CAPER March 2013

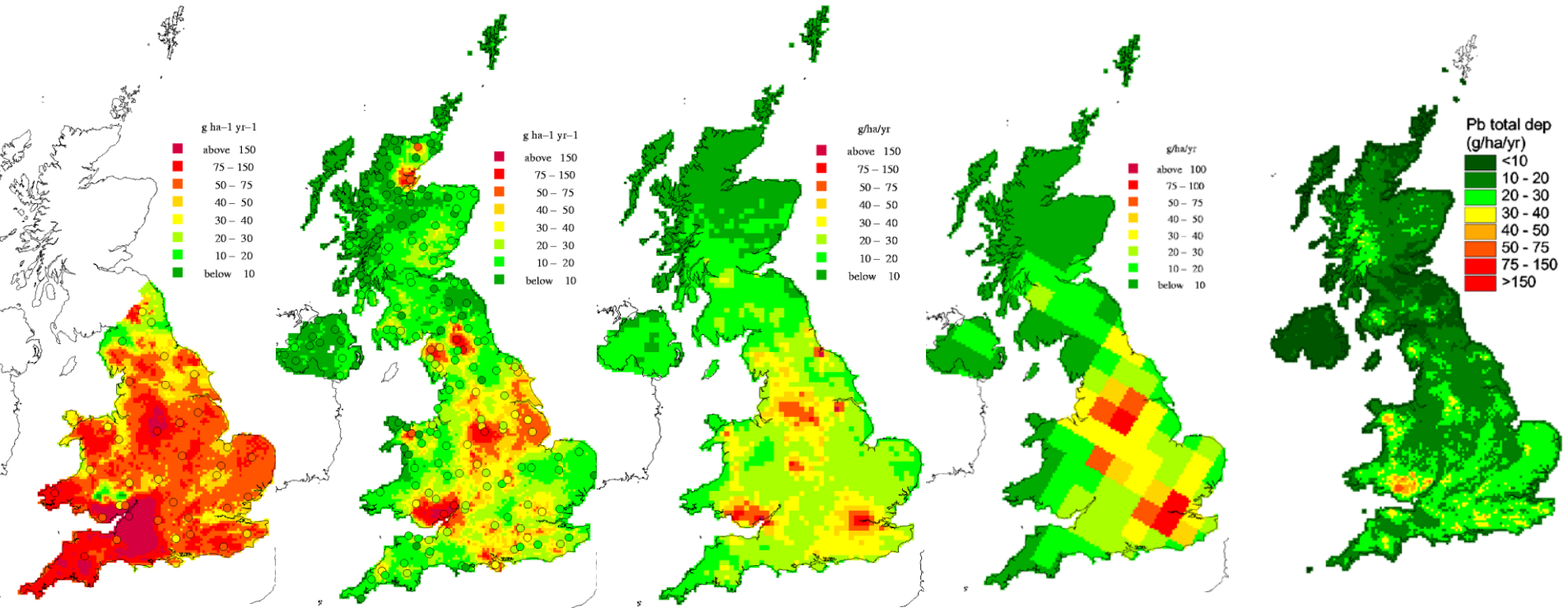
Heavy metal emissions, concentrations and deposition in the UK

Comparisons between deposition and emission inventory values for metals

Background

- Several methods available to monitor metal concentrations in air and deposition
- Wet deposition collectors
- Inferential methods for dry deposition (The estimates are made using measured concentrations and a deposition model
- Passive samplers (eg Frisbee)
- Moss sampling (moss accumulates some metals)

Frisbee network (95-98) (b) Moss survey (2000) (c) FRAME-HM (NAEI, 1998) (d) EMEP (1998) (e) New network (2003/04)



UK maps of Pb deposition derived with five different methods.

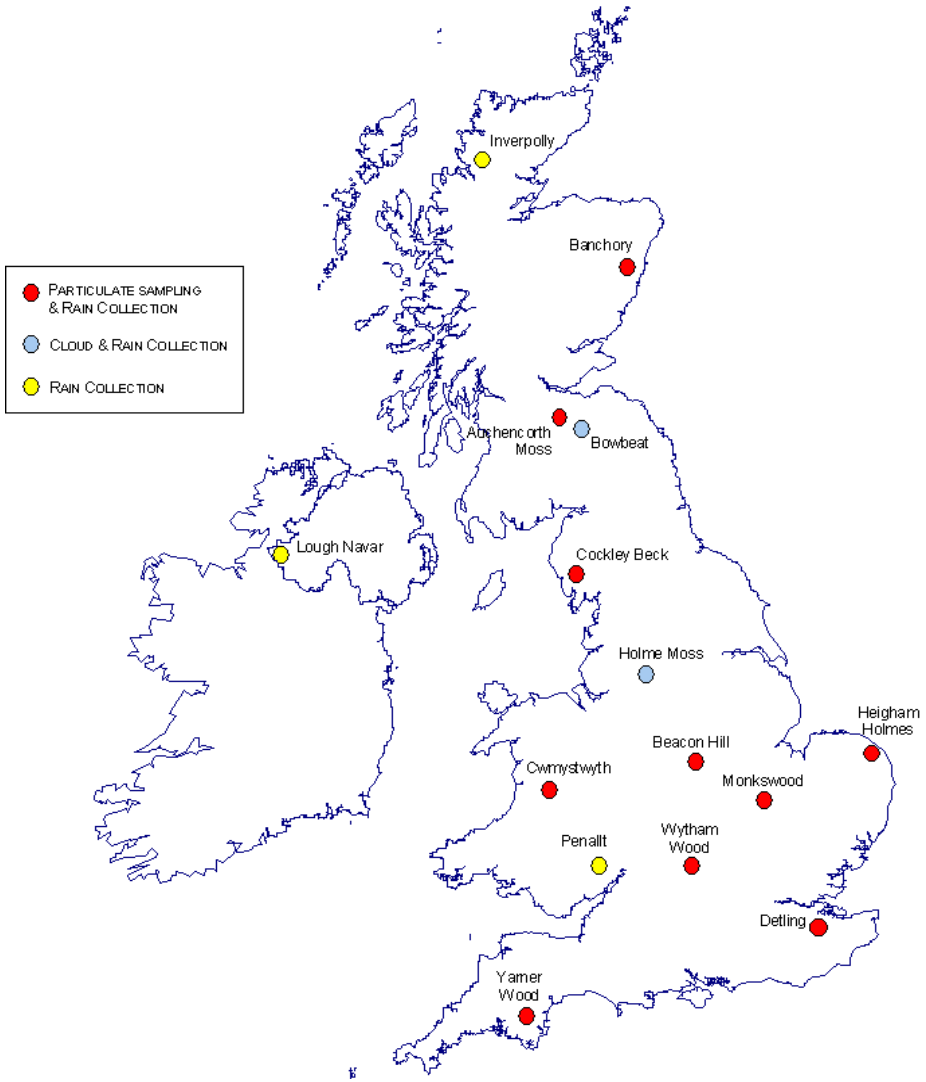


Figure 1: The UK Rural Heavy Metals Monitoring Network

Sampling Intervals at each site

SITE	Sampling Interval			
	Heavy Metals in Particles	Heavy Metals in Precipitation	Hg in Air	Hg in Precipitation
Auchencorth Moss	1-Week	1-Week	2-Week	1-Month
Banchory	1-Week	1-Week	2-Week	1-Month
Monks Wood	1-Week	1-Week	2-Week	1-Month
Yarner Wood	1-Week	1-Week	2-Week	1-Month
Cockley Beck [1]	1-Week	1-Week	2-Week	1-Month
Cwmystwyth	1-Week	4-Week	2-Week	1-Month
Wytham Wood [1]	1-Week	4-Week	2-Week	1-Month
Heigham Holmes [2]	1-Week	4-Week	2-Week	1-Month
Detling [2]	1-Week	4-Week	2-Week	1-Month
Beacon Hill [1]	1-Week	4-Week	2-Week	1-Month
Bowbeat [3]		4-Week	2-Week	1-Month
Holme Moss [3]		4-Week	2-Week	1-Month
Inverpolly		1-Month	2-Week	1-Month
Penallt		1-Month	2-Week	1-Month
Lough Navaar		1-Month	2-Week	1-Month

[1] Replaced Rural Trace Element (RTE) site, [2] Replaced North Sea Network (NS) site, [3] Cloud and Precipitation high altitude sites.

Auchencorth Moss

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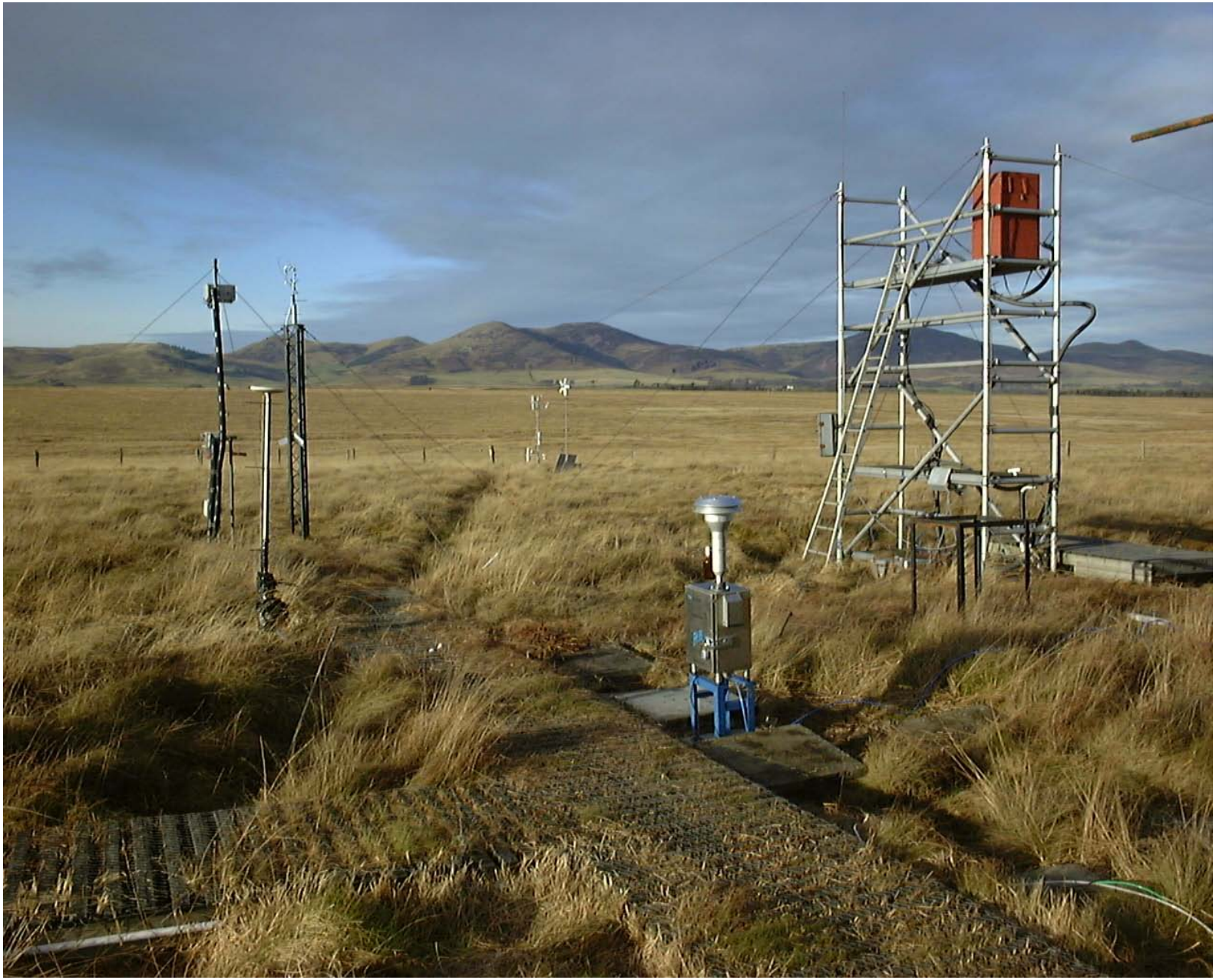
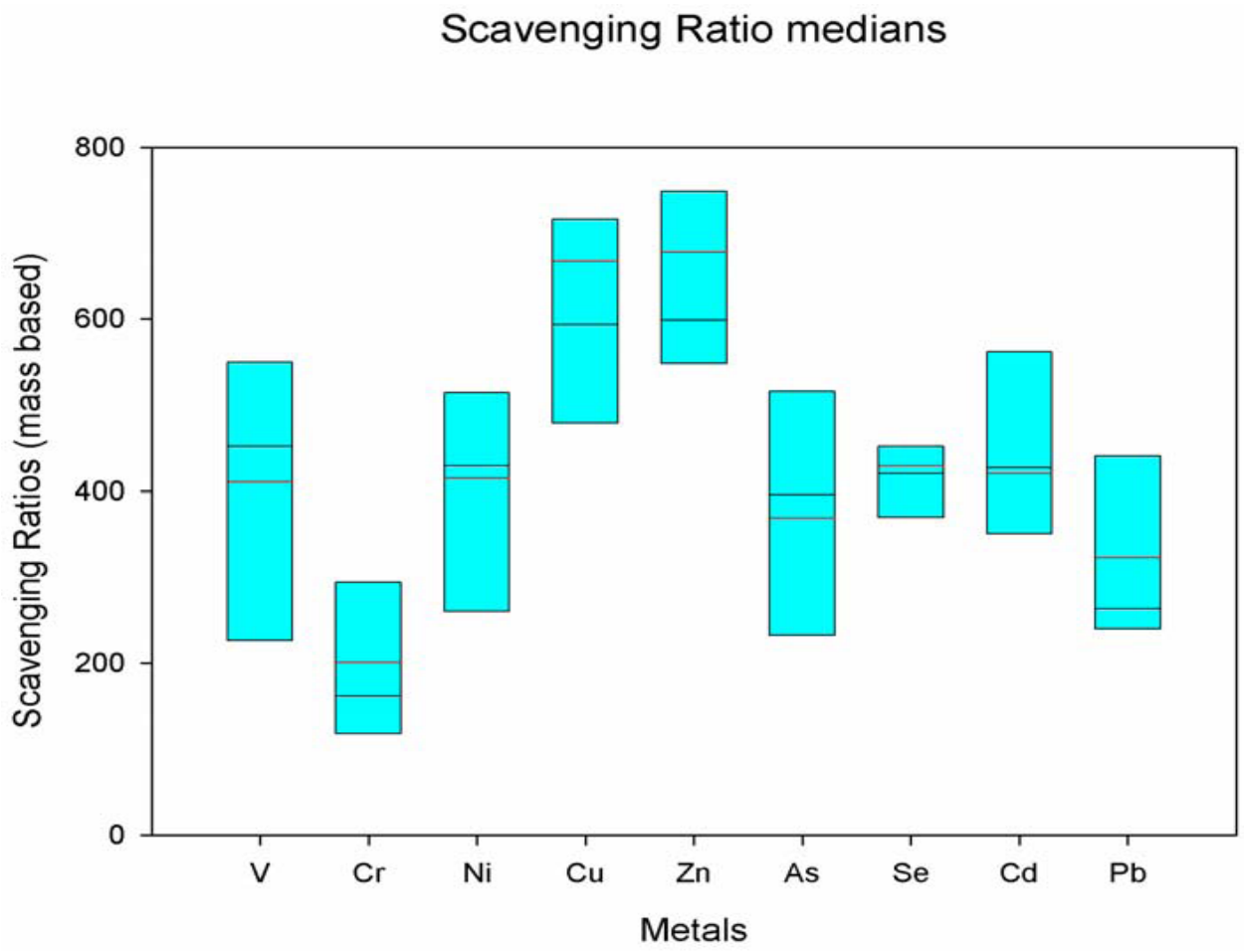


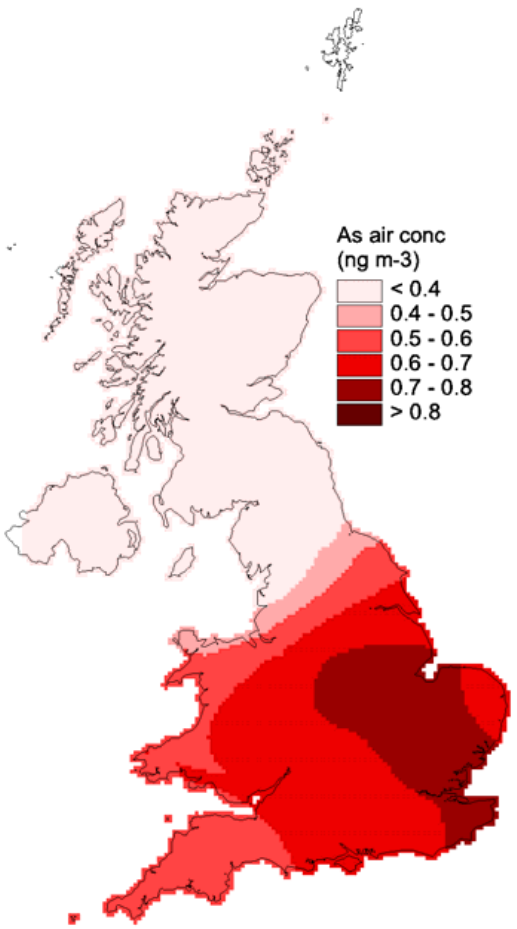
Volume Weighted Average Concentration in Rainfall (**2005**) ug/l									
	V	Cr	Ni	Cu	Zn	As	Se	Cd	Pb
MONKSWOOD	0.43	0.12	0.51	1.08	9.59	0.23	0.18	0.06	1.15
COCKLEY BECK	0.32	0.05	0.22	0.37	3.14	0.09	0.17	0.06	0.60
AUCHENCORTH	0.27	0.07	0.34	0.48	6.23	0.12	0.17	0.04	0.51
BANCHORY	0.26	0.06	0.23	0.33	4.24	0.08	0.14	0.03	0.45
YARNER WOOD	0.68	0.07	0.42	0.42	4.95	0.10	0.21	0.04	0.73
WYTHAM WOOD	0.57	0.12	0.33	1.24	8.64	0.18	0.16	0.04	1.59
CWMYSTWYTH	0.23	0.03	0.12	0.25	2.37	0.10	0.13	0.03	0.34
HEIGHAM HOLMES	0.60	0.09	0.33	0.87	5.85	0.13	0.21	0.04	1.23
BEACON HILL	0.56	0.16	0.29	1.34	10.20	0.26	0.18	0.03	2.15
DETLING	1.05	0.15	0.47	1.86	10.37	0.23	0.22	0.04	2.17
INVERPOLLY	0.12	0.02	0.19	0.29	1.43	0.06	0.19	0.02	0.07
LOUGH NAVAR	0.12	0.05	0.08	0.20	1.15	0.17	0.20	0.00	0.13
PENALLT	0.36	0.04	0.19	0.65	5.04	0.23	0.10	0.05	0.93
BOWBEAT RAIN	0.29	0.08	0.20	0.42	7.06	0.07	0.18	0.04	0.59
HOLM MOSS RAIN	0.62	0.23	0.33	1.57	12.20	0.54	0.36	0.04	2.27
BOWBEAT CLOUD	1.30	0.24	2.34	2.53	15.76	0.39	1.06	0.15	2.56
HOLM MOSS CLOUD	3.67	0.72	3.18	8.87	44.05	1.16	1.98	0.52	9.72

2005 volume weighted mean rain concentration at each site, filtered to remove outliers + or – 2 x S. Dev.

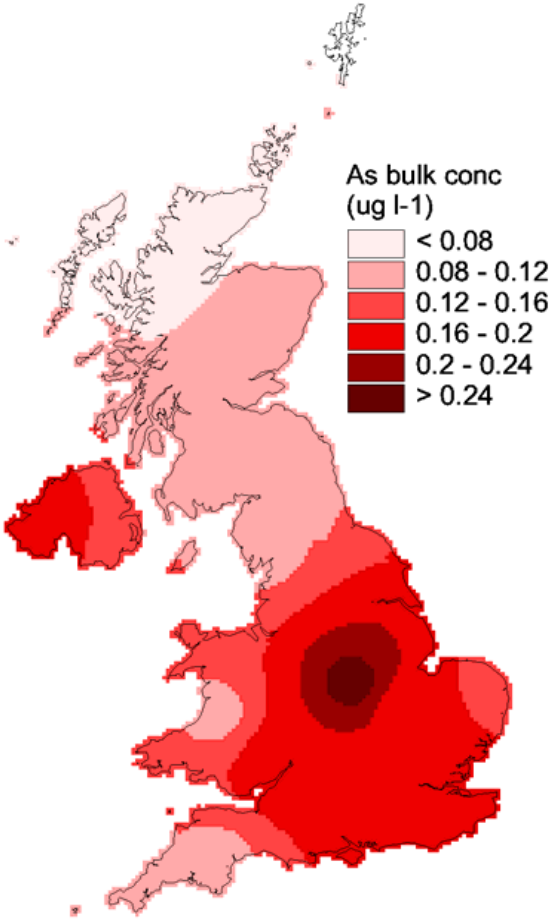


Box plot representing the 5% - 95% range of scavenging ratio medians at each site for each metal. The red line represents the arithmetic mean of values of the medians; the black line represents the median of the medians.

Arsenic (As)

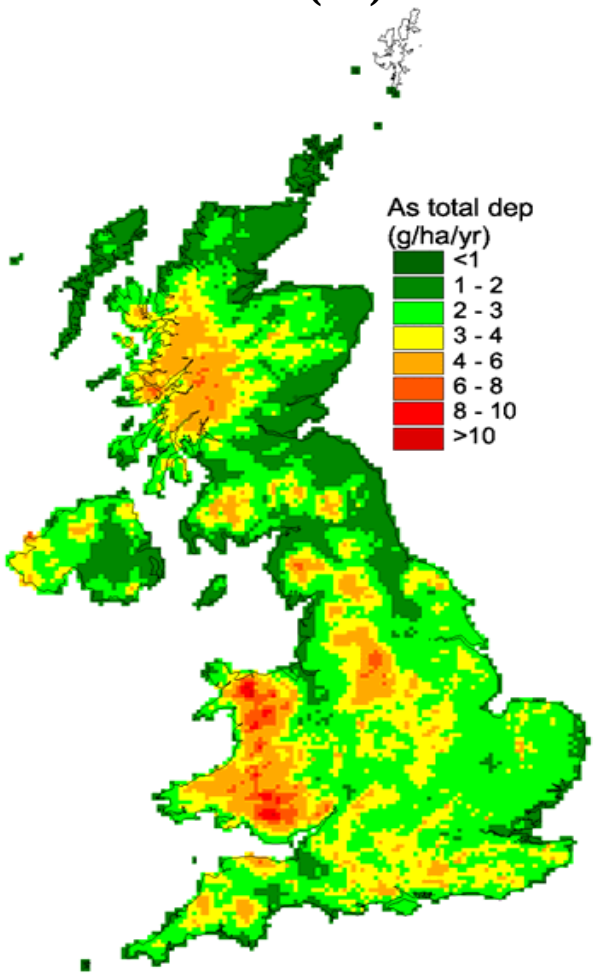


As concentration in air (ng m^{-3})



As concentration in precipitation (ug l^{-1})

Arsenic (As)



As total deposition (g ha^{-1} yr^{-1})

Summary of 2004 UK heavy metal deposition estimates as components of wet, dry and cloud.

tonnes	As	Cd	Cr	Cu	Ni	Pb	Se	V	Zn
Total UK Deposition	75.9	10.3	61.3	324.7	107.5	492.5	84.1	193.5	2277.4
Dry Deposition	23.1 (30.4%)	2.5 (24.8%)	20.2 (32.9%)	95.6 (29.4%)	31.5 (29.3%)	146.2 (29.7%)	13.6 (16.2%)	59.5 (30.8%)	380.3 (16.7%)
Wet Deposition	51.9 (68.4%)	6.6 (73.3%)	40.1 (65.4%)	222.6 (68.6%)	74.3 (69.1%)	338.4 (68.7%)	68.4 (81.3%)	130.7 (67.5%)	1868.4 (82.0%)
Cloud Deposition	0.95 (1.3%)	0.2 (1.9%)	1.1 (1.8%)	6.5 (2.0%)	1.7 (1.6%)	7.9 (1.6%)	2.1 (2.5%)	3.3 (1.7%)	28.7 (1.3%)

(Amount in parenthesis is percentage of total deposition)

A comparison of measured and modelled metal deposition for 2005 in the UK

	As	Cd	Cr	Cu	Ni	Pb	Se	Zn
Emissions [tyr-1]								
NAEI 1998	26.3	8.4	91.6	93.7	243.9	855	54.5	832
NAEI 2005	14.3	3.8	35.9	60.1	87.4	117.7	48.6	460.7
Deposition [tyr-1]								
FRAME 1998	18.3	7.3	40.3	51	157	510	>34.8	726
FRAME 2005	6.9	3.5	22.4	57.4	58.7	85.7	29.6	489.9
Import	2.9	2.2	17.7	31.5	17.5	34.6	18.6	344
Measurements 2005	73.2	10.0	51.7	333.1	155.4	398.0	85.0	2186.8
Measured dep / modelled dep	10.6	2.8	2.28	5.8	2.6	4.64	2.87	4.46

Measured deposition greatly exceeds modelled values

- The measurements are incorrect
  - analysis is generally (+- 10%)
  - dry dep on bulk collector ~(+30%)
  - dep velocities for metals (+- 50-100%)
  - Mapping the wet deposition (+- 20%)

- Collectively these do not generate an order of magnitude difference between the inventory and the measurement (Pb, Zn, Cu, As)

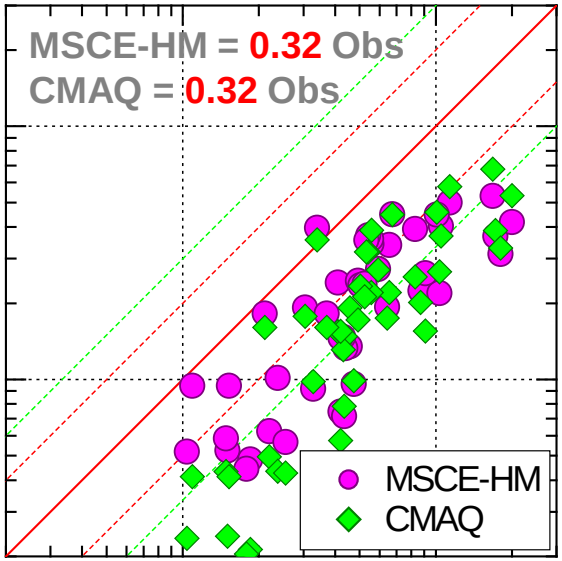
The metal inventories are incorrect

- EMEP (MSC East)conclude that the inventories are deficient for most metals)
- Systematic errors are widespread and there are no validation studies
- The UK is the first country to establish a network of rural stations to quantify dry deposition and wet deposition of metals

Model intercomparison EMEP

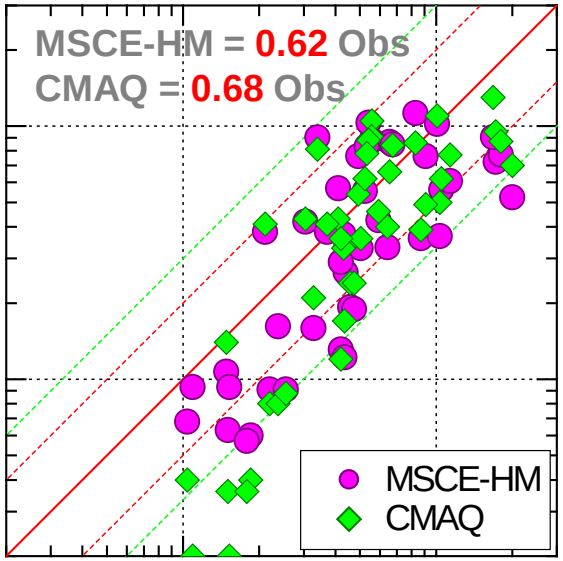
Annual mean Cd concentration in precipitation (2000)

based on official data



70% underestimation

based on ESPREME data



30-40% underestimation

Conclusions

- Total measured deposition of metals in the UK exceeds the modelled deposition by between a factor of 4 and 10 for Pb, Zn, Cu and As due to insufficient emissions in the UK inventory.
- The measured deposition total even exceeds the NAEI inventory emission for most metals (for Pb, Cu, Zn and As by a factor of 4 to 5).
- Inventories of metal emission throughout Europe are too small to reproduce measured deposition.
- Re-suspension of metal containing aerosols by wind and mechanical action (including vehicles) is an important contributor to metal deposition, and not included in the inventory but is most unlikely to be only missing source.

Conclusions

- Inadequate emission inventories currently preclude strategies to progress strategies for control…we do not yet know the main sources