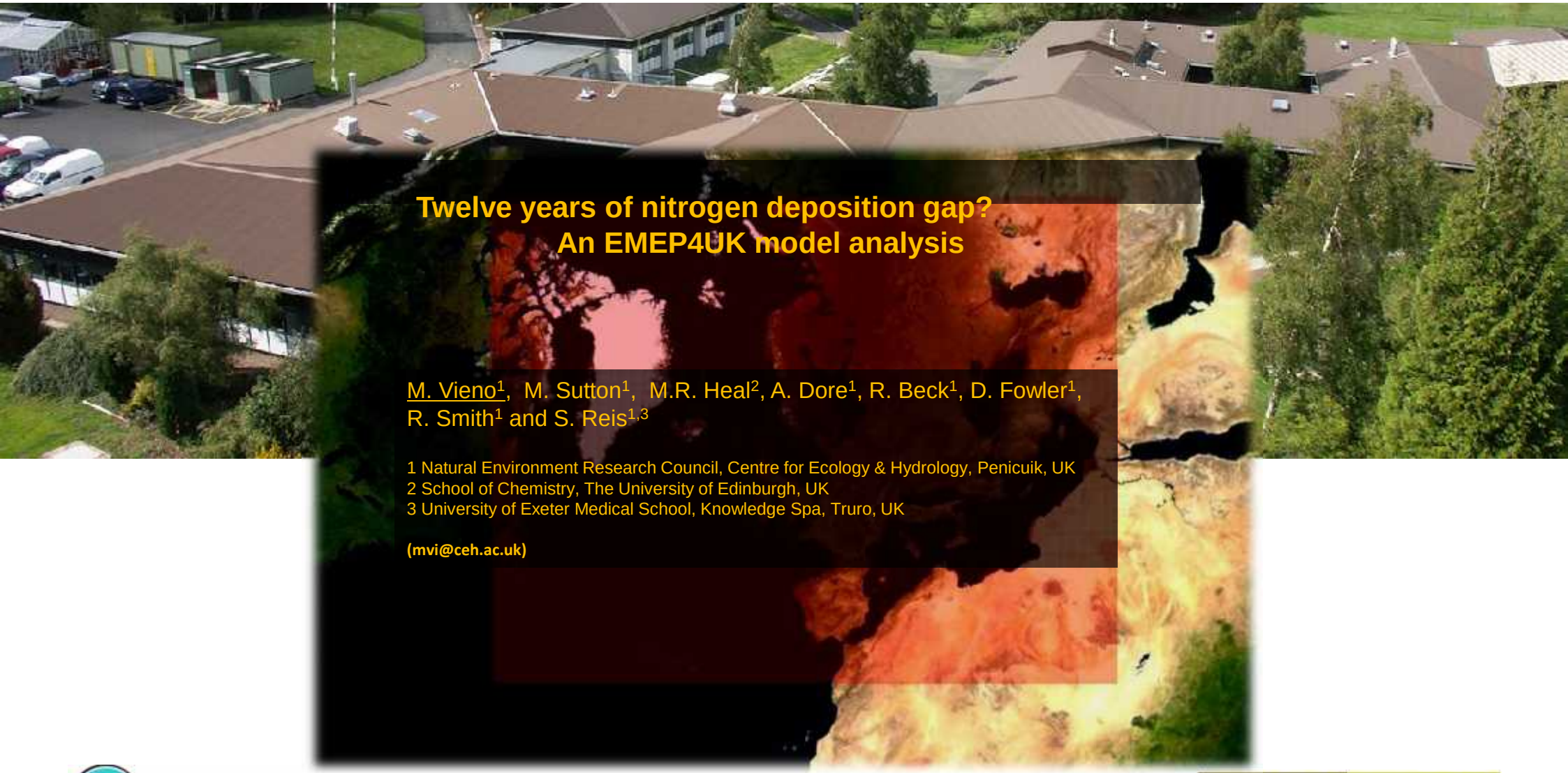

Twelve years of nitrogen deposition gap? An EMEP4UK model analysis

M. Vieno[1], M. Sutton[1], M.R. Heal[2], A. Dore[1], R. Beck[1], D. Fowler[1], R. Smith[1] and S. Reis[1,3]

1 Natural Environment Research Council, Centre for Ecology & Hydrology, Penicuik, UK
2 School of Chemistry, The University of Edinburgh, UK
3 University of Exeter Medical School, Knowledge Spa, Truro, UK

(mvi@ceh.ac.uk)

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The UK nitrogen and sulphur deposition is currently calculated using a combination of models and observations

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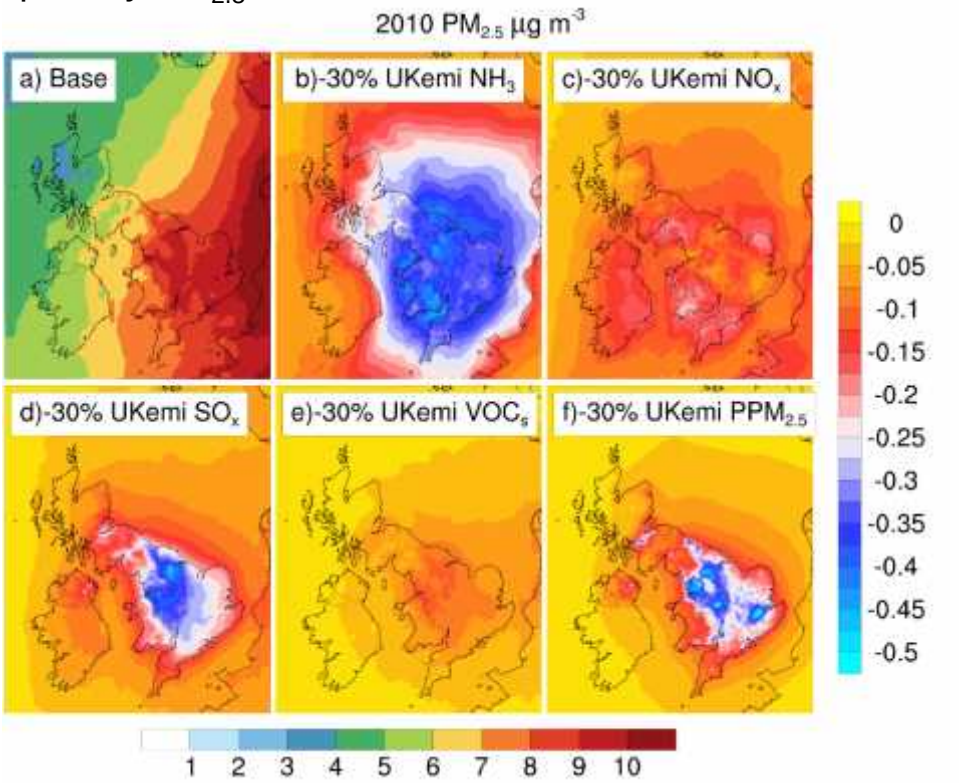
Ammonia is the most efficient way to reduce $PM_{2.5}$ in the UK

Spatial response of 2010 $PM_{2.5}$ due to a 30% UK emission reduction of individual precursors and primary $PM_{2.5}$



	$PM_{2.5}$	SIA	$PM_{2.5}$
	Derwent et al., 2009	Harrison et al., 2013	Vieno et al., 2016
note	mean 15:00z values	19 March - 19 May 2007	UK average (7.2 μgm^{-3})
Emissions reduction	Base year 2006	Base year 2007	Base year 2010
30% SO_2	97%	97%	97.3%
30% NO_x	99%	97%	98.5%
30% NH_3	96%	94%	96.1%
	Data from Harrison et al., 2013		

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How the models compare with observations (2003)

Nitrate in precipitation (annual mean)

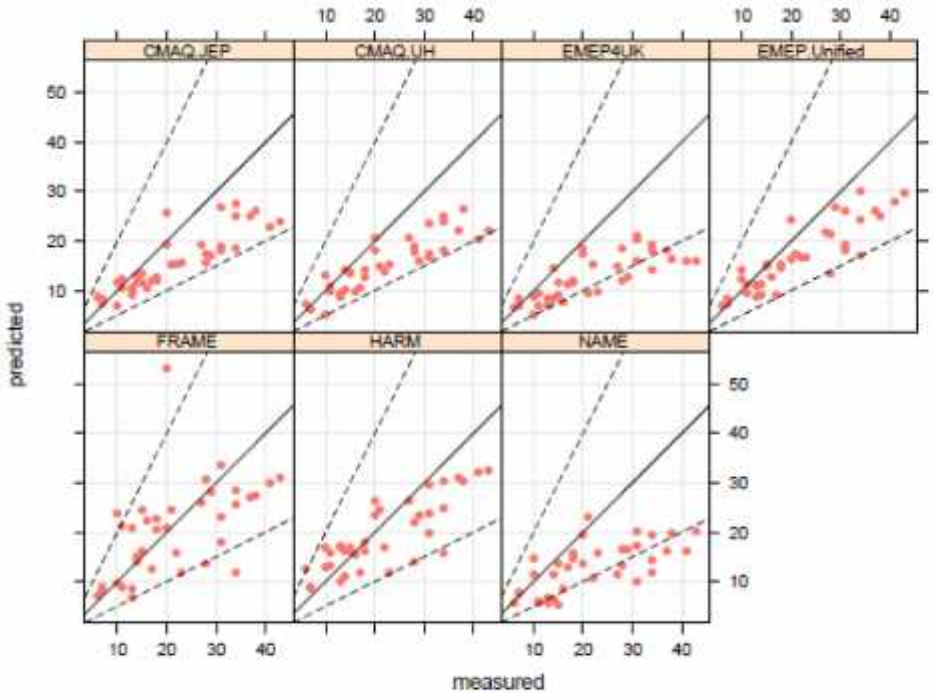

Figure 65: Measured versus predicted annual mean nitrate in precipitation concentrations.

Non Sea salt sulphate in precipitation (annual mean)

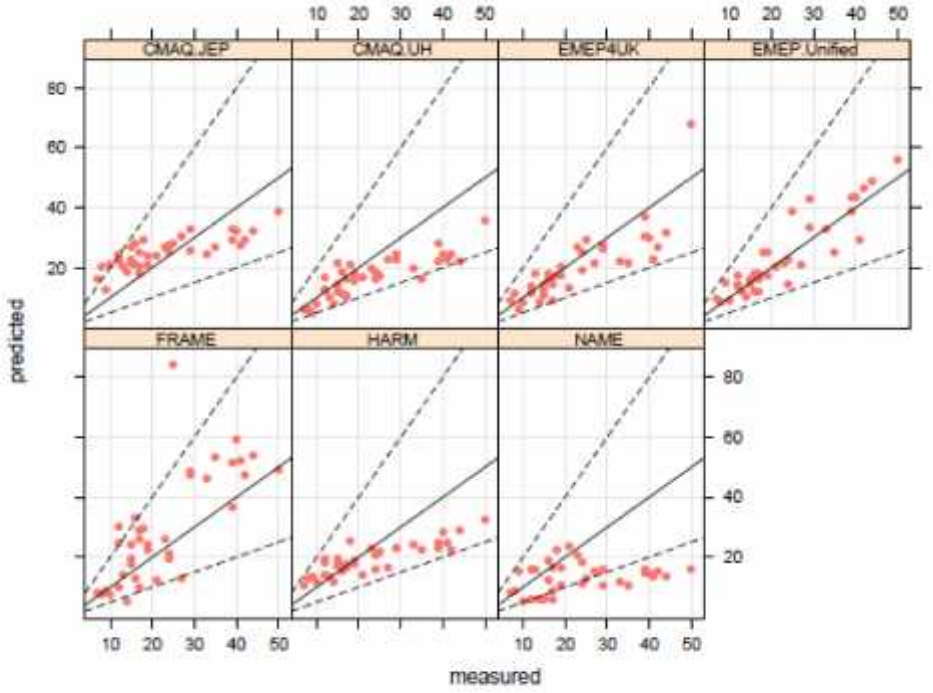

Figure 57: Measured versus predicted annual mean non-sea salt SO_4 in precipitation concentrations.

Dore et. al., 2015

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Scatter plot of the annual average modelled concentrations in precipitation with measurements from the UKEAP precipitation chemistry monitoring network (µeq l^{-1}).
~ 30 sites across the UK

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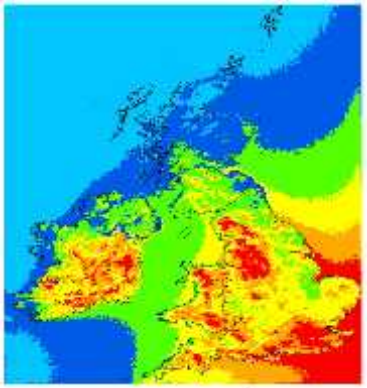
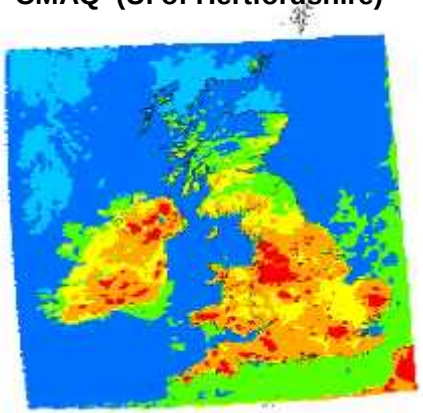
Models used in the UK to calculate the nitrogen deposition

CBED (CEH)

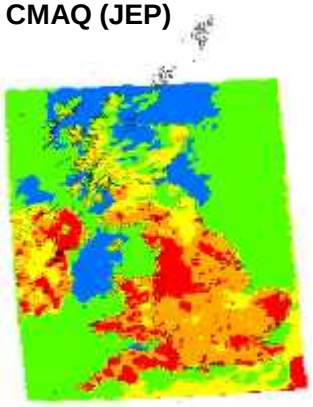
FRAME (CEH)



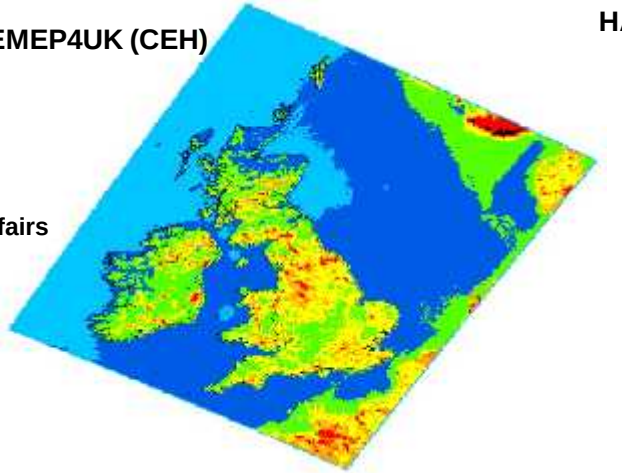
CMAQ (U. of Hertfordshire)



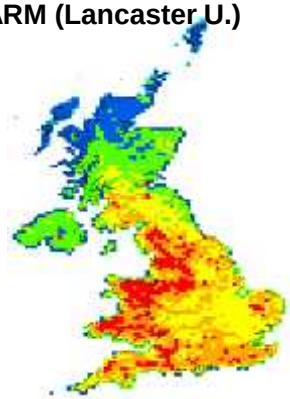
CMAQ (JEP)



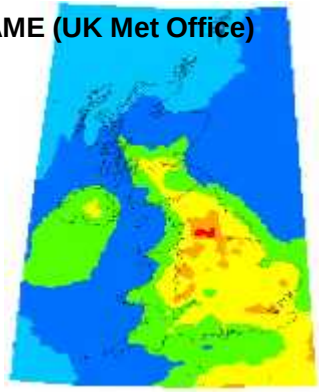
EMEP4UK (CEH)



HARM (Lancaster U.)



NAME (UK Met Office)



Deposition
keq ha^{-1} $year^{-1}$

Year 2003
Total (dry + wet)
Nitrogen (NO_x + NH_x) deposition

UK Department for Environment, Food & Rural Affairs (DEFRA) model inter-comparison
Carslaw et. al., 2011

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Dore et. al., 2015

Concentration Based Estimated Deposition (CBED)

CBED is a collection of routines which provide an estimate of deposition derived from the concentration data collected by the UK national monitoring networks.

The separate deposition components estimated are:

- dry (gases, aerosols, cloud droplets)
- wet (pollution ions in rainfall)

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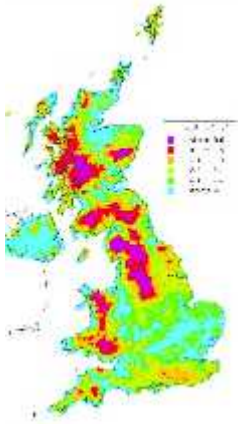
CBED – components of UK budget

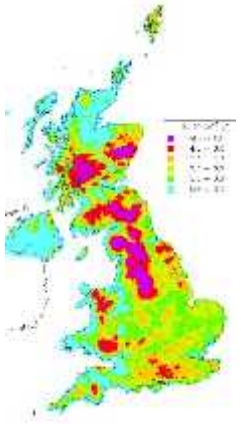
Year 2014

Wet deposition

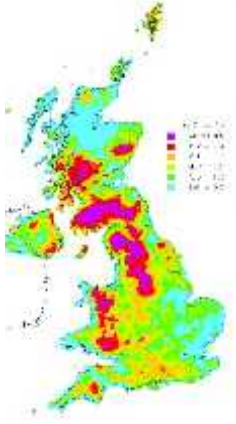
S



oxidised N

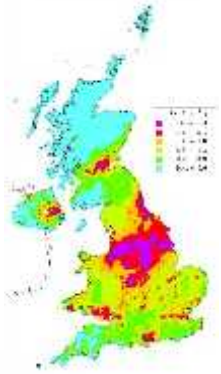


reduced N



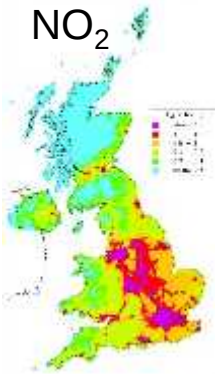
Dry deposition

S



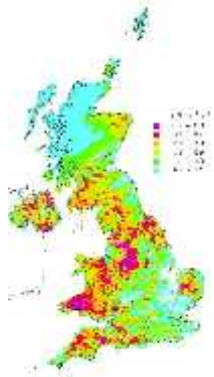
oxidised N

NO_2



HNO_3

reduced N



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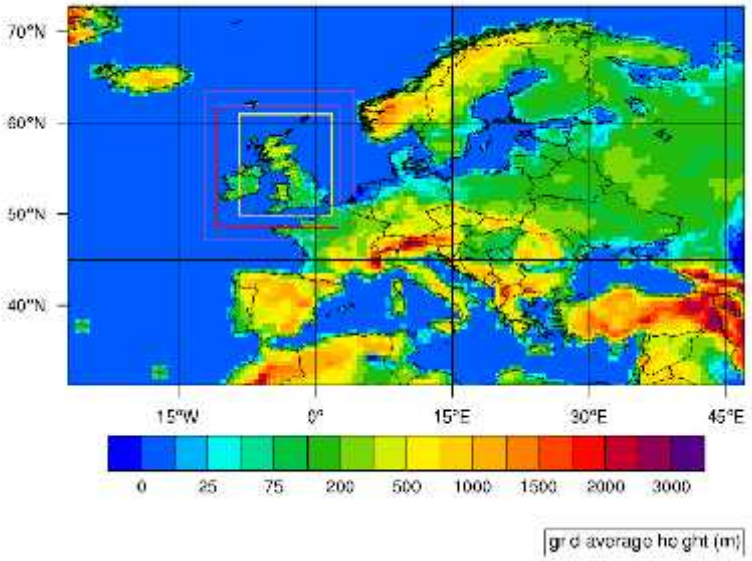
www.emep4uk.ceh.ac.uk

EMEP4UK model



- **3D + time model (Eulerian) – Open source (www.emep.int)**
- **The Meteorological Synthesizing Centre-West (MSC-W) of the European Monitoring and Evaluation Programme (EMEP) has been performing model calculations in support of the Convention on Long Range Transboundary Air Pollution (CLRTAP) for more than 30 years**
- **EMEP4UK (Vieno et. al, 2014, 2016) - Core model derived from EMEP MSC-W model (Simpson et al., 2012) currently rv4.10 – used here rv4.3**
- **Land cover specific dry deposition and wet deposition removal processes**
- **Meteorology driver is the Weather Research Forecast model (WRF 3.8 www.wrf-model.org), used here 3.1.1**
- **One way nested.**
- **Vertical domain from surface (45 m) up to 100hPa (~16 km)**
- **Hourly, daily, monthly, and annual output of more than 150 species**
- **Global emissions HTAP, EU emission EMEP, UK emissions NAEI, and shipping emissions FMI (J.-P. Jalkanen et. al., 2016).**

Vieno, M., Heal, M. R., Williams, M. L., Carnell, E. J., Nemitz, E., Stedman, J. R., and Reis, S.: The sensitivities of emissions reductions for the mitigation of UK pm2.5, Atmos. Chem. Phys., 16, 265-276, 10.5194/acp-16-265-2016, 2016

Vieno, M., Heal, M. R., Hallsworth, S., Famulari, D., Doherty, R. M., Dore, A. J., Tang, Y. S., Braban, C. F., Leaver, D., Sutton, M. A., and Reis, S.: The role of long-range transport and domestic emissions in determining atmospheric secondary inorganic particle concentrations across the UK, Atmos. Chem. Phys., 14, 8435-8447, 10.5194/acp-14-8435-2014, 2014

Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J. P., Valdebenito, Á., and Wind, P.: The EMEP MSC-W chemical transport model – Part 1: Model description, Atmos. Chem. Phys. Discuss., 12, 3781-3874, 10.5194/acpd-12-3781-2012, 2012

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This work was supported jointly by the UK Department for the Environment, Food and Rural Affairs (Defra 2011-2014), the NERC Centre for Ecology and Hydrology (CEH), the EMEP programme under the UNECE LRTAP Convention, the Norwegian Meteorological Institute (Met.No) and the European Union projects NitroEurope IP and ÉCLAIRE.

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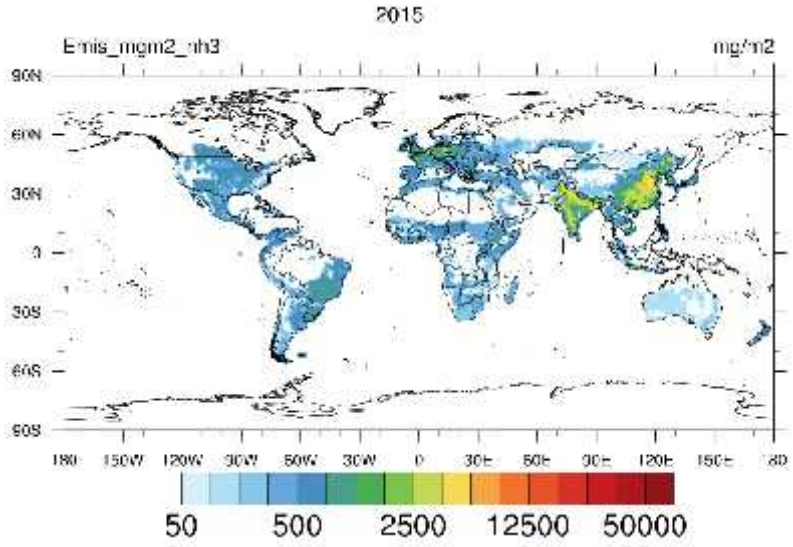
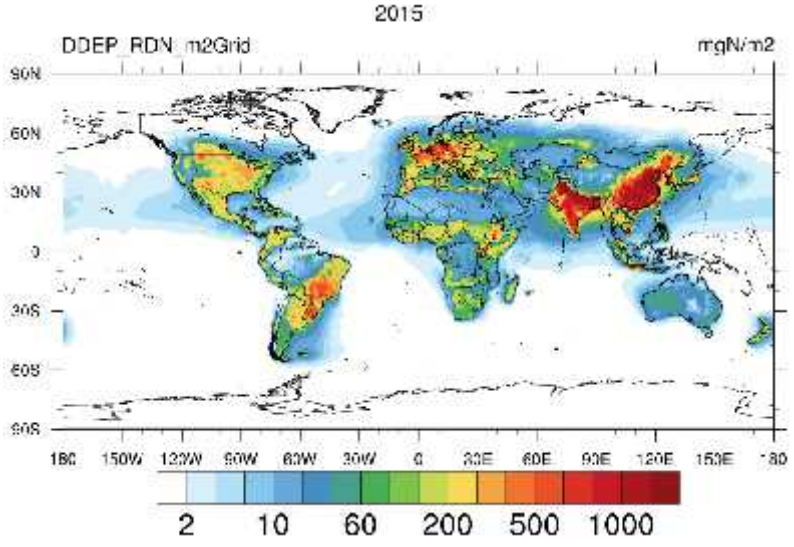
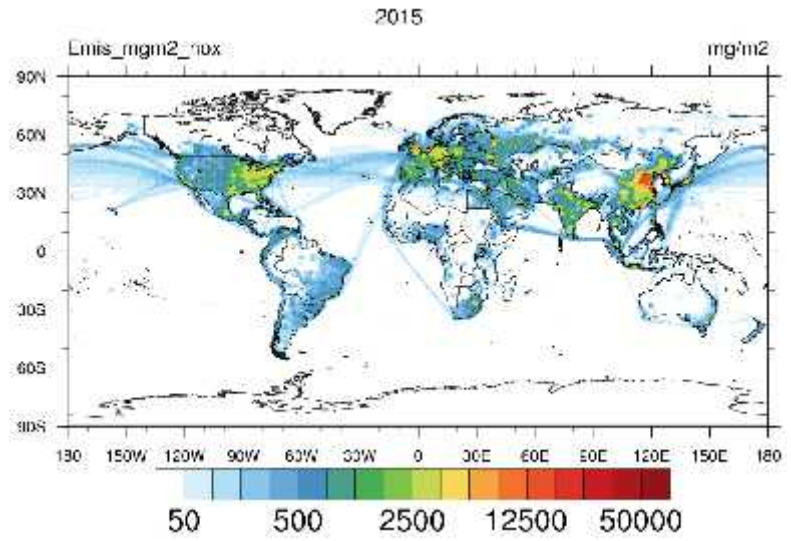
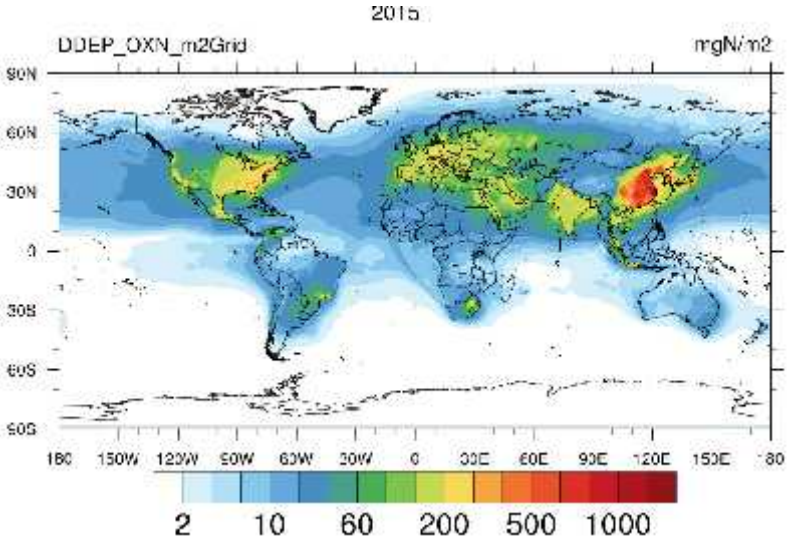
UK nitrogen in the world context (preliminary)









Preliminary EMEP4WORLD

WRF meteorology 2015

Global emissions 2005, EU and UK 2015

Currently no validation outside EU

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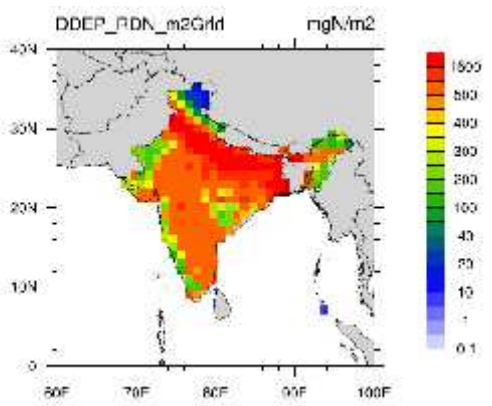
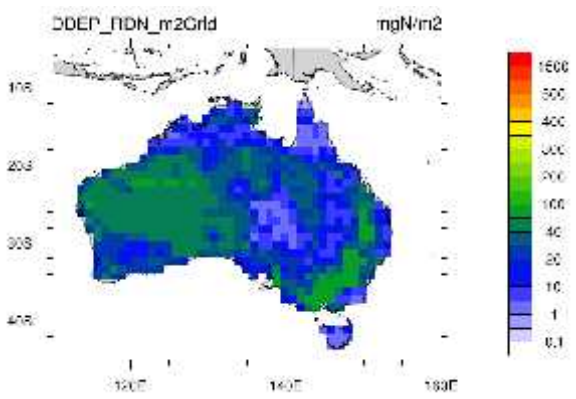
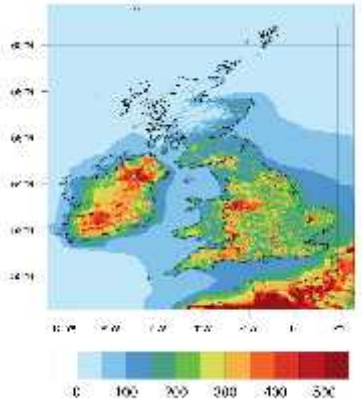
EMEP4UK reduced nitrogen UK deposition for the year 2015

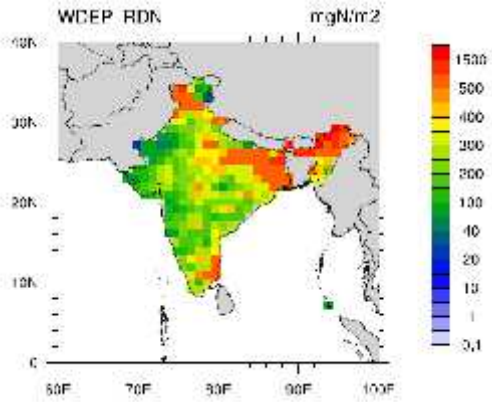
dry deposition
mgN m^{-2}

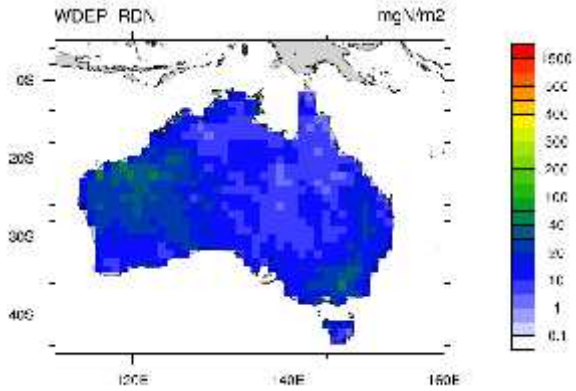


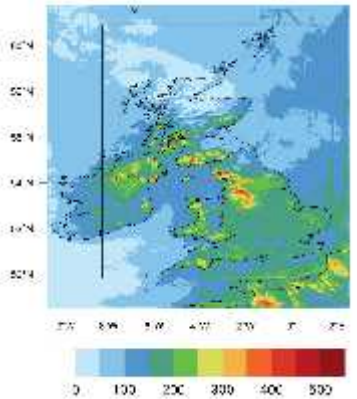




wet deposition
mgN m^{-2}







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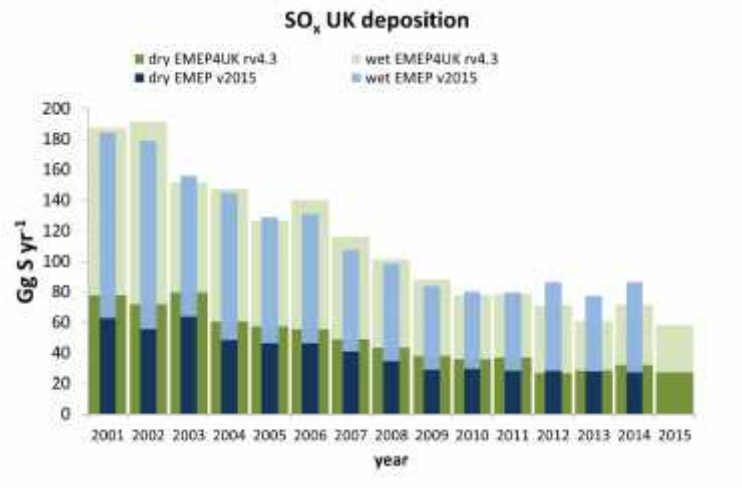
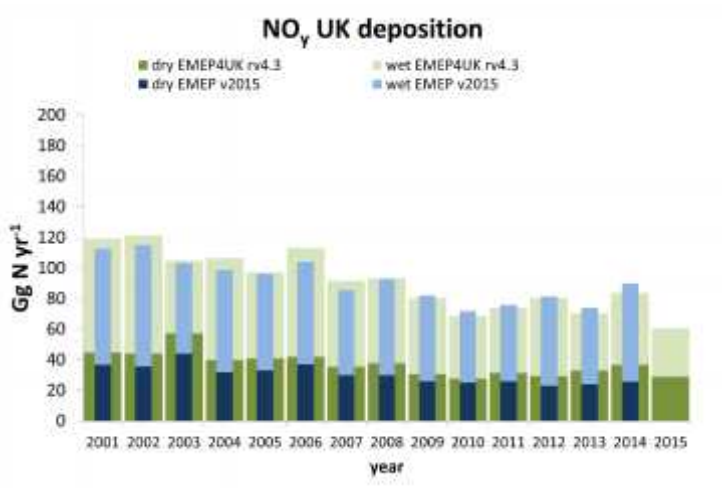
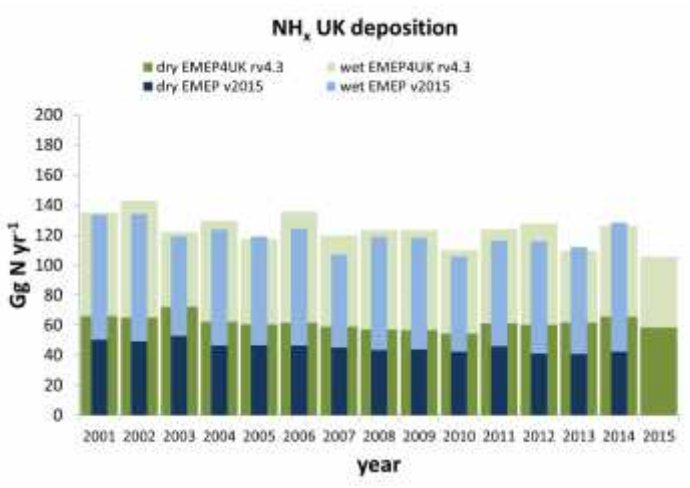
EMEP4UK rv4.3 vs EMEP MSC-w official v2015 emissions data







EMEP MSC-w uses rv4.8 version, more updated emissions, and ECMWF meteorology

The horizontal resolution is 50 km x 50 km and it is extensively QA/QC

Light GREEN EMEP4UK wet
Dark GREEN EMEP4UK dry

Light BLUE EMEP MSC-w wet
Dark BLUE EMEP MSC-w dry

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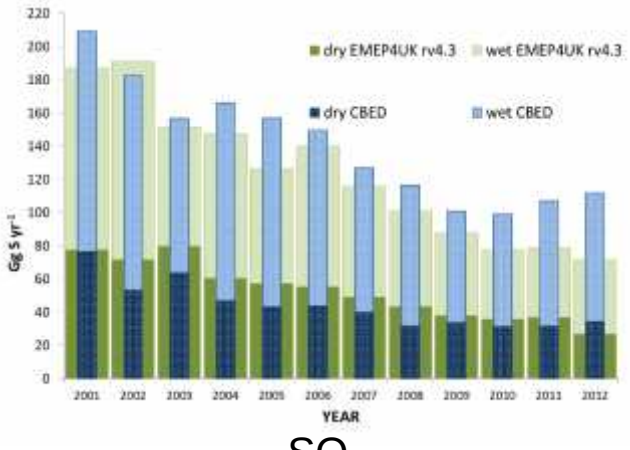
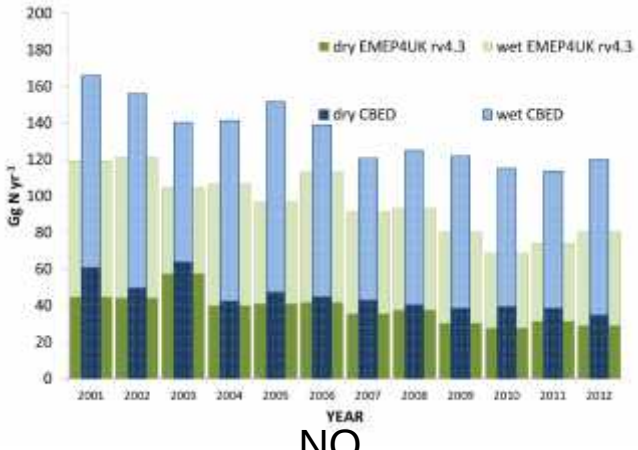
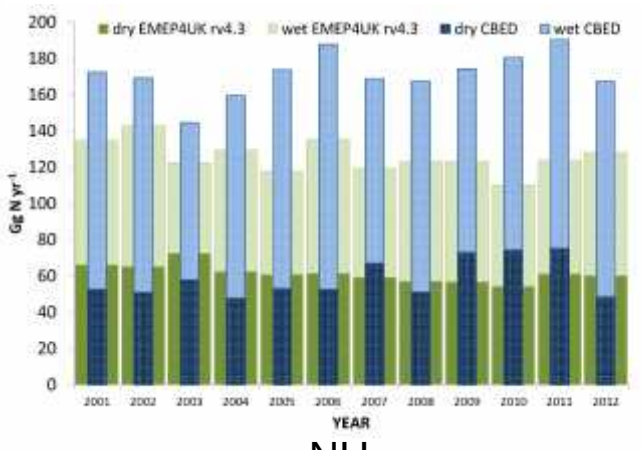
Changing N and S deposition over time in the UK



SO_X



NO_y



NH_X

Light GREEN EMEP4UK wet
Dark GREEN EMEP4UK dry

Light BLUE CBED wet
Dark BLUE CBED dry

- Model may underestimate wet deposition (rainfall) and spatial pattern of rainfall
- Emissions based on NAEI and EMEP 2012 rescaled to annual total
- Wet deposition may be over-estimated due to dry deposition on the surface of bulk collectors

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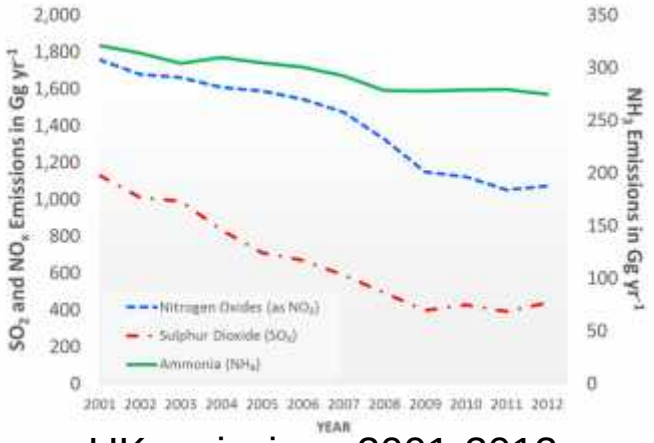
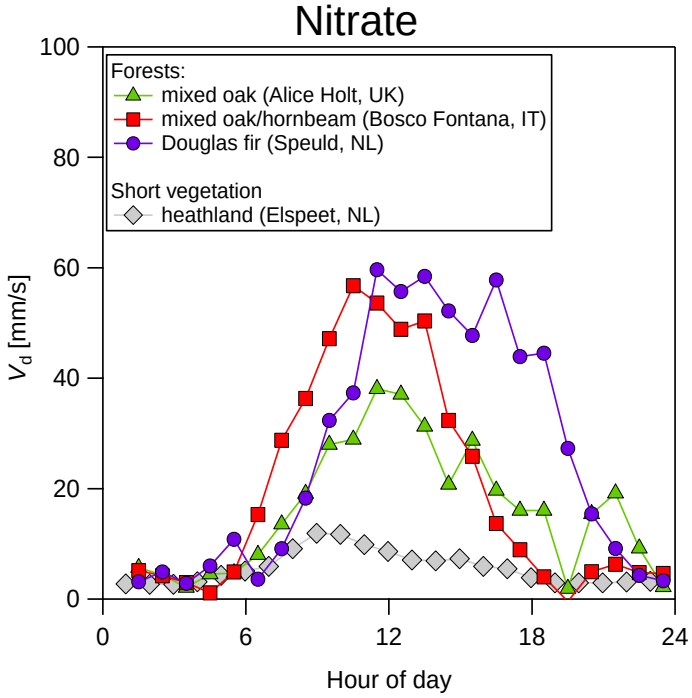


UK emissions 2001-2012

Missing processes….

Fluxes of individual aerosol chemical components:
ubiquitous fast deposition of nitrate due to volatilisation near/within canopies



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Dr Eiko Nemitz
en@ceh.ac.uk

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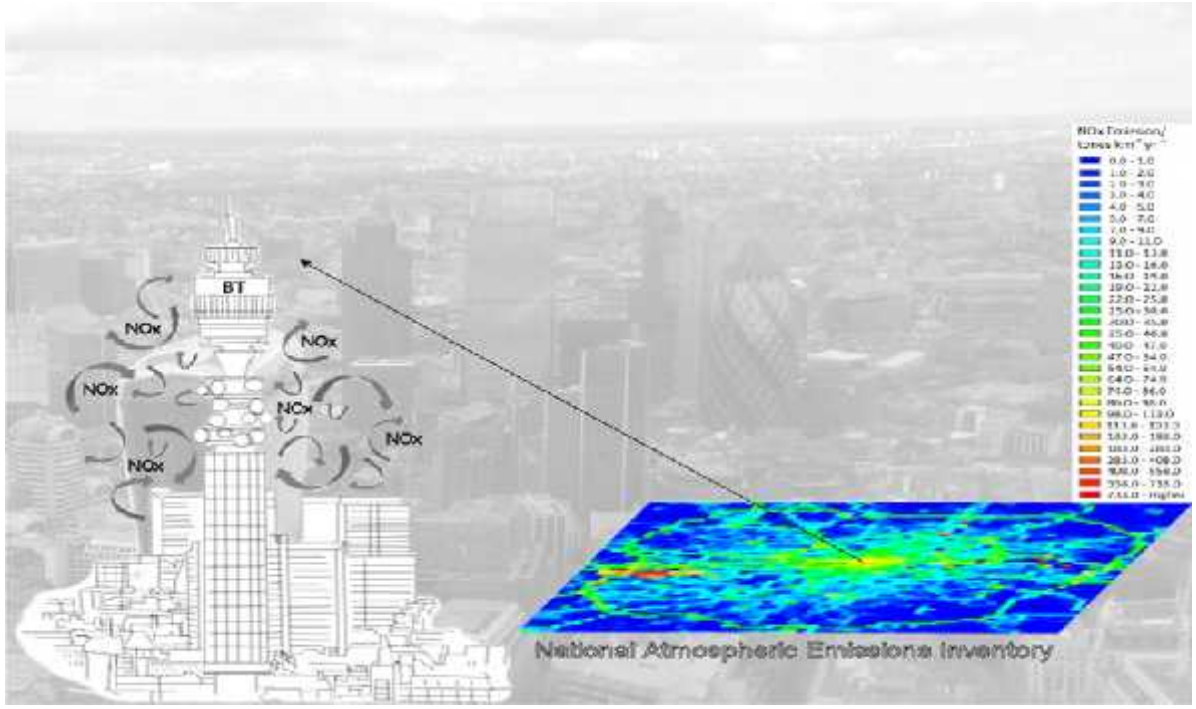
Are the emissions used in model accurate?



The measurements are on average 80% higher than the NAEI emission inventory for all of London

Published in: James D. Lee; Carole Helfter; Ruth M. Purvis; Sean D. Beevers; David C. Carslaw; Alastair C. Lewis; Sarah J. Møller; Anja Tremper; Adam Vaughan; Eiko G. Nemitz; *Environ. Sci. Technol.* **2015,** 49, 1025-1034. DOI: 10.1021/es5049072

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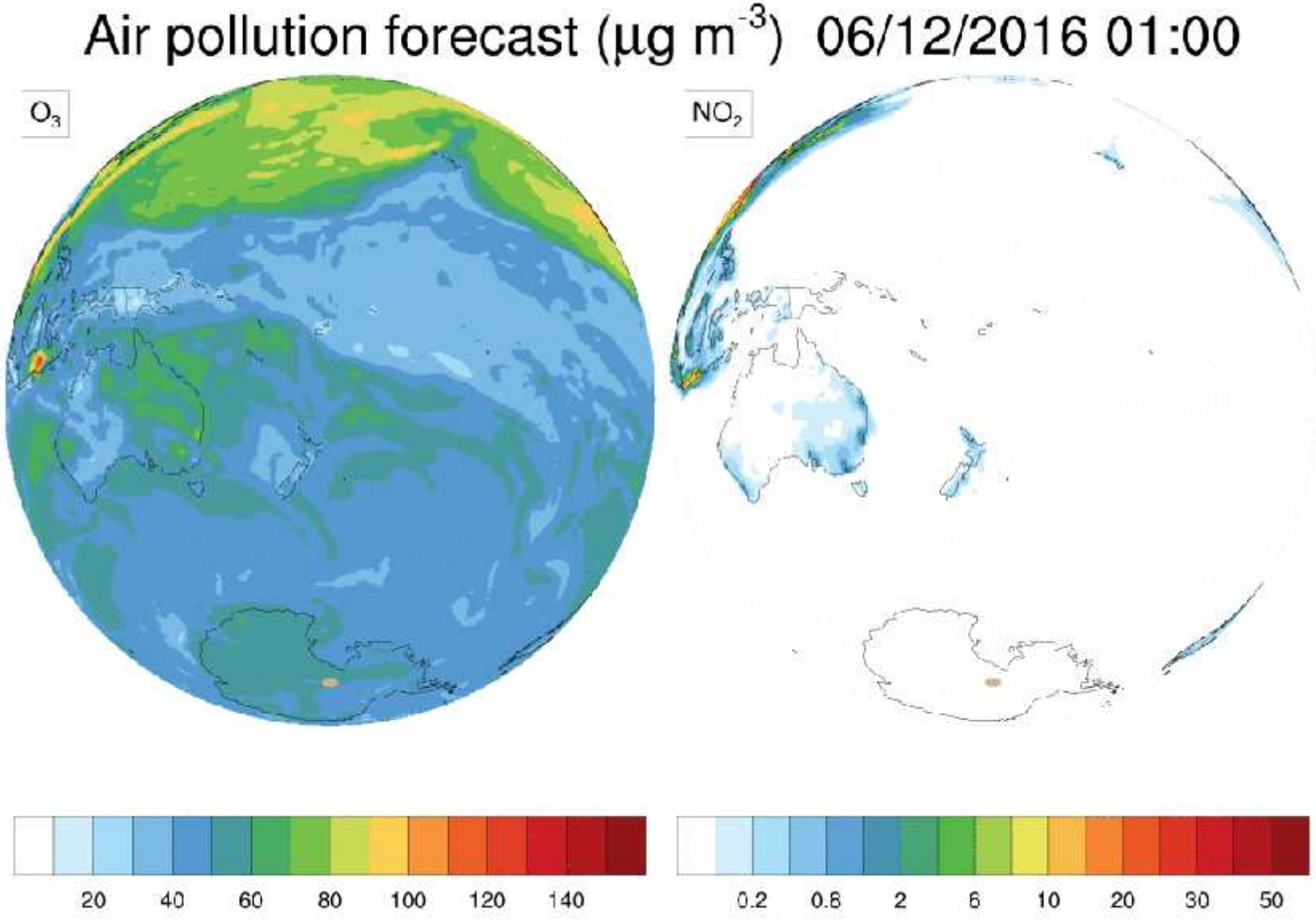
…also just because it runs



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conclusions

- Further analysis of wet deposition removal processes is required
- Using a better MP scheme for WRF
- EMEP4UK is similar for dry deposition to CBED suggesting that long range transport may not be well represented
- Emissions uncertainties play a role
- Observations bias such as dry deposition on rain collectors
- Test the model outside EU

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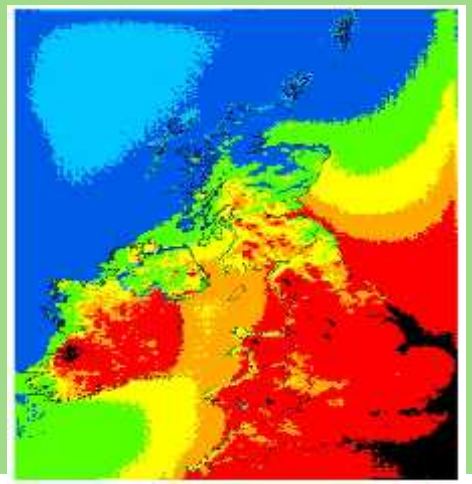
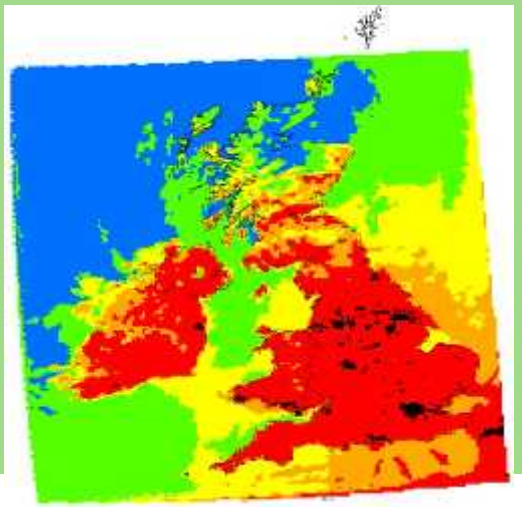
Total Acid (NOx + NHx + S) deposition 2003

CBED

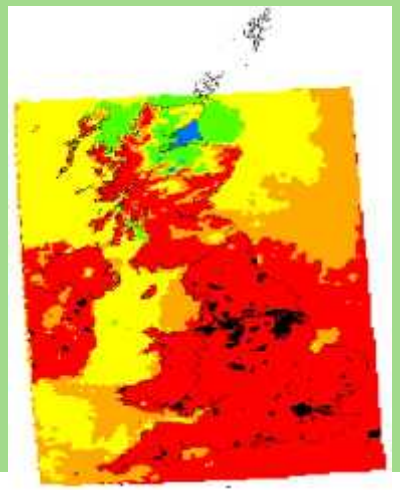
FRAME



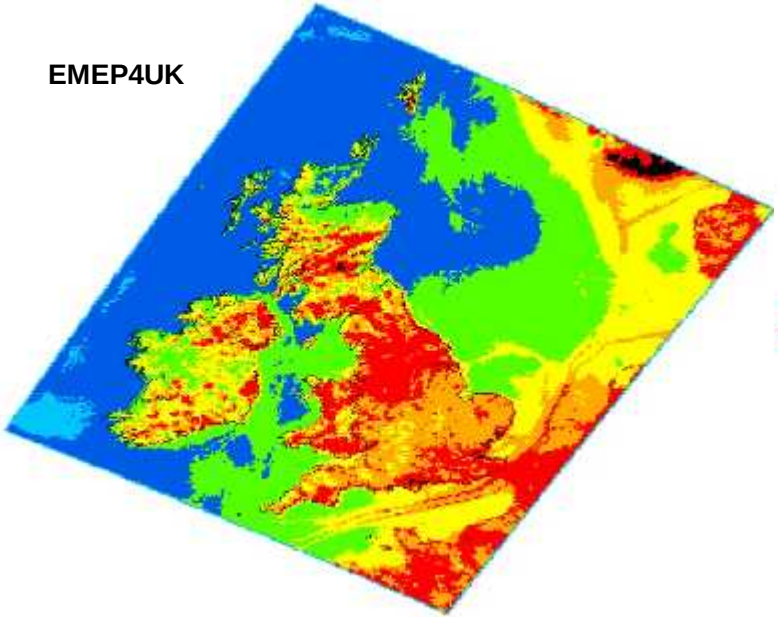
HERTS



JEP

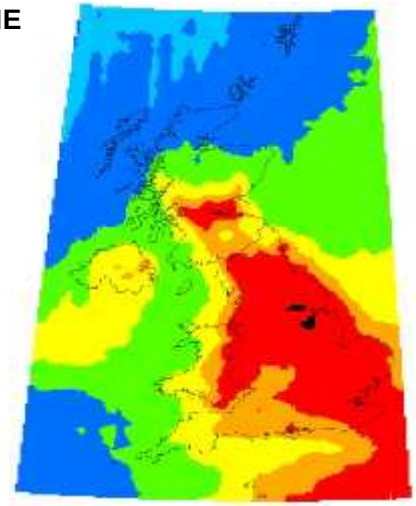


EMEP4UK



HARM

NAME



Deposition
keq ha^{-1} $year^{-1}$

- <0.2
- 0.2 0.1
- 0.1 0.6
- 0.6 0.8
- 0.8 1
- 1 2
- >2

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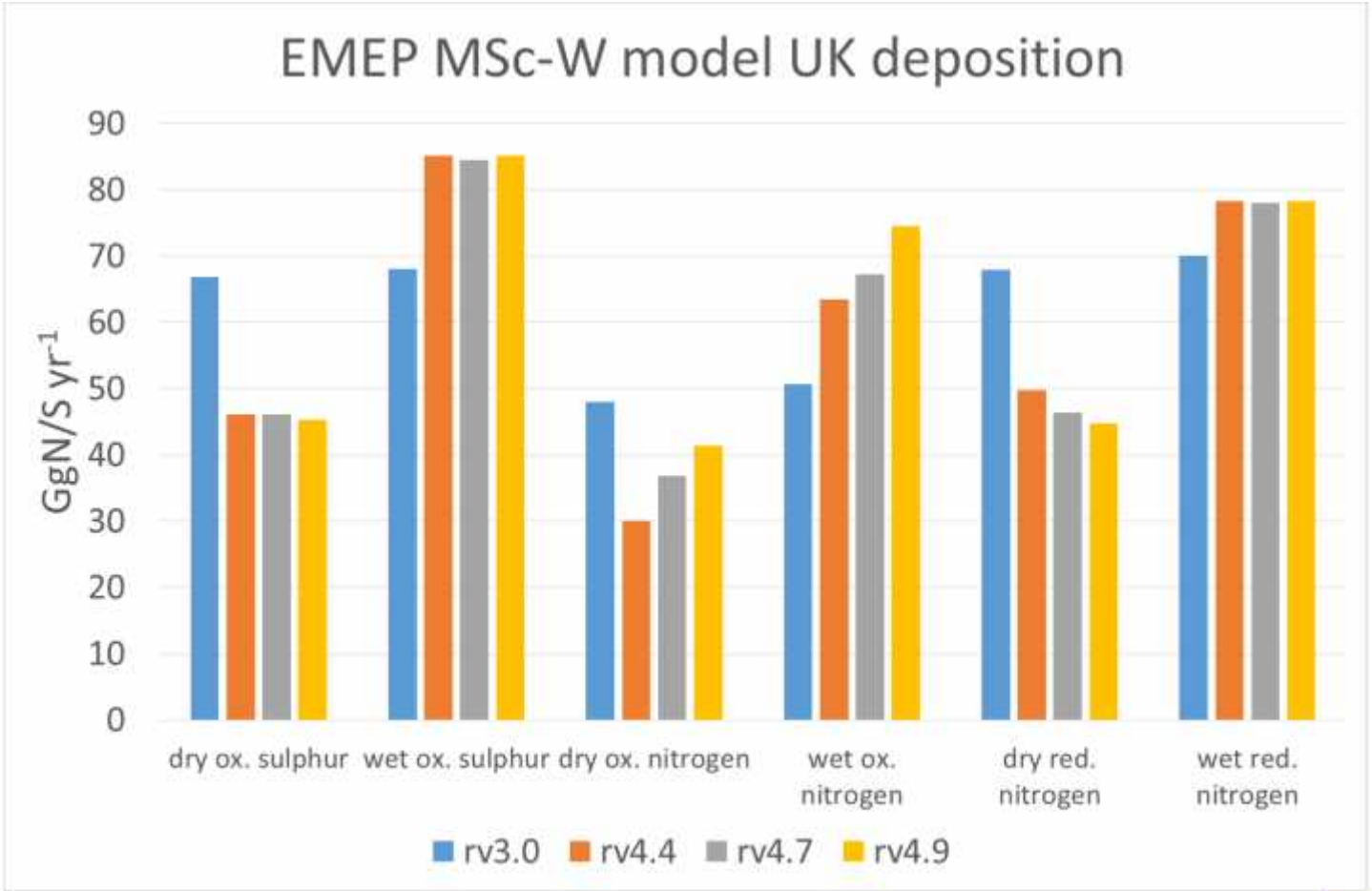

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2001 - 2012 UK emissions reduction and UK deposition

A ~60% of UK SO_2 emissions reduction: 53% (EMEP4UK) and 46% (CBED) reduction in SOX deposition

A ~39% of UK NO_x emissions reduction: 28% (EMEP4UK) and 28% (CBED) reduction in OXN deposition

A ~14% of UK NH_3 emissions reduction: 5% (ACTM) and 3% (CBED) reduction in RDN deposition.

European emissions reductions between 2001 and 2012 will have also impacted on UK deposition, as up to 60% of secondary inorganic aerosols are directly imported from mainland Europe and contain N and S in the form of ammonium nitrate and sulphates (Vieno et. al., 2014).

Note: not a trend just 2001 compared to 2012!

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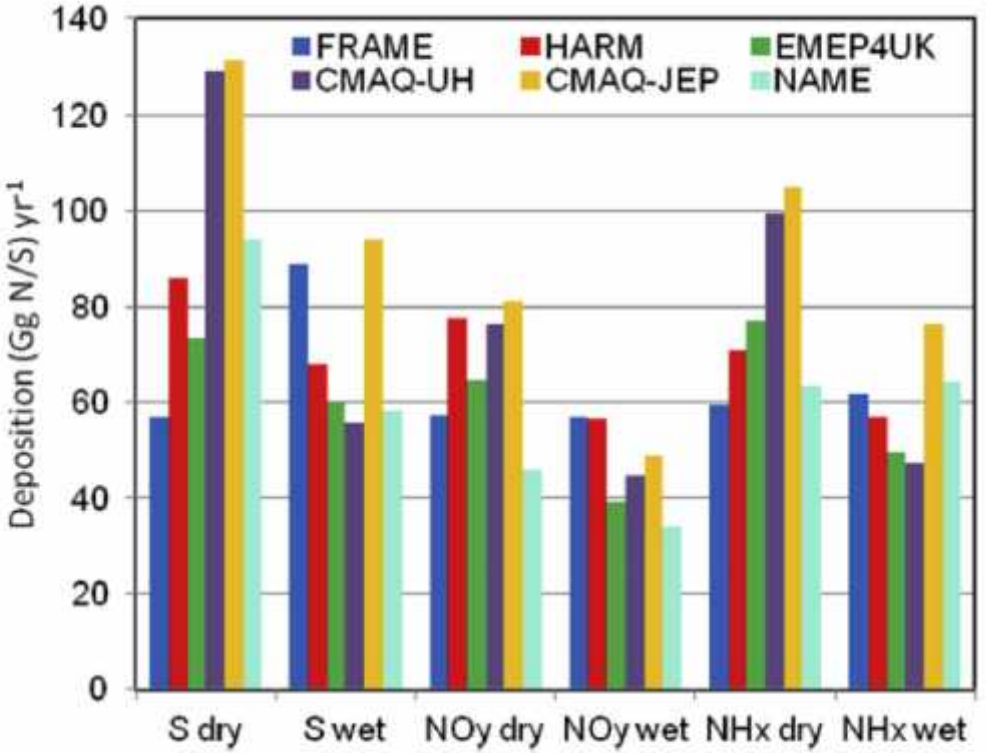

Fig. 2. The total UK annual wet and dry deposition budgets of SO_x, NO_y and NH_x for the different models (Gg N/S).

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