Application of CMAQ to Regulatory Issues in the UK Power Sector

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Overview

JEP Mesoscale Modelling Capability
(Paul Sutton)

> The Joint Environment Programme (JEP).
> JEP requirements & selection of mesoscale model.
> Current JEP Models-3 set-up.
> JEP validation of Models-3 simulation.

Regulatory Applications
(Steve Griffiths)

> 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.

Joint Environmental Programme (JEP)

> Future environmental regulation is among the most significant source of risk factors affecting plant operation and asset strategy.

> Key factors include air quality, health effects & ecosystems effects.

> Research programme jointly funded by eight companies – cover majority of the UK coal and oil-fired generation.

> Investigate environmental issues of relevance to the power industry.

> Sector level discussions with the Environment Agency & DEFRA.

JEP Has Developed an In-house Mesoscale Modelling Capability

> This allows JEP:

- To produce its own independent view of the environmental impact of JEP power stations.
- To assess the consequences of developing UK, EU & UN/ECE regulation on JEP power stations.
- To participate in discussions of the developing regulation.

> Regulatory issues addressed by JEP mesoscale modelling:
Air Quality, Acid Deposition, Eutrophication, Ozone & Particulates

Selection of Mesoscale Model

> Key JEP requirements of mesoscale model:

– **Multi-issue:** Air quality, acidification, eutrophication, ozone, particulates in a single 'one atmosphere' model - consistency.

– **Multi-timescale:** Range of timescales to enable simulation of air quality episodes through to annual depositions – dynamic model.

– **Flexibility of spatial scales:** To enable simulation of single power stations through to transboundary calculations – via grid nesting.

– **Treatment of point sources:** Plume rise.

– **'Future proof' science:** Software modularity of science treatment.
Active research & development of science.

– **Transparent:** Open source-code, widely available.

> **JEP selected Models-3/CMAQ as best-fit to its requirements.**

JEP Models-3 Timeline

1999

- **Model Selection and Review**
- **Build European & UK version**
  - 1st CMAQ Users in UK
  - Initial evaluation of Models-3
- **Maintain Models-3 capability**
  - Upgrade Models-3 versions
  - Upgrade computer hardware
  - Validation studies
- **Application to regulatory issues**
  - Power station footprints
  - Population exposure studies
  - Habitats assessment
- **JEP organised Models-3 workshops**
- **Currently:**
  - JEP is using CMAQv4.7, MCIPv3.4.1 & SMOKEv2.5
  - Participating in CREMO & DEFRA Air Quality Model Intercomparison

Now

Current JEP Models-3 Set-up (1)

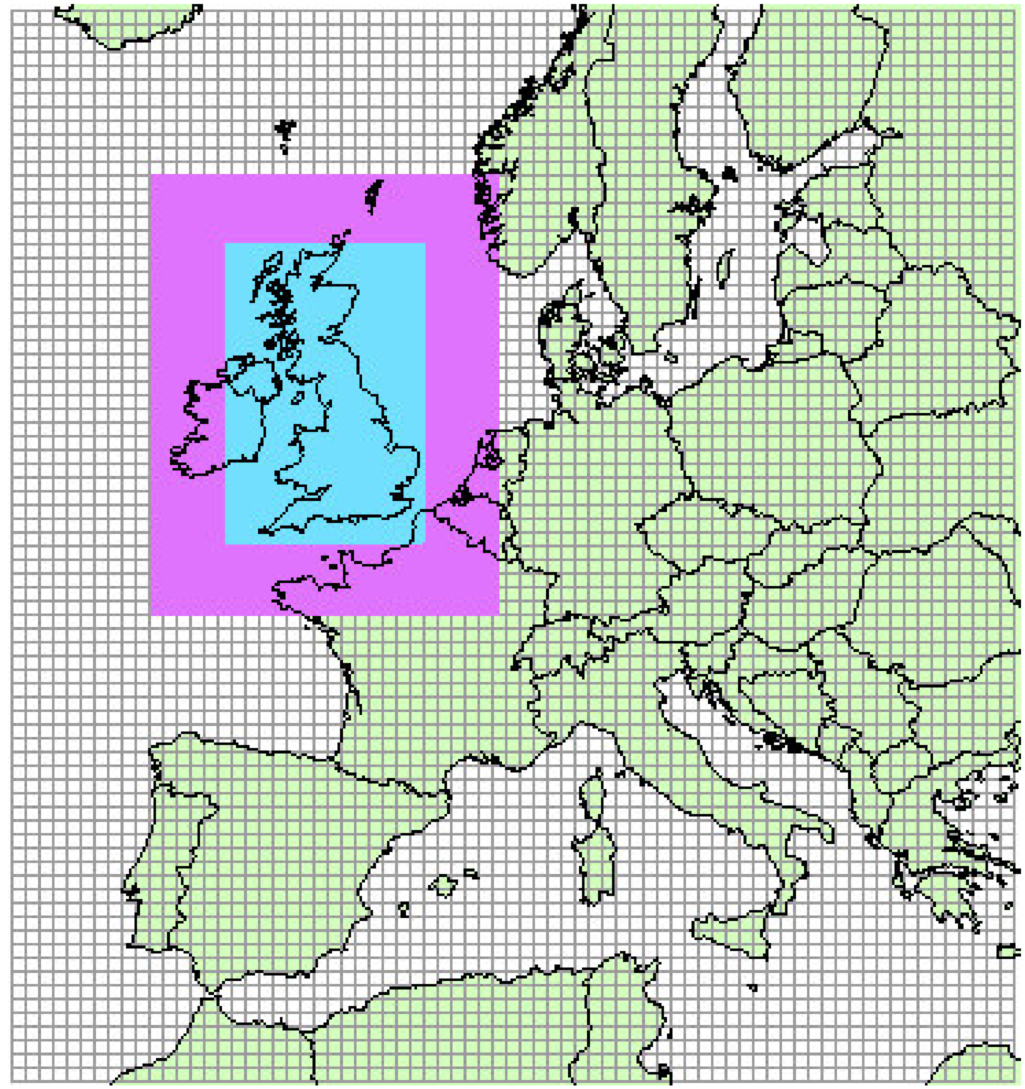
> Using CMAQv4.7.

> Have modelled whole calendar years.

> Nested horizontal grids (45km/15km/5km).

> 15 vertical layers (0 to 15km). (Ground layer depth ~35-40m.)

> CB05CL chemical scheme with coupling to aqueous and cloud processes.



Current JEP Models-3 Set-up (2)

> Emissions input data obtained from:

  – Public domain sources: EMEP, GEIA and NAEI.

  – Actual hourly emissions data for JEP power stations.

> Models-3 pre-processing of emissions data done using SMOKEv2.5.

> Outer grid boundary conditions were taken from STOCHEM dataset.

> Initial conditions were obtained using a ‘spin-up’ process:

  – Runs started on 25th Dec of previous year to allow one week of spin-up.

  – Initial conditions for 25th Dec generated using the same approach as for the boundary conditions for the outer grid.

Current JEP Models-3 Set-up (3)

> Meteorological input data produced using WRFv3.0.1. Models-3 pre-processing done using MCIPv3.4.1.

> HP XW6400 workstation.

  – 2x quad-core Xeon processors (2.33GHz speed).

  – 8GB RAM.

Validation of Ground Level Air Concentrations Simulation (1)

> Compared 2003 annual mean ground level air concentrations measured at monitoring sites with values modelled by Models-3 on 5km grid.

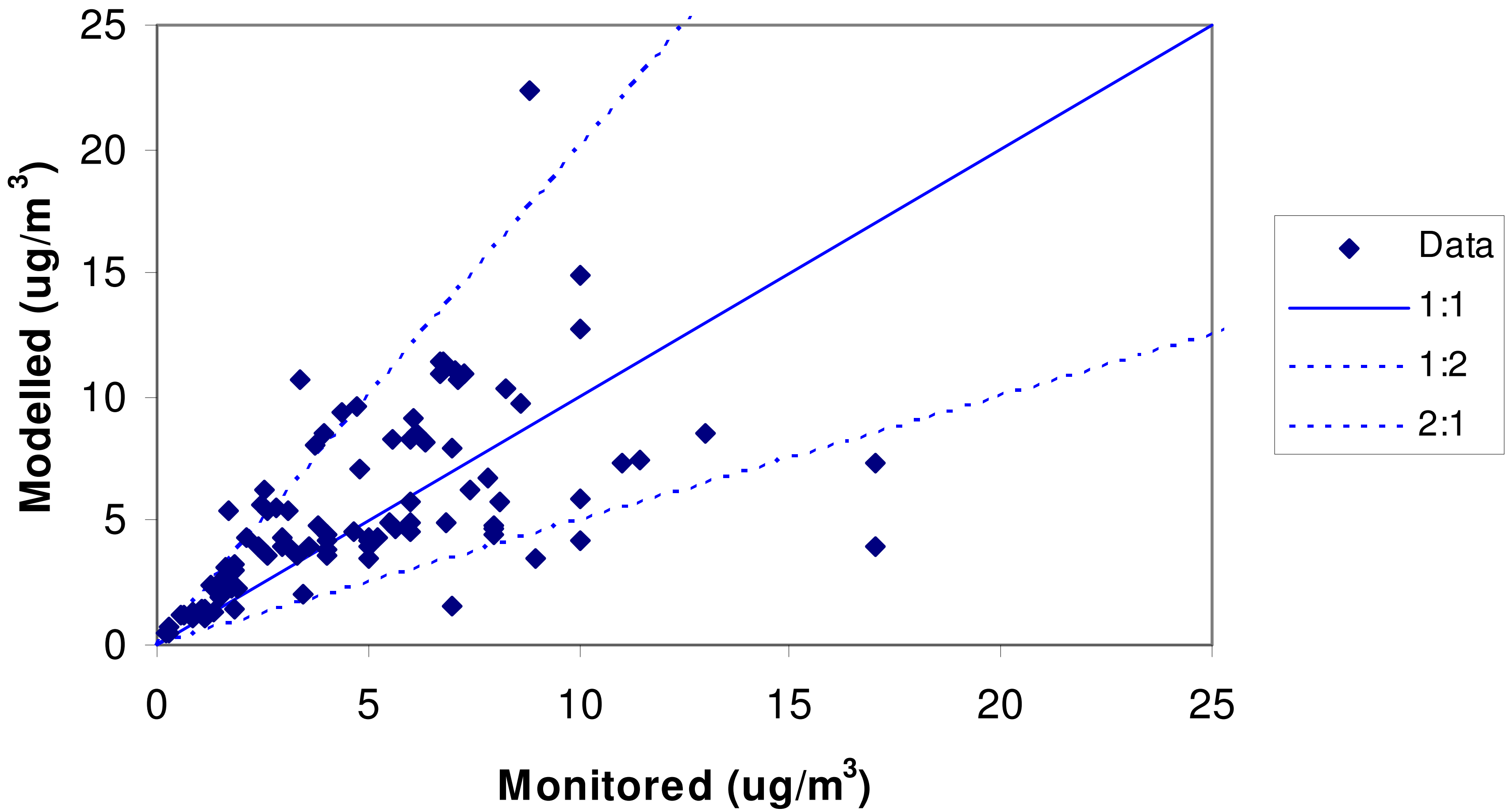
> The following chemical species and corresponding monitoring sites were used:

Measured Species	Monitoring Sites
SO_2	AURN+JEP+ADMN
NO_X	AURN+JEP
NH_3	NAWN
NH_4^+	NAWN
HNO_3	ADMN
SO_4^{2-}	ADMN
nss-SO_4^{2-}	ADMN
NO_3^-	ADMN

- ‘Urban centre’, ‘urban industrial’, ‘roadside’ and ‘kerbside’ sites were excluded from the AURN dataset.
- Appropriate combinations of modelled species are summed to correspond to measured species.

Validation of Ground Level Air Concentrations Simulation (2)

SO2 annual mean ground level air concentration



Validation of Ground Level Air Concentrations Simulation (3)

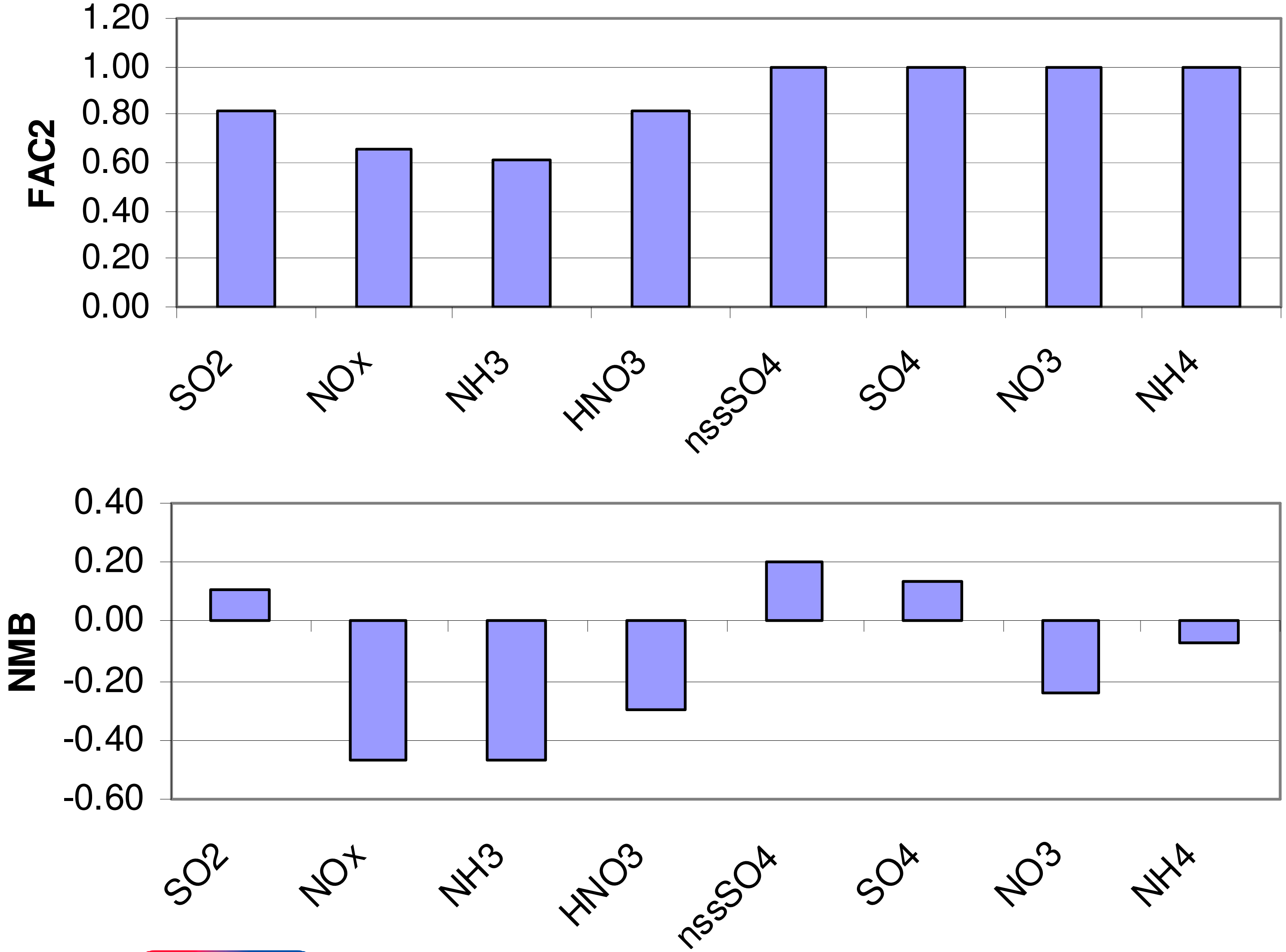
> Model performance assessed using two standard quantities:

- *FAC2= Fraction of simulated values where* $2.0 \geq S_i / O_i \geq 0.5$.

- $$NMB = \frac{\sum_{i=1}^{N} (S_i - O_i)}{\sum_{i=1}^{N} O_i}$$

where
N is the number of data points
S_i is the simulated value for a data point
O_i is the observed value for a data point

Validation of Ground Level Air Concentrations Simulation (4)



- The precision with which these quantities can be determined needs to be considered. For example, if the conversion from ppbV→ug/m^3 is done at 10℃ rather than 20℃, this would reduce the NMB values by 0.04.

Validation of Wet Deposition Simulation (1)

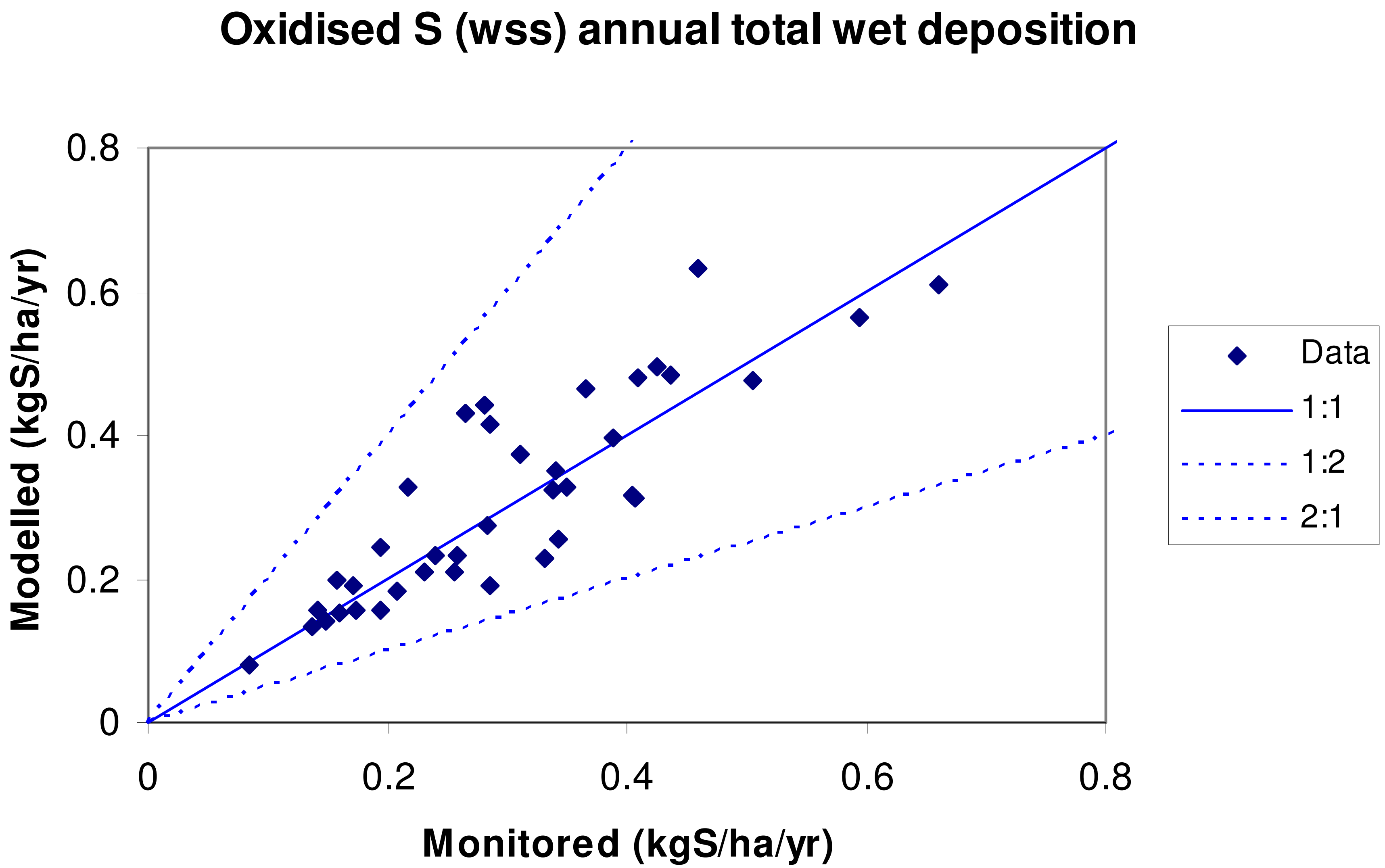
> Compared 2003 annual total wet deposition measured at monitoring sites with values modelled by Models-3 on 5km grid.

> The following chemical species and corresponding monitoring sites were used:

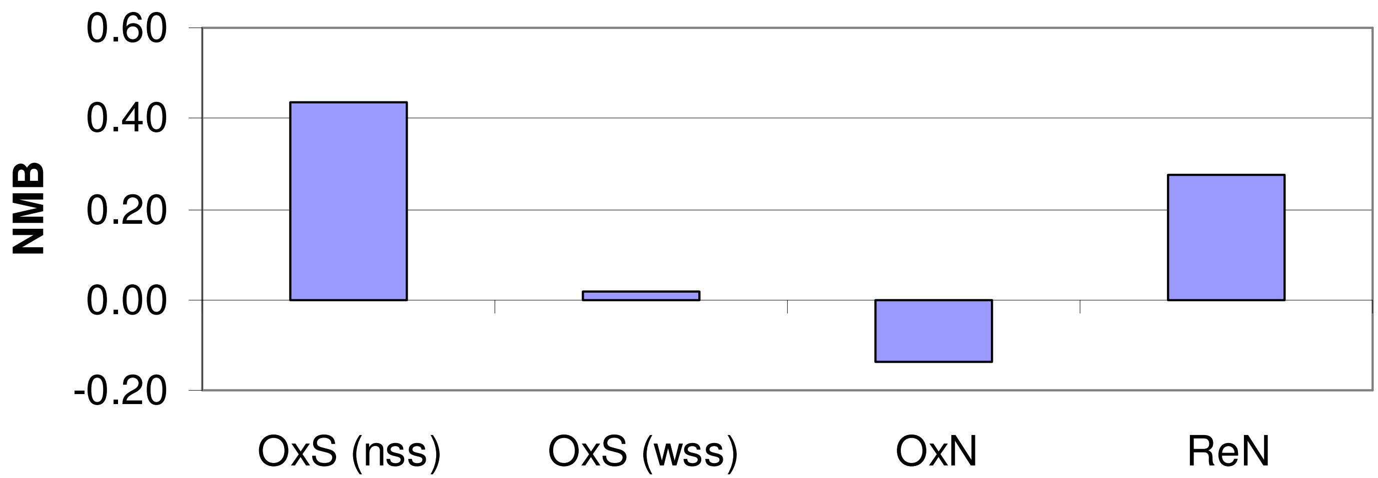
Measured Species	Monitoring Sites
Oxidised S (wss)	ADMN
Oxidised S (nss)	ADMN
Oxidised N	ADMN
Reduced N	ADMN

- Appropriate combinations of modelled species are summed to correspond to measured species.

Validation of Wet Deposition Simulation (2)



Validation of Wet Deposition Simulation (3)



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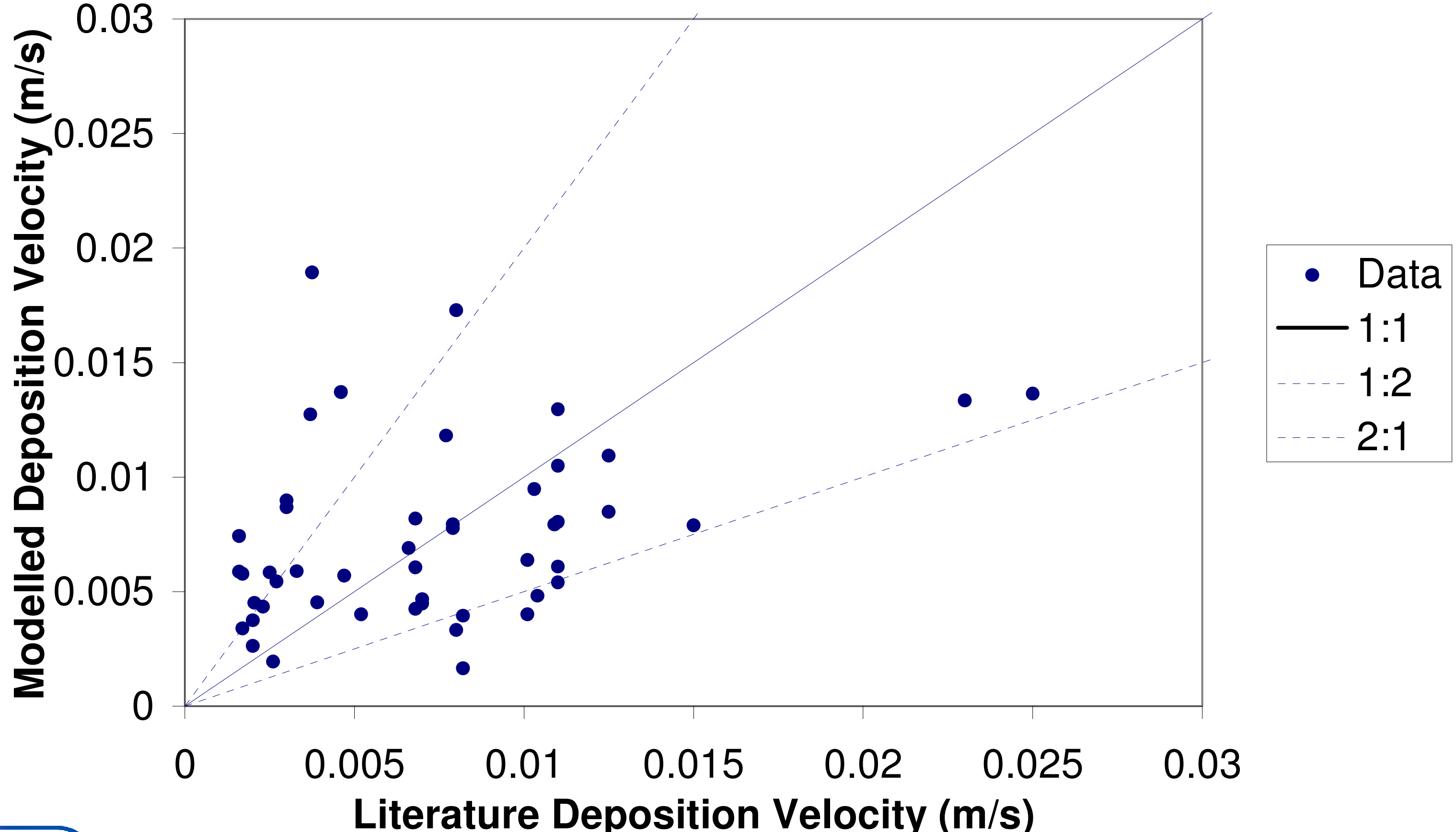
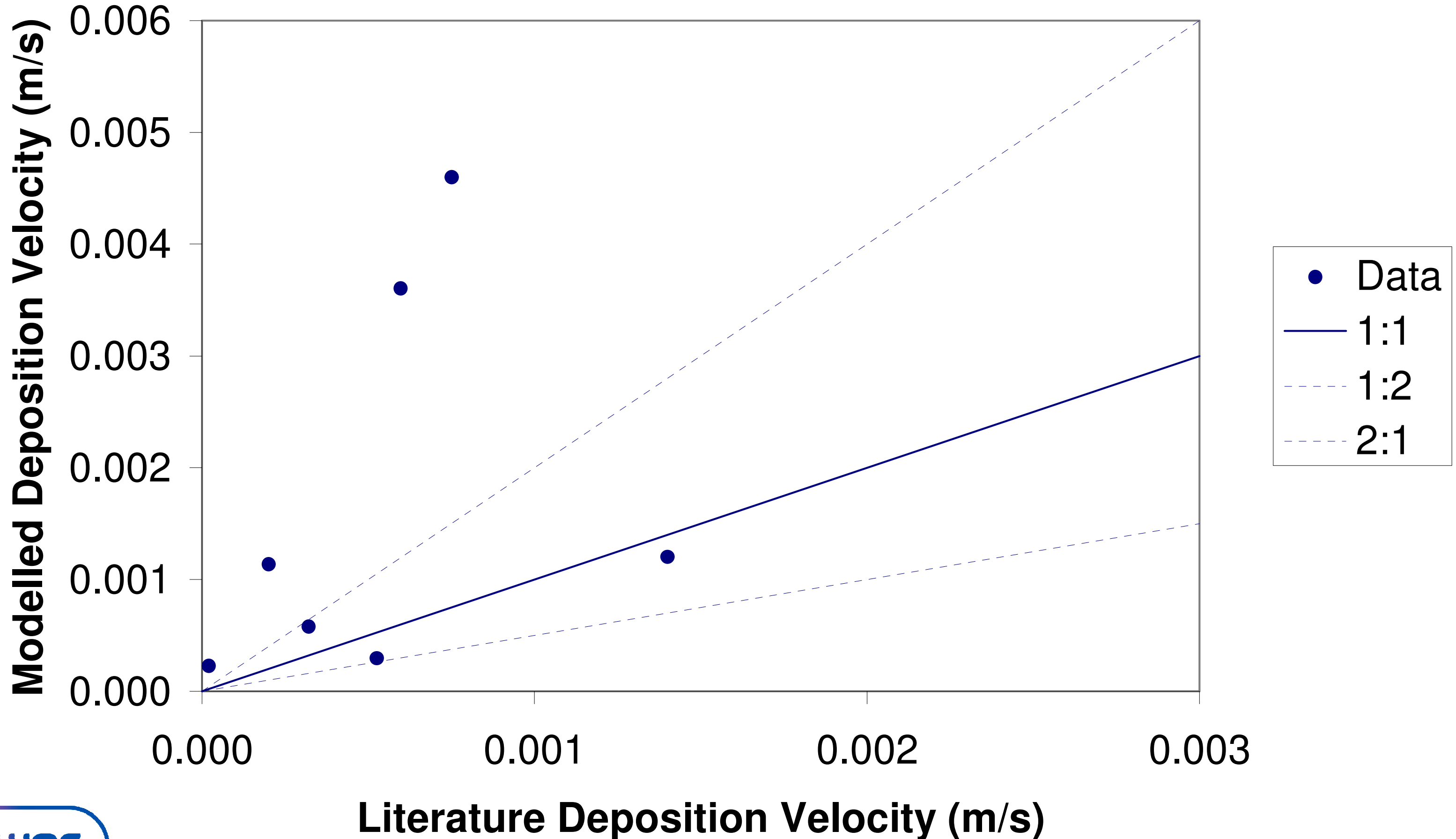
Validation of Dry Deposition Simulation (1)

> Compared SO_2 dry deposition velocities obtained from literature for a variety of cases (e.g. land use, season, dry/wet, day/night) with values modelled by MCIPv2.2 (‘Models-3’ scheme).



Validation of Dry Deposition Simulation (2)

> Compared NO_2 dry deposition velocities obtained from literature for a variety of cases (e.g. land use, season, day/night) with values modelled by MCIPv2.2 ('Models-3' scheme).



Conclusions

> CMAQ selected as mesoscale model providing best-fit to JEP requirements.

> JEP has invested significant resources into building UK CMAQ capability.

> JEP has extensive experience with CMAQ over the last 10 years.

> Validation studies show, in general, good agreement between CMAQ modelled data & observed data.

> Validation confirms the CMAQ model is suitable for addressing regulatory issues.