Application of CMAQ to Regulatory Issues in the UK Power Sector

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Regulatory Applications

- Source impact approach - Power station footprints
- Habitats Directive – Acid and Nitrogen deposition
- Ambient Air Quality Directive – $PM_{2.5}$ concentrations
- NECD and Gothenburg protocol – Sensitivities to particulate toxicity assumptions
- Conclusions

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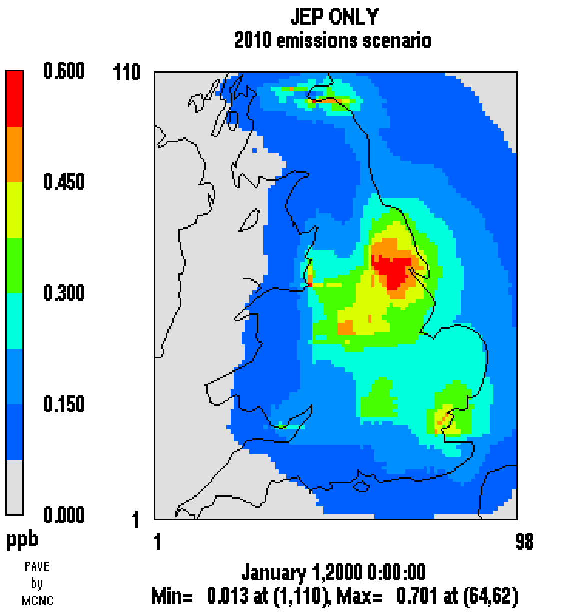
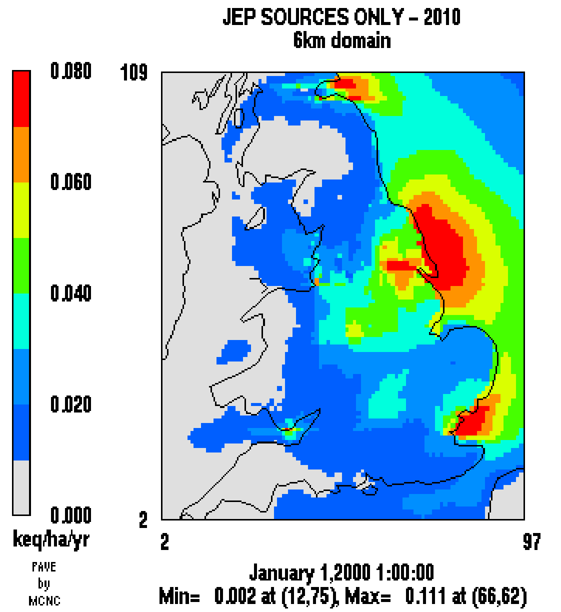
Emission Source Footprints

Generated by running model with and without source emissions
Shows the effect of a new source on air quality or deposition
Shows the effect of removing emissions from a source
Can be applied by any combination of country/sector/source/pollutant

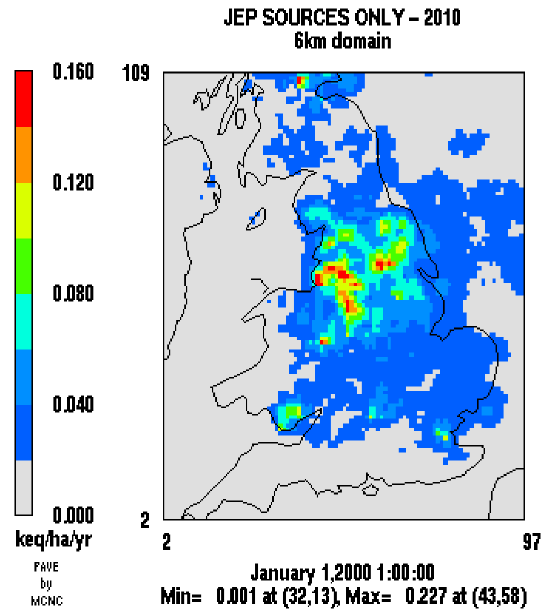
Average SO2 concentration



OxS annual dry deposition



OxS annual wet deposition



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Habitats Directive - Acid deposition footprints

- Power station PPC assessment of impacts on Habitats Directive sites
- S and N deposition footprints for 2010 generated with FRAMEv5.3 model
- 118 individual point sources plus SNAP sectors
- JEP ran CMAQv4.3 to assess FRAME footprints & compared to other models
- Significant difference in results – Deposition ratios for 6km domain shown
- Plume-rise restriction and calibration process applied in FRAME

Ratios	FRAME(calibrated) / CMAQ			
	Power Stations	All Sources		
Ox S	4.2	1.6		
Ox N	4.5	1.8		
Red N	n/a	0.9		

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Ratios	FRAME(calibrated) / CMAQ		FRAME(raw output) / CMAQ	
	Power Stations	All Sources	Power Stations	All Sources
Ox S	4.2	1.6	3.1	1.2
Ox N	4.5	1.8	2.4	1.0
Red N	n/a	0.9	n/a	0.9

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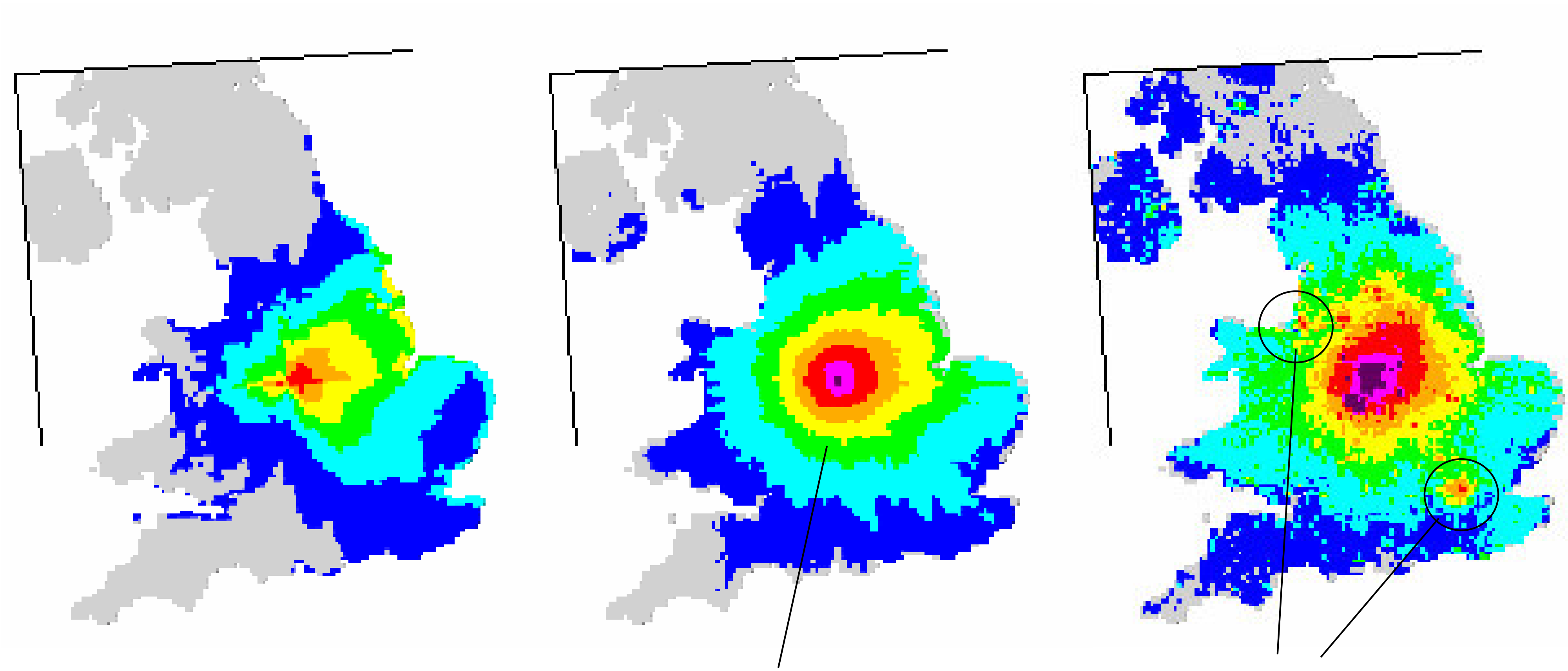
Single station footprint – Dry Sulphur Deposition

CMAQ
Total: 1.0ktS/yr

Non-calibrated FRAME → Calibrated FRAME
Total: 2.8ktS/yr → Total: 3.8ktS/yr



Oxidised S dry deposition
2010 emissions

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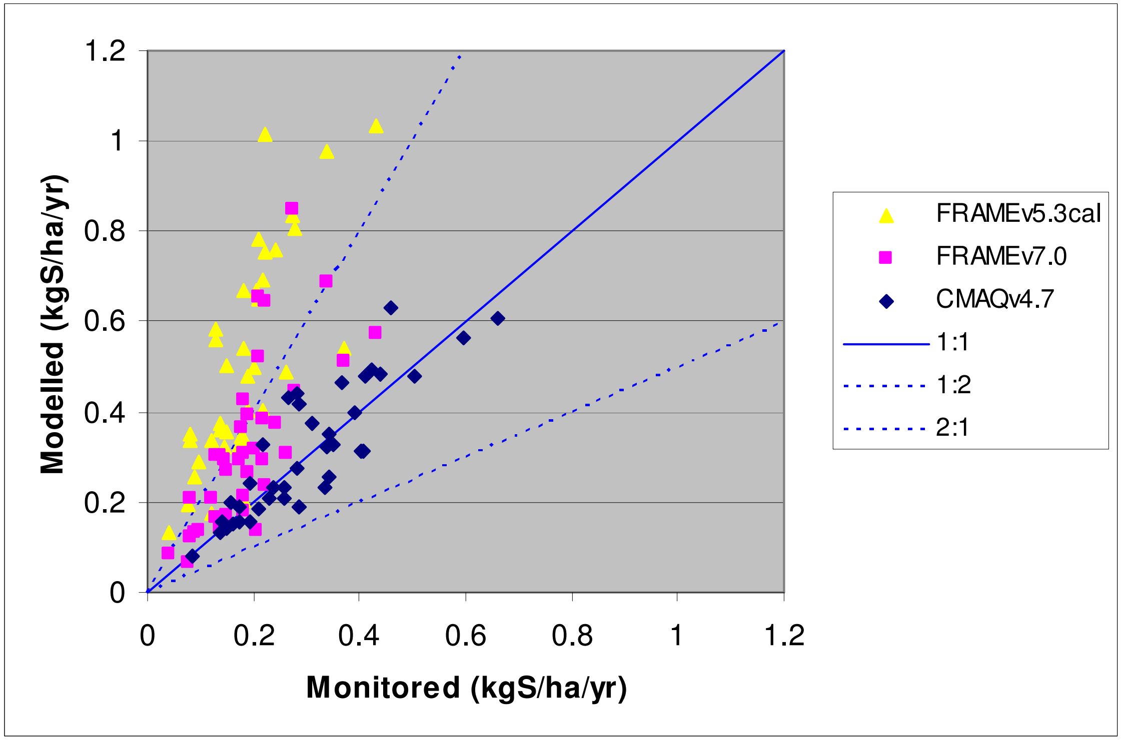
Model Comparison

- JEP work demonstrated that FRAME substantially over-estimated power station impacts – cited by regulators in PPC assessment conclusions
- FRAMEv7 model now addresses plume rise issues
- Comparison of FRAMEv5.3, FRAMEv7 with CMAQv4.6 for 2003 (CREMO)

Data from UK wet deposition monitoring network – annual totals



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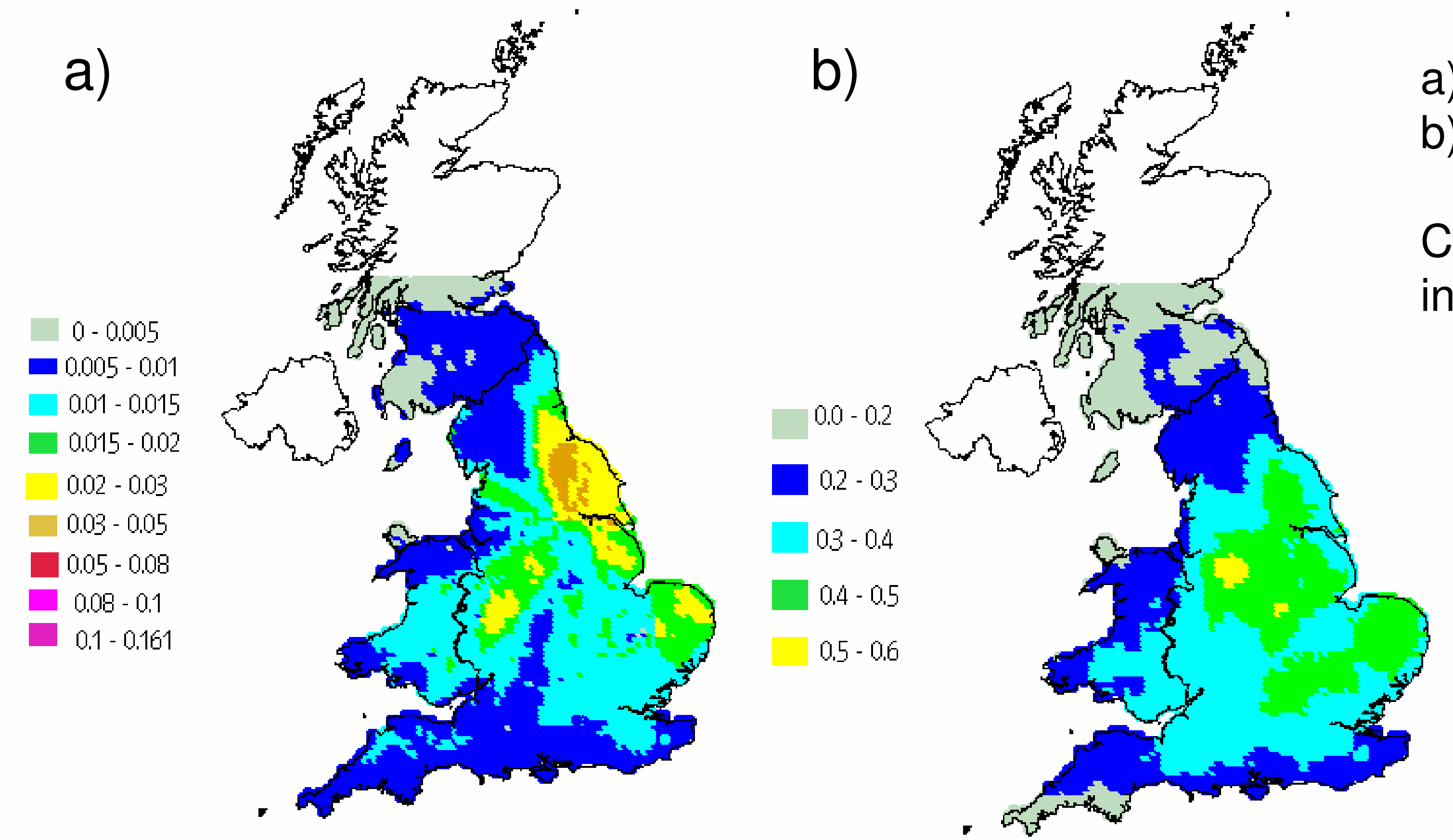
Ambient Air Quality Directive - Footprints

- Individual footprints and combined JEP coal-fired power station footprints produced for 2010 emissions scenario for $PM_{2.5}$



a) Individual Station
b) All JEP stations

Concentrations in ug/m^3

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Ambient Air Quality Directive – Mean and Max

- Average and maximum annual $PM_{2.5}$ mean concentrations over UK land
- 2015 limit value is 25ugm^{-3}, 2020 indicative limit 20ugm^{-3}, plus AEI

Individual Station 2010 (worst-case)	**Station (ug/m3)**	**Background (ug/m3)**	**as %BG**	**as %20ug/m3**
Grid average Concentration	0.05	7.3	0.7%	0.2%
Grid maximum Concentration	0.16	7.9	2%	0.8%
Combined JEP 2010				
Grid average Concentration	0.41	6.8	6.0%	2.1%
Grid maximum Concentration	0.84	9.6	8.7%	4.2%
Combined JEP 2016				
Grid average Concentration	0.19	6.6	2.8%	0.9%
Grid maximum Concentration	0.36	9.1	3.9%	1.8%

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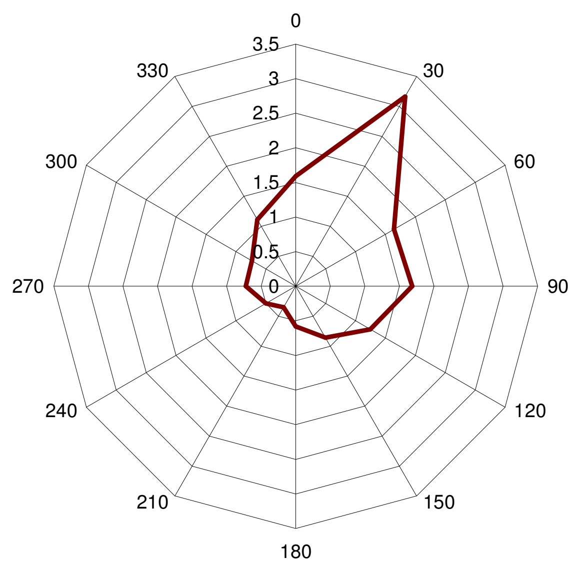
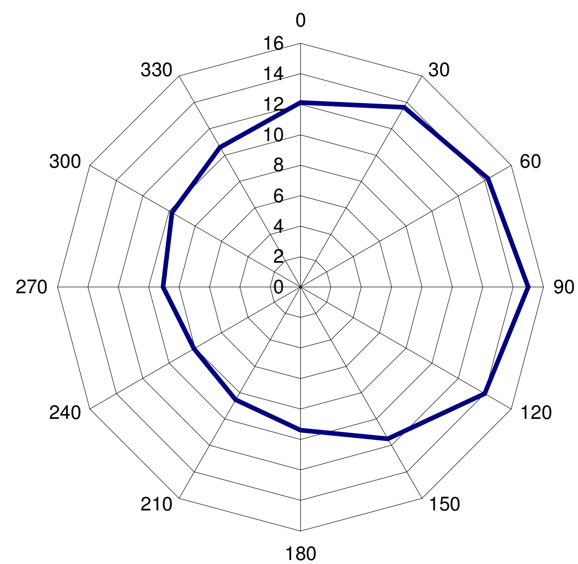
Ambient Air Quality Directive – Link to other evidence

- Power station contribution is very small and declining
- Minimal contribution relative to limit values and exposure reduction
- Consistent with evidence from local scale modelling and monitoring

HARWELL - SO2 concentrations



HARWELL - PM2.5 concentrations



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Implications of PM toxicity for EU Emissions Policy

- European legislation such as NECD and Gothenburg protocol supported by cost-benefit studies of population exposure
- Damage costs dominated by particulate health effects
- Based on the assumption that all $PM_{2.5}$ mass is equally toxic
- Legislation focussed on total mass reduction

- Toxicology does not support a role for secondary inorganic mass in particulate toxicity – sulphate, nitrate & ammonium
- Potentially no health benefits from reducing this component
- Potential over-estimation of damage costs

- Model impacts for different emission sectors for 2010 scenario
- Assess exposure based on different toxicity assumptions

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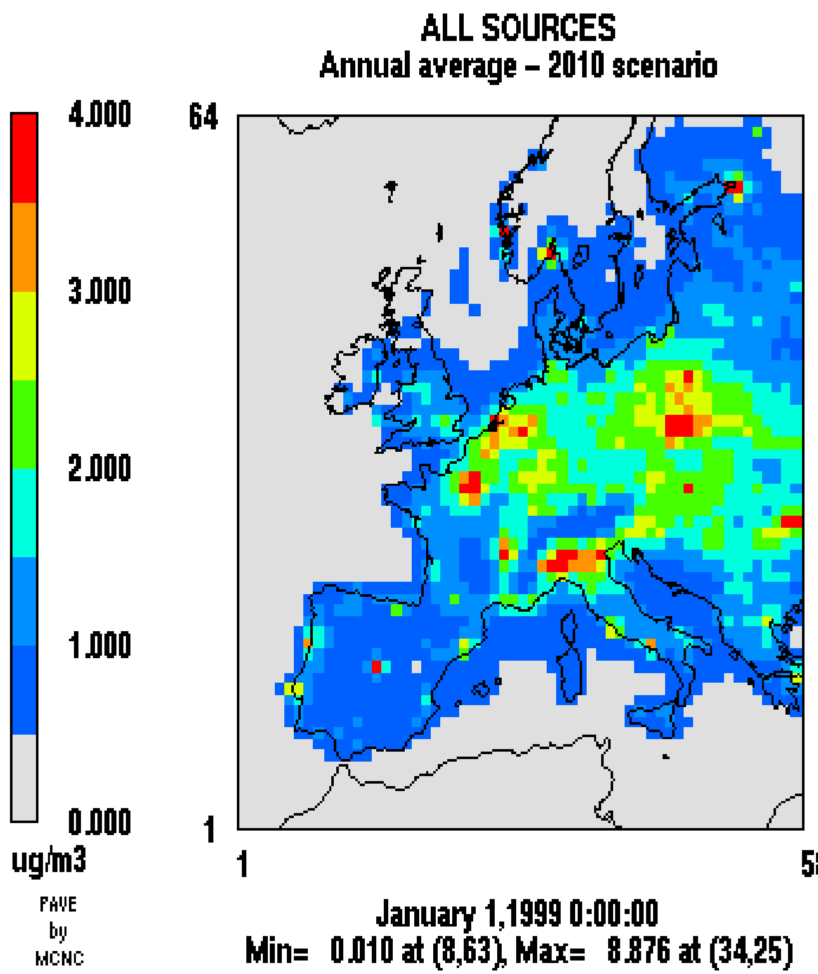
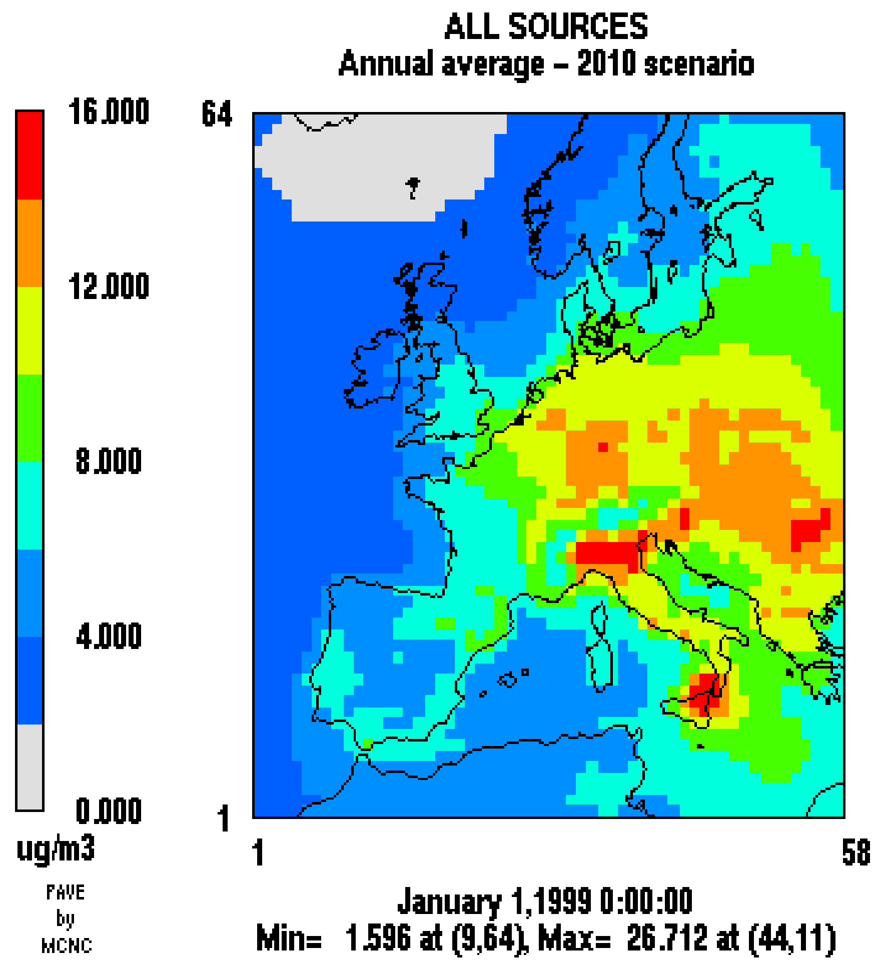
All source primary and secondary $PM_{2.5}$ concentrations

Primary PM2.5 concentration



Secondary PM concentration



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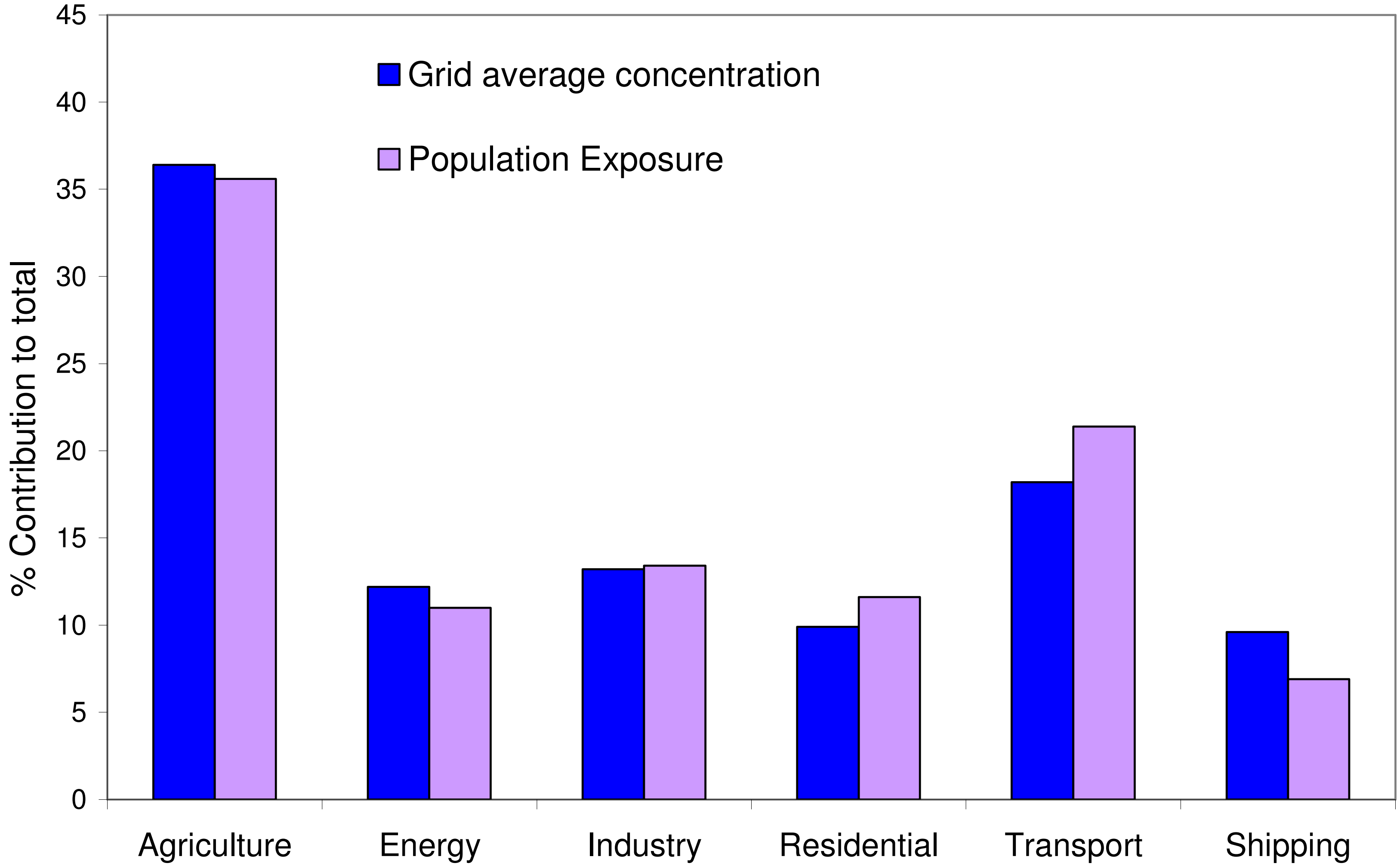
Impact of considering population exposure – Total $PM_{2.5}$



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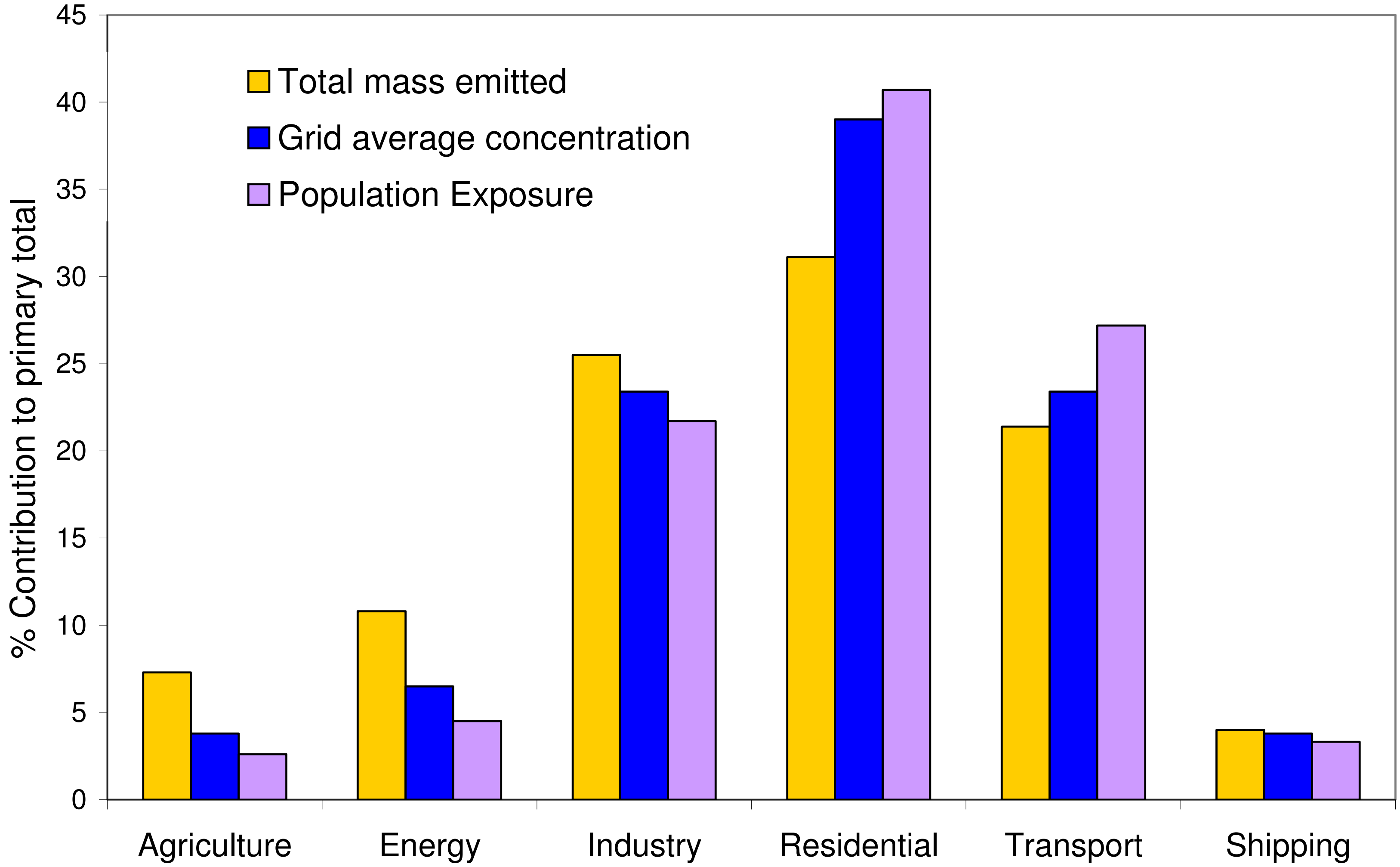
Impact of considering population exposure – Primary $PM_{2.5}$



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Implication for Damage Costs ($PM_{2.5}$ chronic mortality)

Number of additional cases of a health outcome given by:

$$\Delta cases = I_R \times CRC \times Population\ Exposed\ x\ Increase\ in\ concentration$$

I_R is baseline incidence rate in population: 1013 per 100000

CRC is the concentration response co-efficient: 0.6%/μgm^{-3} for $PM_{2.5}$

$$Damage\ cost = \Delta cases\ x\ Value\ of\ health\ outcome$$

Assuming equal toxicity – 18% of damage costs due to primary

CRC based on urban studies – assume 50% of urban PM is primary

Assuming primary only toxicity reduces damage costs by **65%**

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Conclusions

- CMAQ is a powerful & robust tool for regulatory analysis
- Multi-scale – Assessment at European and UK level
- Single set of runs can be used to assess wide range of impacts – air quality, deposition, primary & secondary species
- Performance validation confirms that CMAQv4.7 is suitable for regulatory analysis
- Open source approach provides high level of confidence for all stakeholders
- Used for policy analysis and to validate / challenge regulatory modelling results
- Has formed a valuable means of engagement with academic and regulatory modelling groups

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