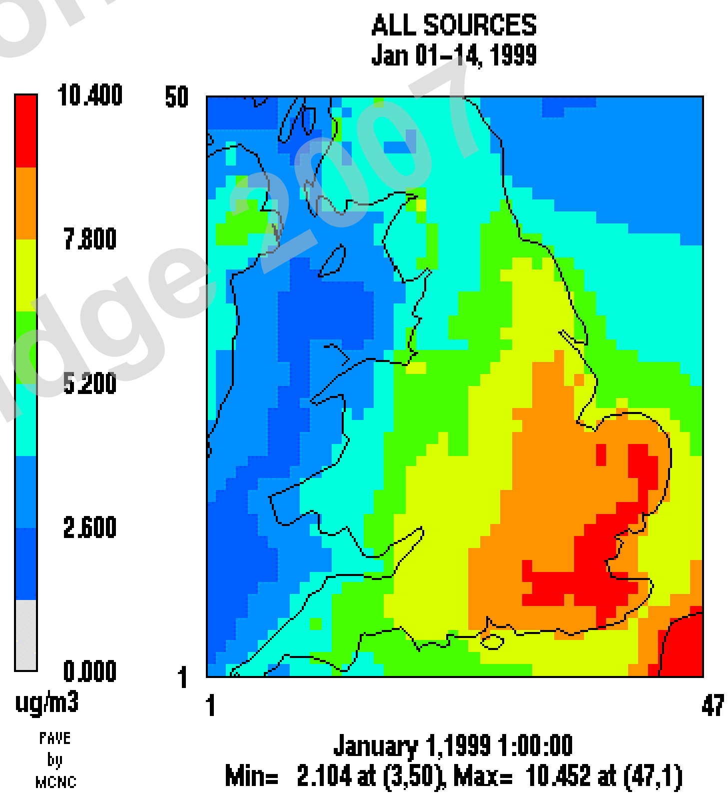
	Winter Period	Summer Period
Maximum power stations contribution μgm^{-3} (primary, secondary)	0.58 (0.007, 0.572)	0.71 (0.009, 0.702)
Maximum corresponding all-sources contribution μgm^{-3}	9.98	6.74
Power stations as % of total	5.8%	10.5%
All source as % of 25μgm^{-3} cap	40%	27%
Power stations as % of 25μgm^{-3} cap	2.3%	2.8%

All-source primary & secondary concentrations

Average primary PM2.5



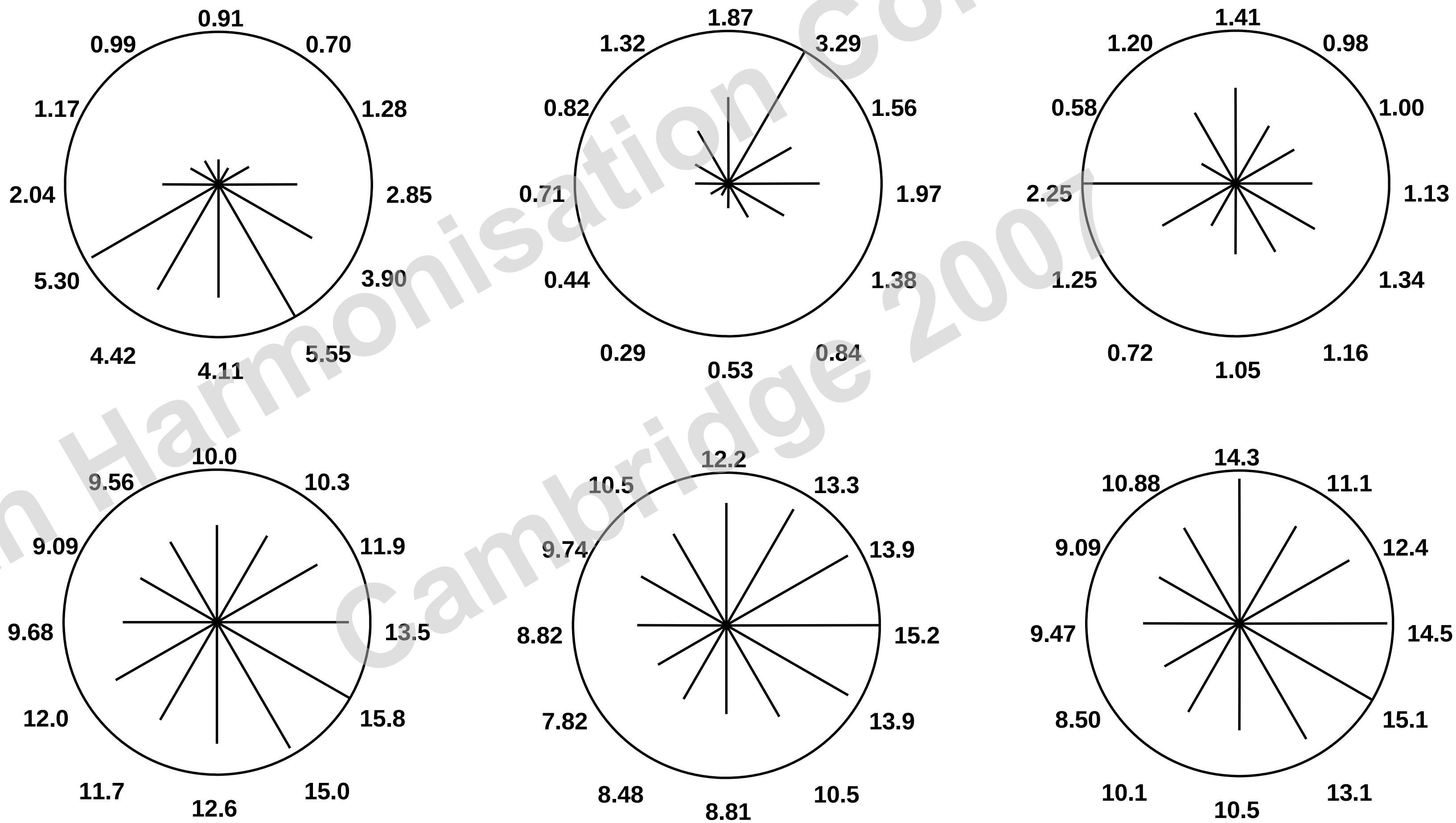
Average secondary PM2.5



Analysis by wind direction

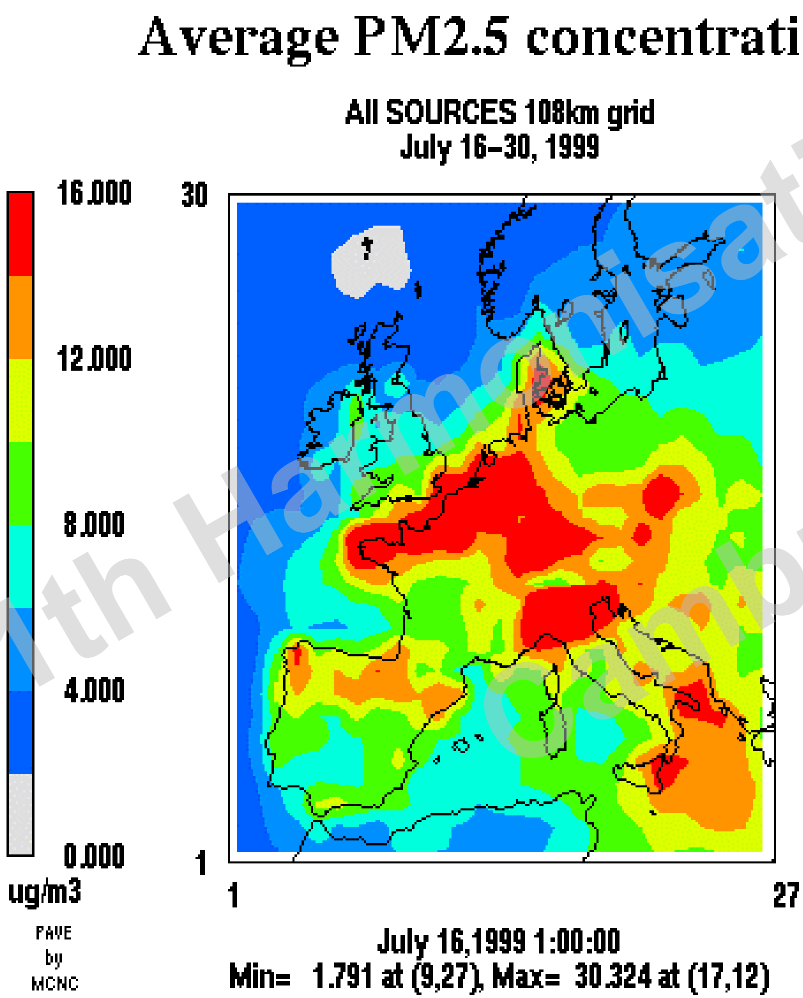
Mean SO_2 by wind direction

Mean $PM_{2.5}$ by wind direction



Cliffe Harwell Rosehurst Farm

Wind-rose analysis of measured data



- Measured $PM_{2.5}$ consistently higher during south-easterly winds
- High concentrations originating over European mainland
- May be compounded by meteorological conditions during south-easterly winds

Conclusions

- JEP coal & oil-fired plant make a minimal contribution in terms of the proposed limit value
- The contribution to overall UK concentrations is modest even at the point of maximum impact
- Primary particulate concentrations from JEP plant are likely to be very low and secondary particulate dominates the industry contribution
- 1999 data suggests a standard of 15 μgm^{-3} or below might cause the UK a problem
- Assessment is worst-case – 2010 at earliest for standards (NECD, LCPD)
- Particulate mass is predominantly made up of secondary particulate
- Distribution pattern and relative concentrations of primary and secondary $PM_{2.5}$ have important implications for emission reduction policy if toxicity resides mainly in primary fraction
- CMAQ is a versatile tool for both impact and policy assessment