Background air quality network monitoring at high and low temporal resolution: Data uses and future challenges

Braban CF[1], Tang YS[1], Twigg M[1] , Vieno M., Malley C., M Jones[1],, Kentisbeer J[1], Leeson S[1], Langford B[1], Nemitz E[1], Simmons I[1], van Dijk N[1], Coyle M[1], Poskitt J[2], Carter H[2], Thacker S[2], Beith S[2], Keenan PO[2], Pereira G[2] , A Lawlor[2], Warwick A[3], Farrand P[3], Fowler D[1], Smith RJ[1] & Sutton MA[1]

Conolly C[4] , Vincent K[4], Yardley R[4], Donovan B[4], Telling S[4], Lingard J[4], Davies M[4], Bevington T[4], Knight D[4] and Ritchie S[4]

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[2] CEH Lancaster, Lancaster Environment Centre, Bailrigg, Lancaster LA1 4AP
[3]CEH Wallingford, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB
[4] Ricardo Energy and Environment, Harwell Business Centre, Didcot, Oxon OX11 0QJ

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Funded by: Department for Environment Food & Rural Affairs

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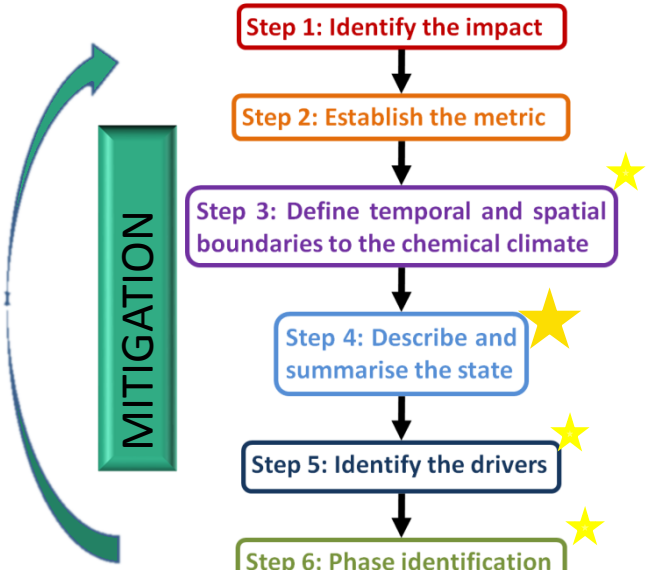
How does monitoring of the rural “background” fit in?



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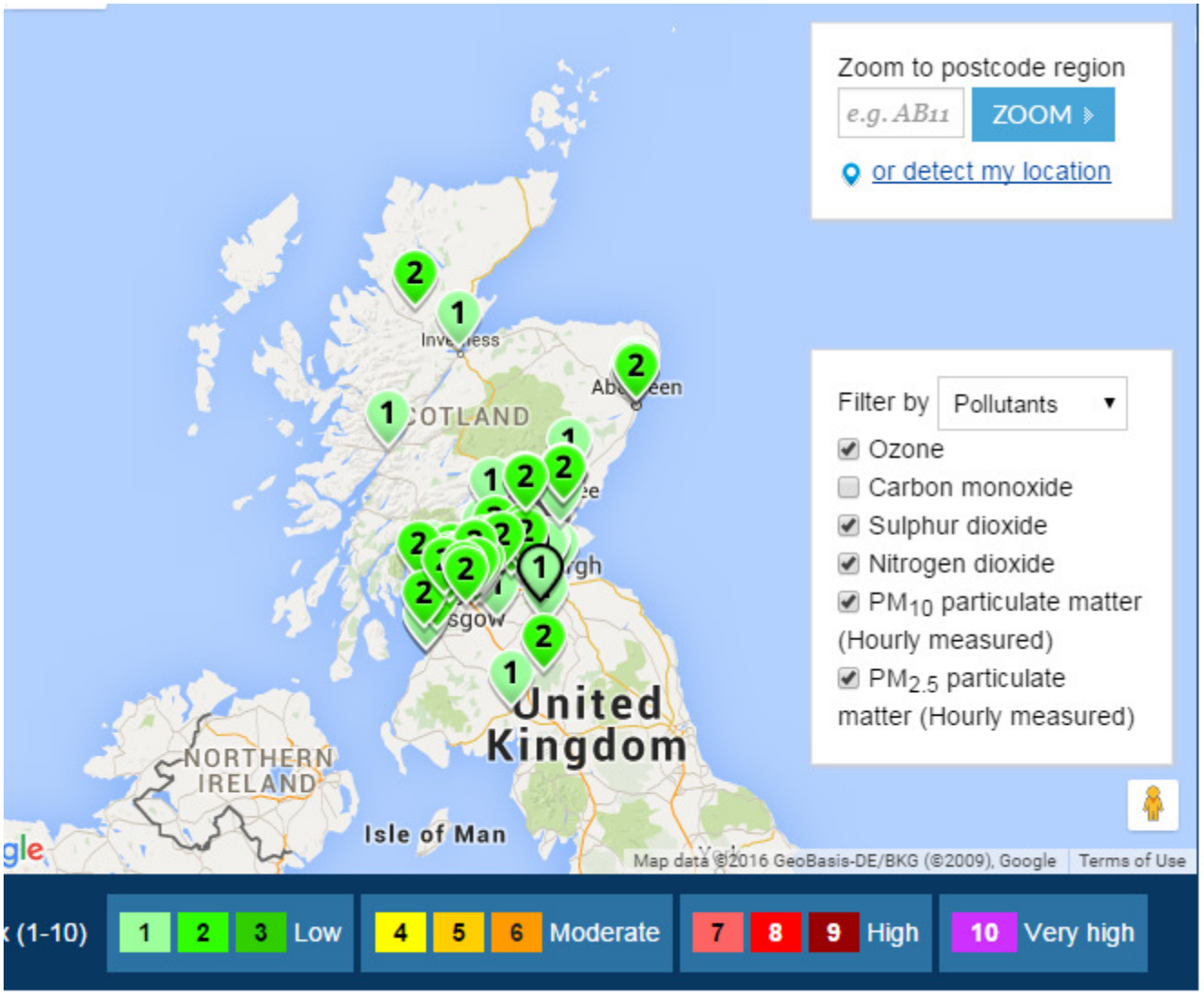
High resolution AQ measurement



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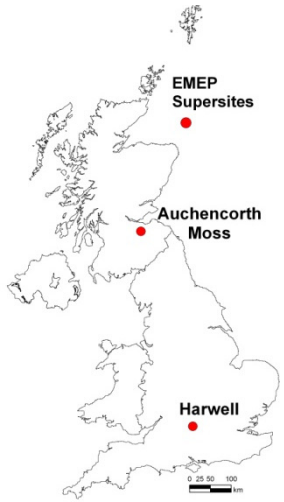
UK EMEP Supersites:



- **UK supersites under the European Monitoring and Evaluation programme (Level II/III)**
  - concentrations, surface/atmosphere exchange fluxes of trace gases and aerosols
  - contribute to all Defra AQ networks.
- Scotland's Auchencorth Moss is a Regional Station within the World Meteorological Organisation's Global Atmosphere Watch programme (WMO-GAW) and is also in greenhouse gas networks

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defra

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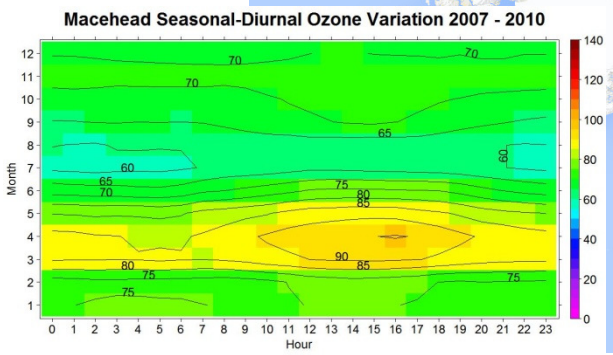
What is a Scottish background in regional context? Ozone

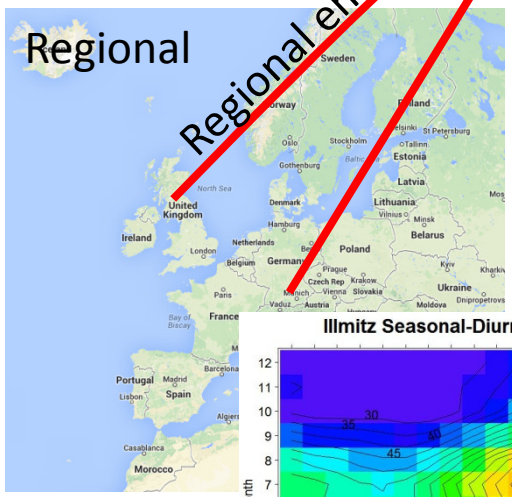
Hemispheric reaction vessel

Hemispheric background concentrations



Regional emissions

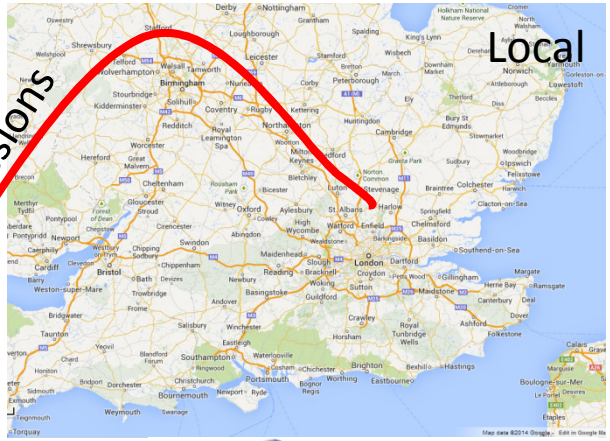
Regional



Regional reaction vessel

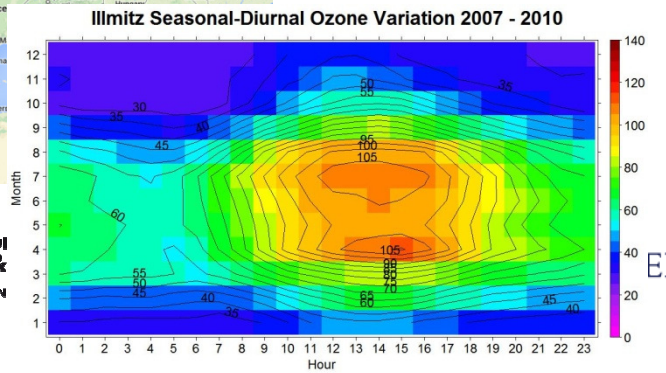
Local emissions

Local



Local reaction vessel

Sample



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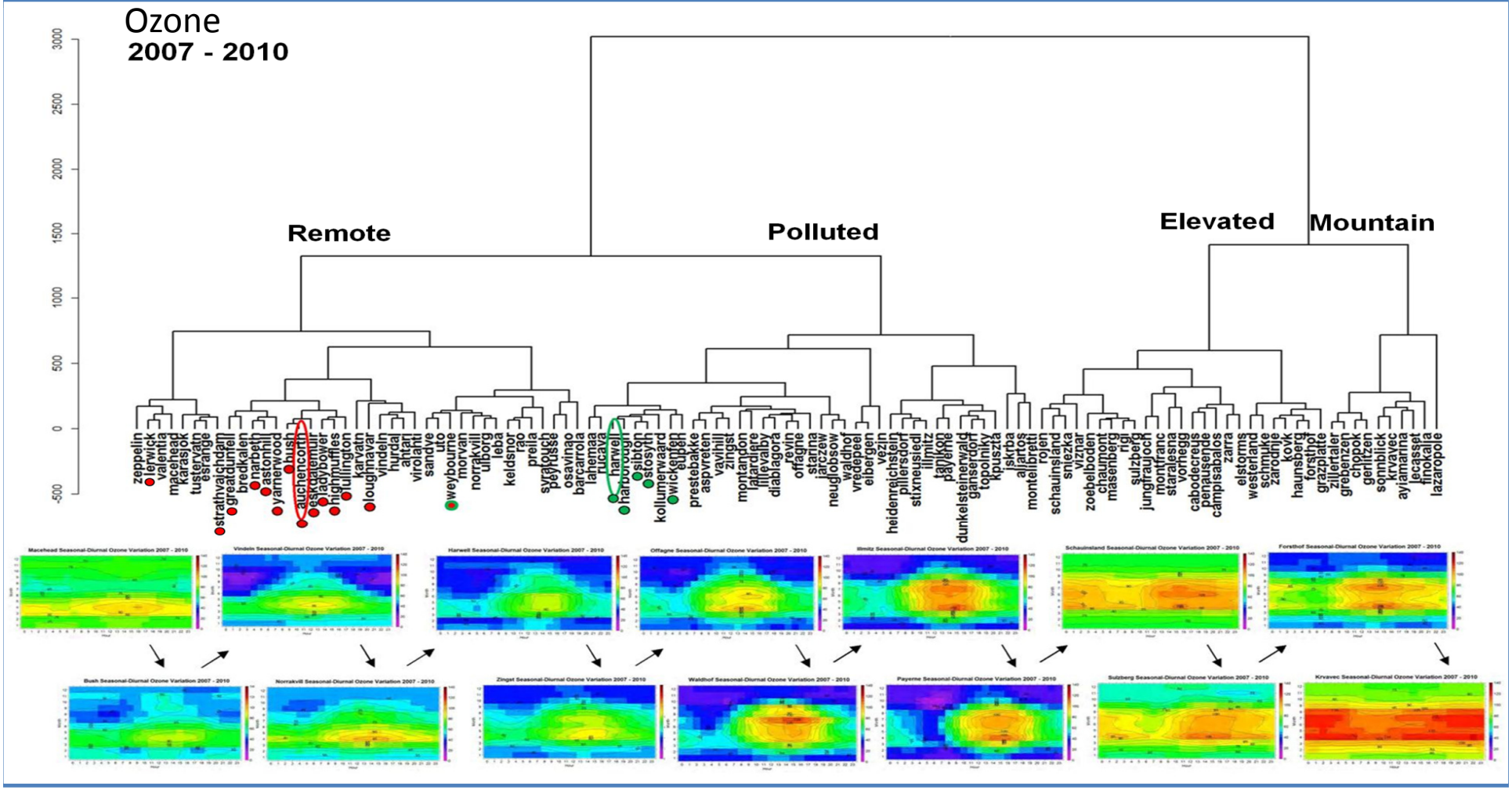
ERSITY of EDINBURGH

What is a Scottish background in regional context?



Scottish background sites cluster with the remote European sites when annual and diurnal cycle of ozone concentrations are analysed.

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Malley, C. S., Braban, C. F., and Heal, M. R.: The application of hierarchical cluster analysis and non-negative matrix factorization to European atmospheric monitoring site classification, Atmospheric Research, 138, 30-40, 2014.

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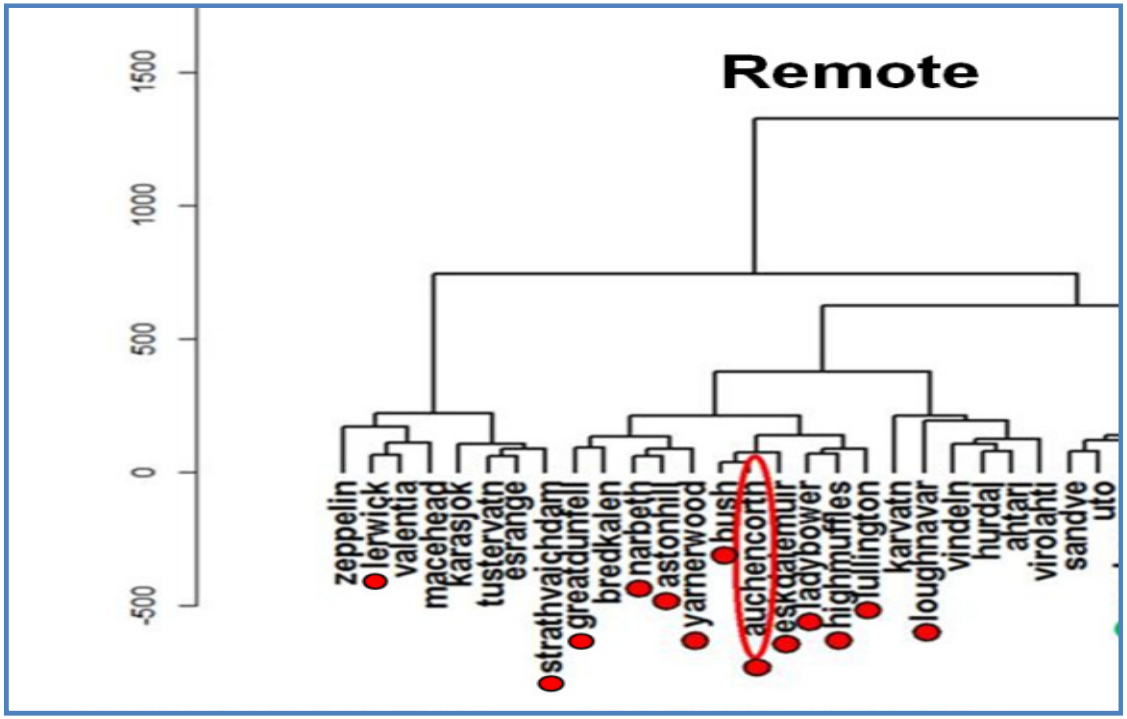

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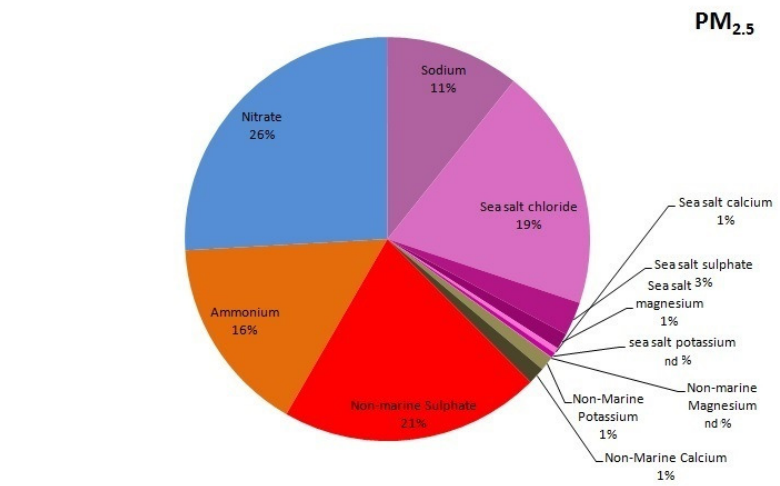
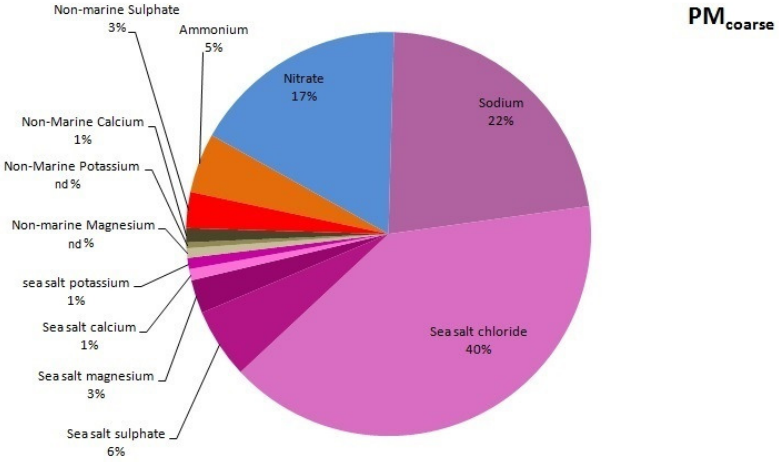
Pollutants measured at UK EMEP Supersites during 2014/15

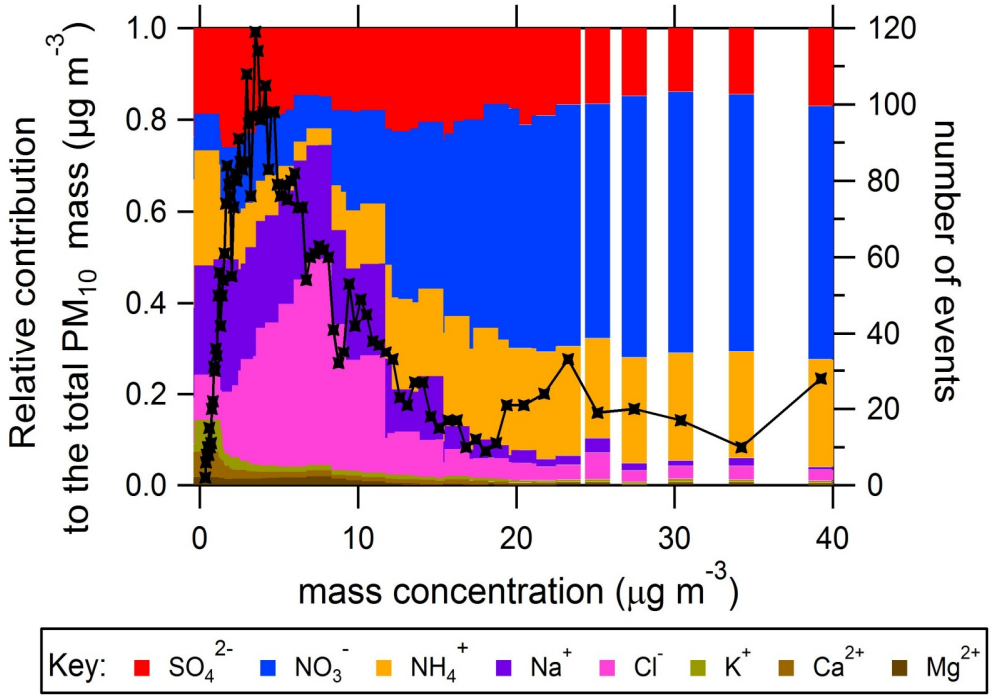
Pollutant	Ha[1]	Au[1]	Level	period	Monitoring network	Contract holder
SO_2, HCl, HNO_3, HONO, NH_3 (MARGA)	X	X	II	Hourly	UKEAP	CEH/Ricardo
$PM_{2.5}$ K^+, Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-} (MARGA)	X	X	II	Hourly	UKEAP	CEH/Ricardo
PM_{10} K^+, Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-} (MARGA)	X	X	II	Hourly	UKEAP	CEH/Ricardo
Elemental mercury	X	X	I	Hourly	UKEAP	CEH/Ricardo
Total gaseous mercury in air	X		II	Hourly	UKEAP	CEH/Ricardo
Meteorological parameters (WS, WD, T, RH, rainfall)	X	X[2]	I	Hourly	UKEAP/CEH	CEH/Ricardo
Precipitation chemistry	X	X	I	Daily	UKEAP	CEH/Ricardo
NO and NO_2 (thermal converter)	X	X	I	Hourly	AURN	Bureau Veritas
Sulphur dioxide	X	X	I	Hourly	AURN	Bureau Veritas
Ozone	X	X	I	Hourly	AURN/CEH	Bureau Veritas
Particulate matter $PM_{2.5,}$ PM_{10}	X	X	I	Hourly	AURN	Bureau Veritas
Particulate matter $PM_{2.5,}$ PM_{10}	X	X	I	Daily	AURN	Bureau Veritas
VOCs in air	X		II	Hourly	Automated HC Netwk	Ricardo
PAH in PM_{10}, air and rain	X	X	I	Monthly	PAH	NPL*
Black carbon	X	X	II	Hourly	Particle numbers/CEH	NPL
Particle counts (>7 nm)	X	X	II	Hourly	Particle numbers/CEH	NPL
Particle size distribution	X	X[2]	II	Hourly	Particle numbers	NPL
PM_{10} carbon-content (EC, OC, total carbon, TC)	X		II	Daily	Particle numbers	NPL
AGANet DELTA sampler PM composition	X	X	I	Monthly	UKEAP	CEH
AGANet Trace gases (HCl, HNO_3, NH_3, and SO_2)	X	X	I	Monthly	UKEAP	CEH
Heavy metals in precipitation	X	X	I	Monthly	Rural metals	CEH
Mercury in precipitation	X	X		Monthly	Rural metals	CEH
Heavy metals in PM_{10}	X	X	II	Weekly	Rural metals	CEH
Persistent Organic Pollutants (POPs) in air	X	X	I	Monthly	TOMPS	U.Lancaster
Trace gas fluxes (O_3, NOx, SO_2)		X	III		NERC NC[2]	CEH
NO and NO_2 (photolytic)		x	I	Hourly	NERC NC[2]	

[1]Ha: Harwell; Au: Auchencorth Moss; [2]NERC CEH National capability funded * NPL: National Physical Laboratory, Teddington, Middlesex.

Supersite Composition of aerosol (MARGA)







Data Use

- Article 6 and Annex IV of Directive 2008/50/EC on Ambient Air Quality and Cleaner Air For Europe
- Met Office, SEPA, Defra,
- Universities, SMES, Consultants
- International research
- PUBLIC DATASET

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Twigg M.M., Di Marco C.F., Leeson S., van Dijk N., Jones M.R., Leith I.D., Morrison E., Coyle M., Proost R., Peeters A.N.M. et al.. 2015. Water soluble aerosols and gases at a UK background site. Part 1: Controls of PM2.5 and PM10 aerosol composition. Atmospheric Chemistry and Physics. 15(14):8131-8145

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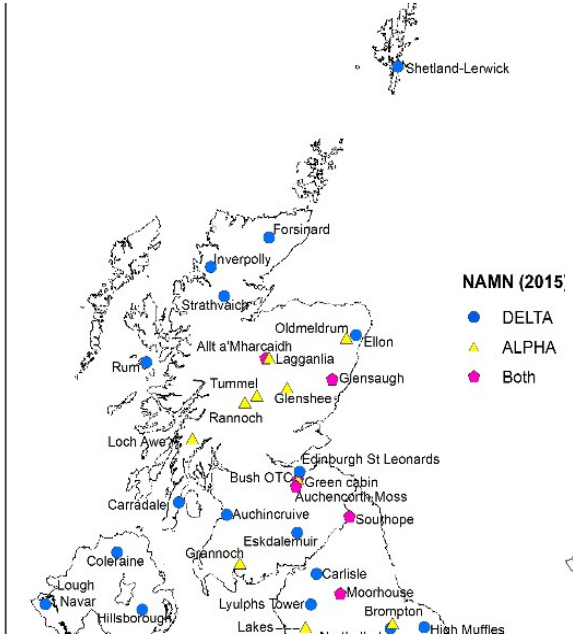
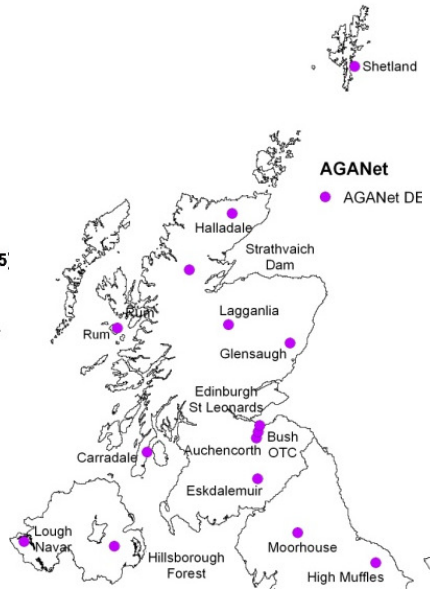
Low temporal resolution AQ measurement
UKEAP component networks in Scotland

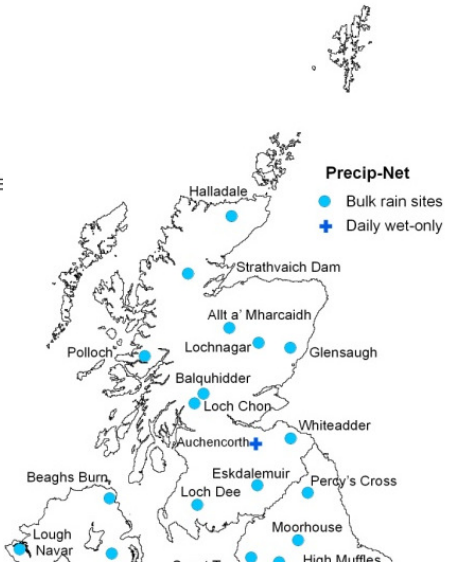
Ammonia
20 sites



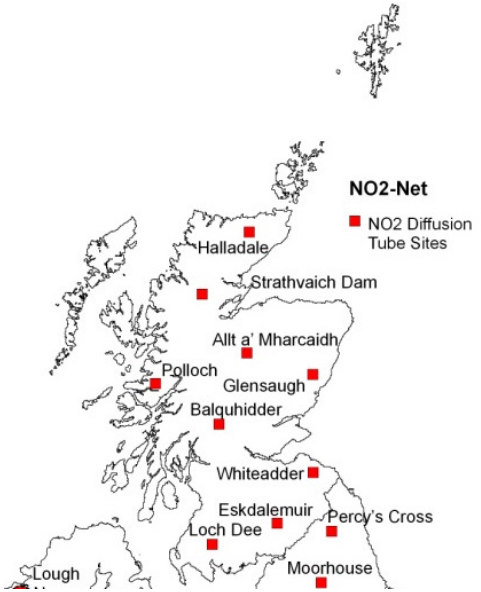
Acid gases & aerosol composition
11 sites



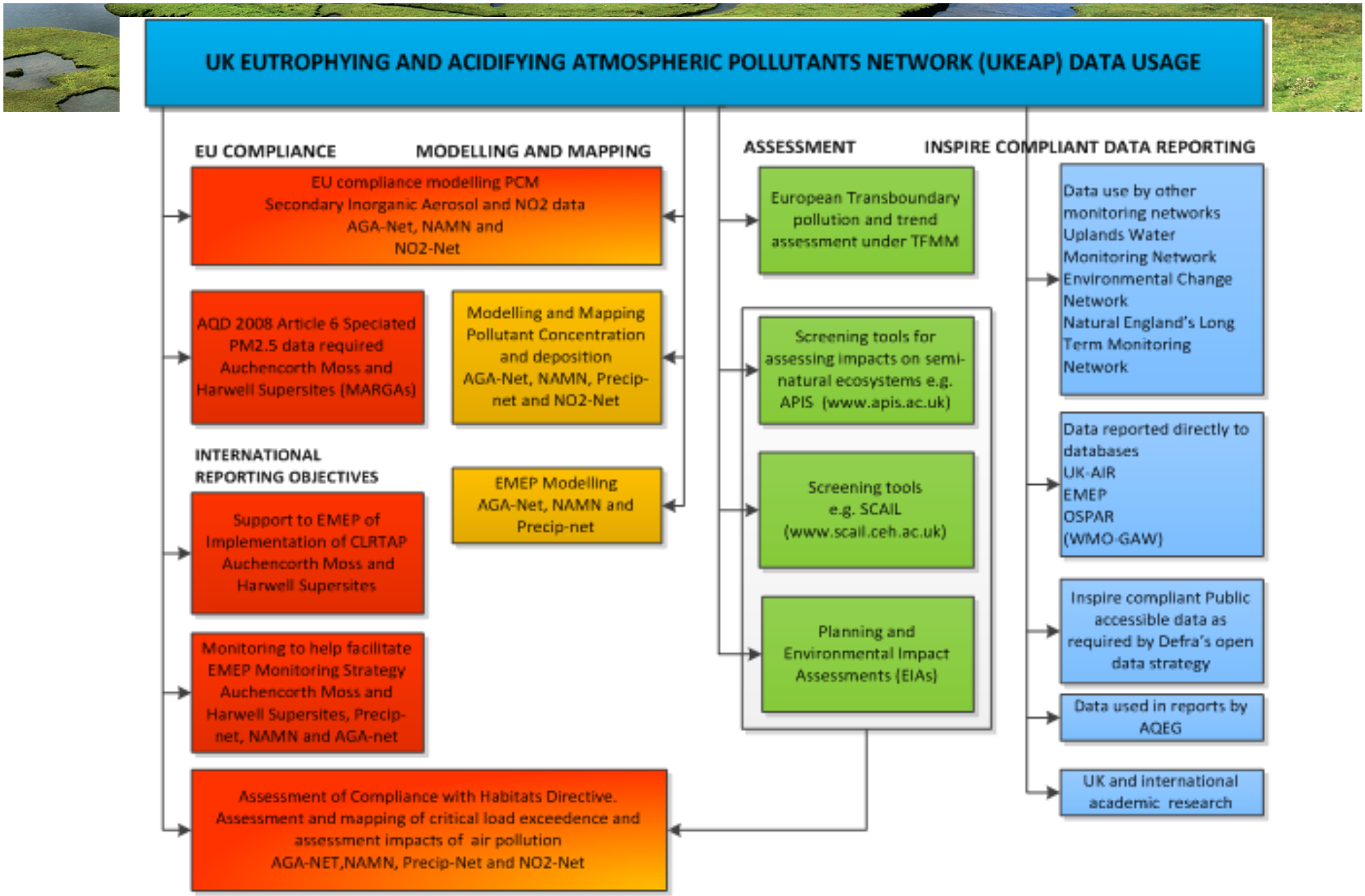
Rain composition
12 sites



NO_2
9 sites



	NAMN	AGANet	Precip-Net	NO_2-Net
Frequency	Monthly	Monthly	2-weekly (daily at 2 sites)	4-weekly
Species	NH_3 NH_4^+	HNO_3, SO_2, HCl, NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}	pH, conductivity, NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+}	NO_2
Inception	1996	1999	1985	1984



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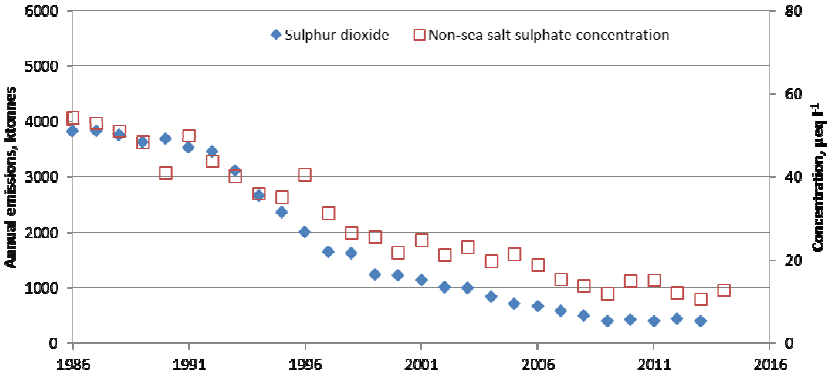
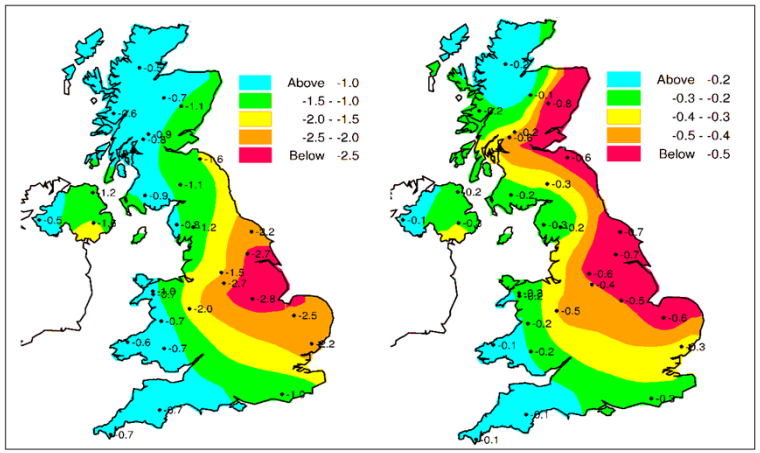
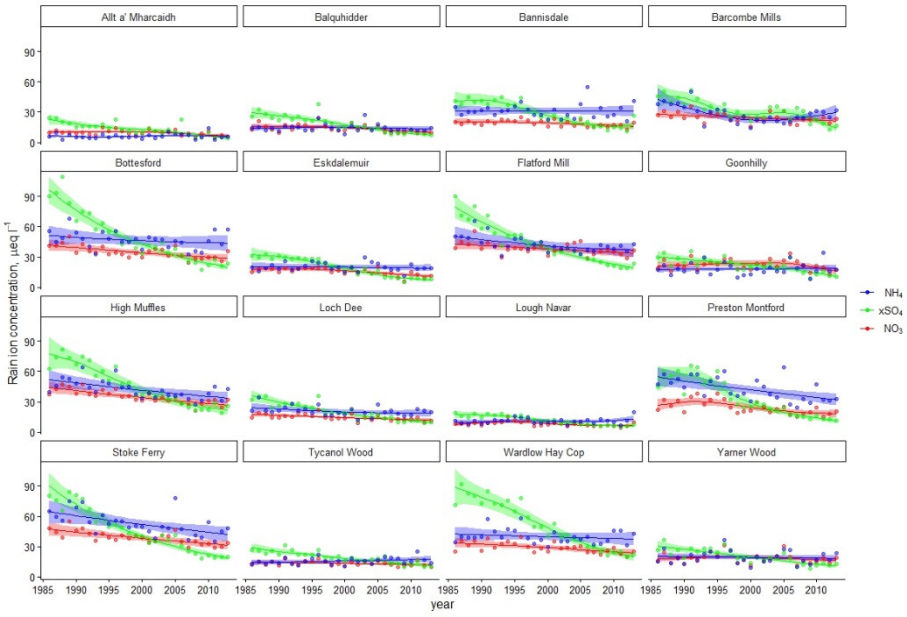
Precip-net composition change

- Rate of nitrate decrease is 5 times lower than sulphate
- Largest decreased observed where coal fired power stations were operating
- Reduction in transport emissions also influencing concentration decreases
- Background concentrations do not show large decreases







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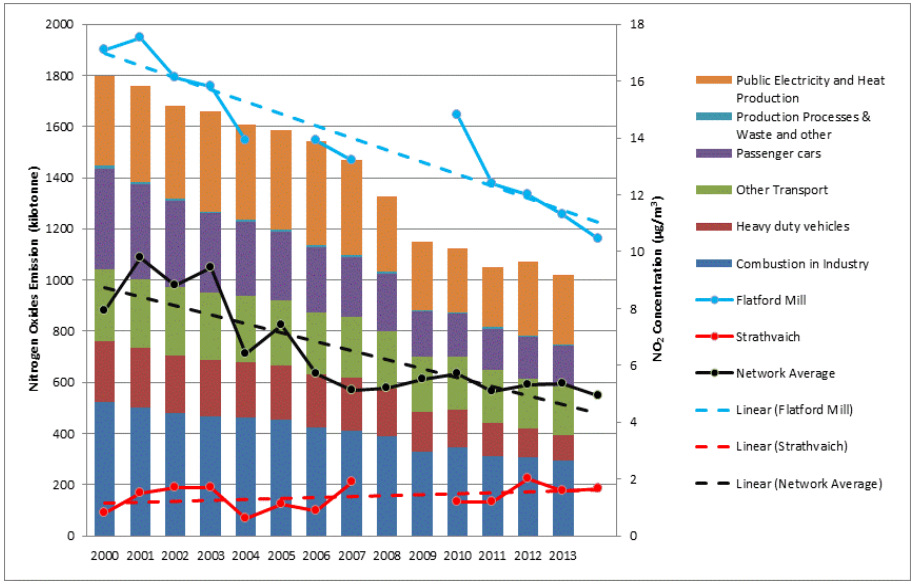
Annual change in non-sea salt sulphate and nitrate concentration (µeq l-1 year-1)

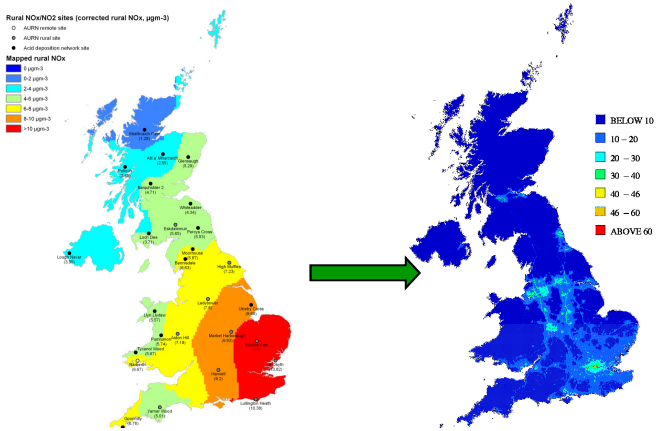
NO2-net

NO2-Net provides input for:

- Defra AQ0650 Modelling Ambient Air Quality (MAAQ)
- Defra AQ0846 Mapping and Modelling of Critical Loads and Levels (CBED, Critical Loads and Levels mapping)
- Assessment of compliance with the Habitats Directive



- **Mean data capture = 97% at sites in 2014**
- **No across-the-board trend observed**
- **Many higher concentration sites seeing reductions as a result of emission reductions**
- **Lower concentration rural sites (e.g. Strathvaich) not seeing same reductions**



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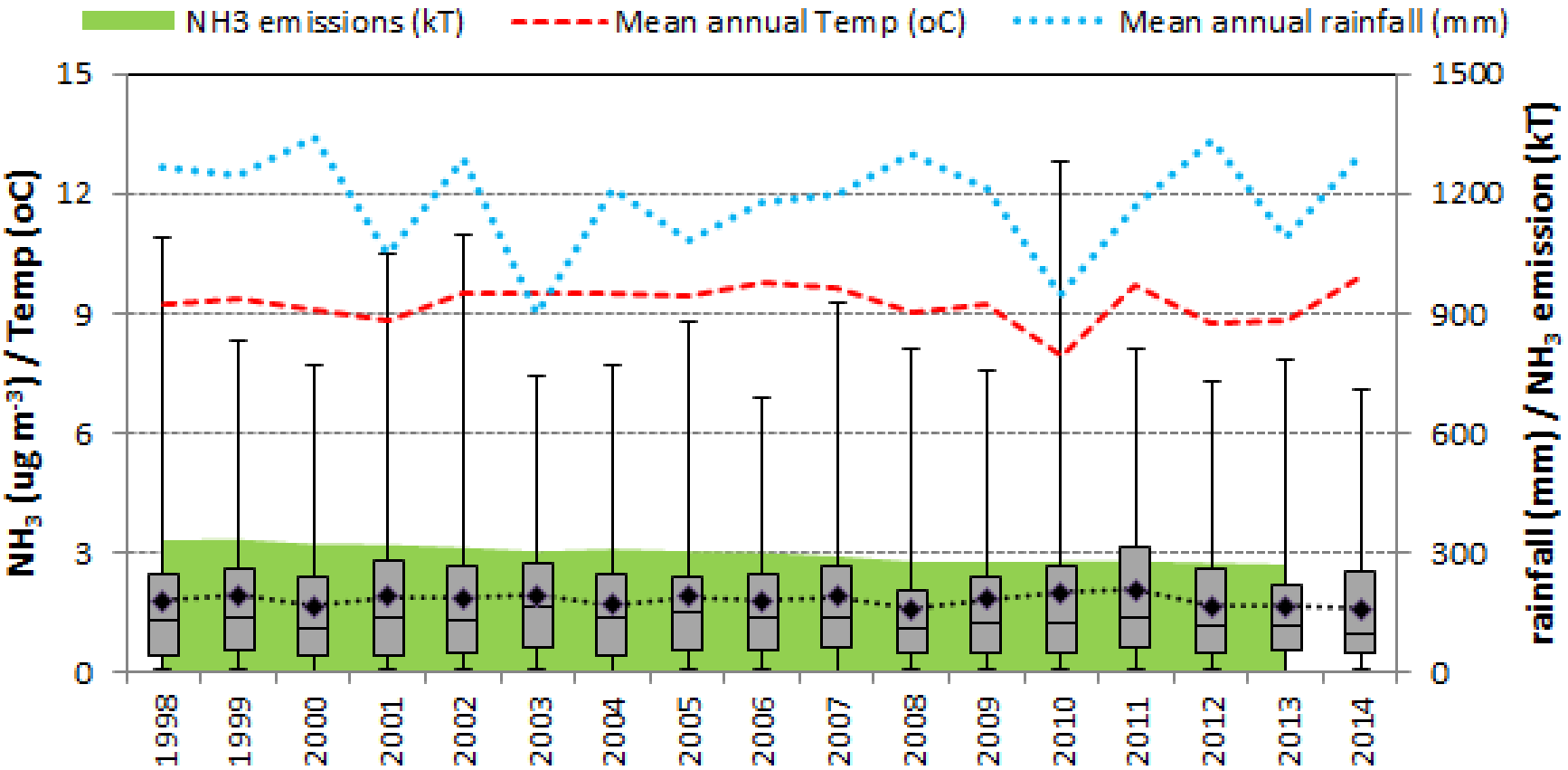
Ammonia: Annual data trends



Changes in atmospheric NH_3 averaged over all sites in NAMN between 1998 and 2014 (N = 75 from year 2000, sites with short runs excluded). UK annual NH_3 emissions (http://naei.defra.gov.uk/) declined by 18 % over this period.

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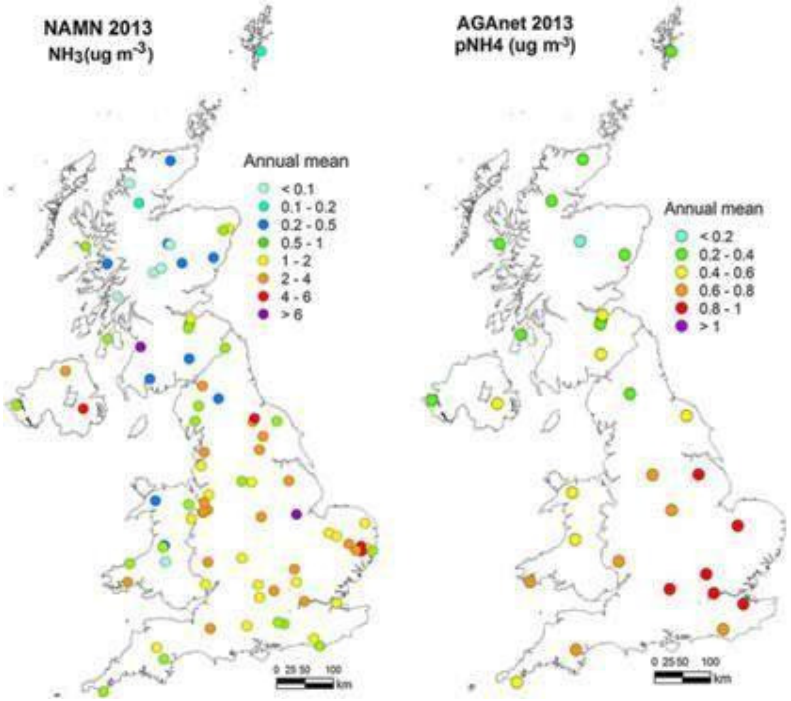
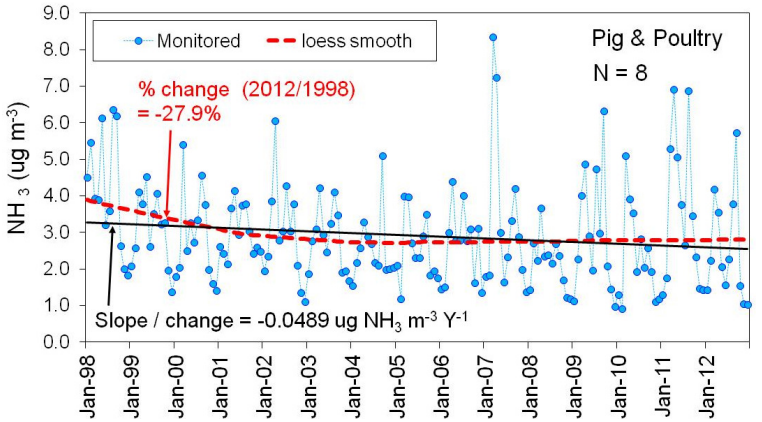
Networks: Defra UK Acidifying and Eutrophying Atmospheric Pollutants (UKEAP)

National Ammonia Monitoring Network

Acid gas and Aerosol Network (AGAnet)

Precipitation network (Precip-Net)





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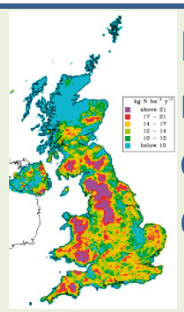
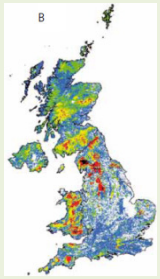
Measurements and models into policy and management

UKEAP monitoring measurements



Modelling and mapping pollutant concentrations and deposition



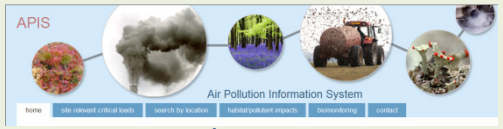
Critical Loads and exceedence mapping

Databases
EMEP
OSPAR
UK-Air

EU compliance modelling (PCM)
Secondary Inorganic Aerosol

National and international assessments atmospheric pollution and deposition to the environment e.g. RoTaP, UNECE

Air pollution information service APIS



http://www.apis.ac.uk/

Site data used by other UK networks:

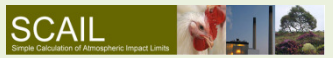
- ECN
- LTMN
-

Public access to data

http://uk-air.defra.gov.uk
http://www.ceh.ac.uk/sci_programmes/UKEAP-Project.html
http://cldm.defra.gov.uk/index.htm
http://uk-air.defra.gov.uk/research/air-quality-modelling

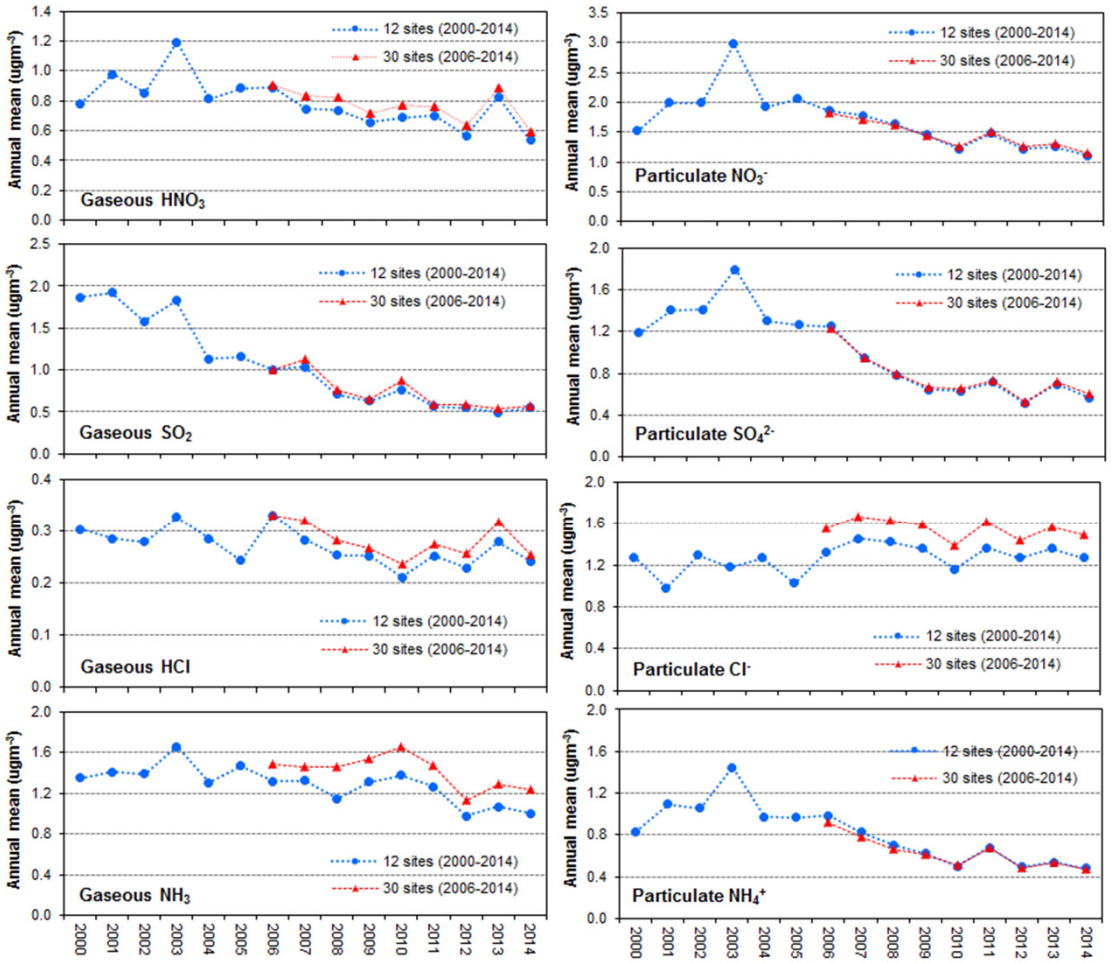
Local Environmental Impact Assessments and planning

Screening tools e.g. SCAIL



http://www..scail.ceh.ac.uk/

Acid gas and aerosol monthly data: evidence for long term changes



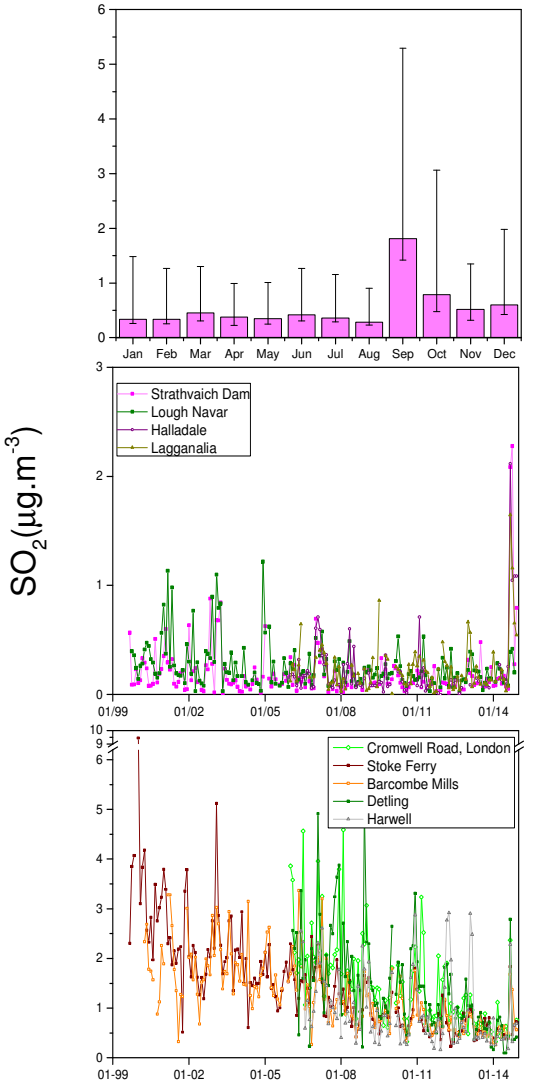


Figure 1: Long-term trend in annual mean concentrations of gases and aerosols monitored in the AGA-Net network. Each data point represents the averaged annual mean from all sites (increased from 12 to 30 sites since Jan 2006) and also the original l2 monitoring sites in the network. NAMN ammonia gas data forAGANet sites are also shown, for comparison.

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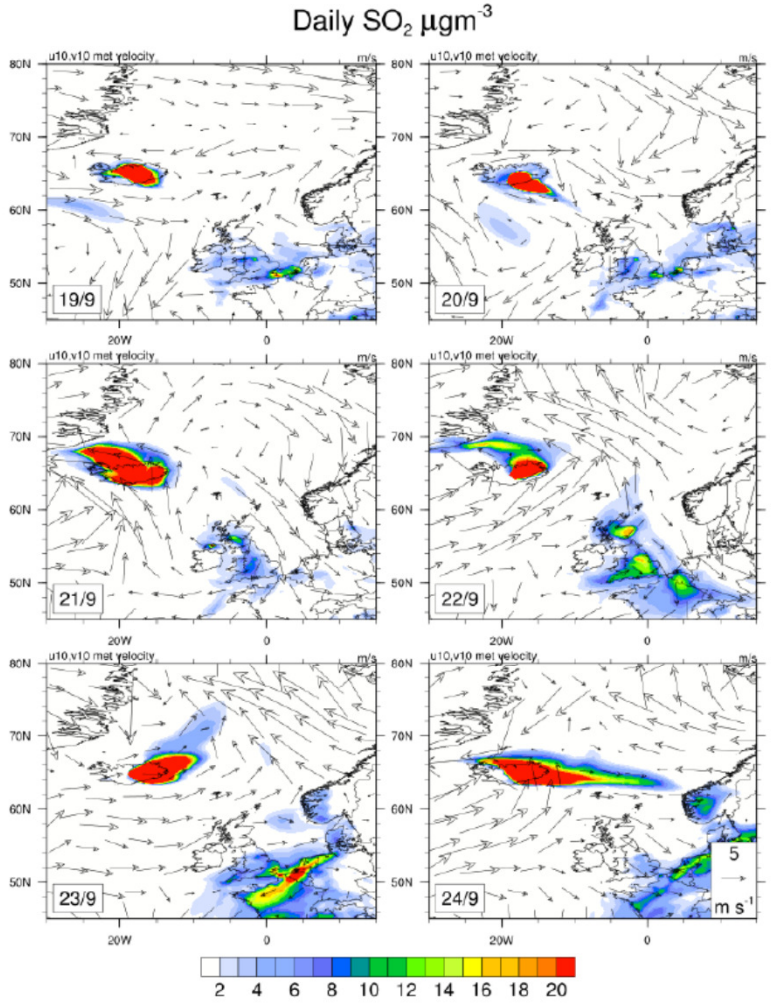
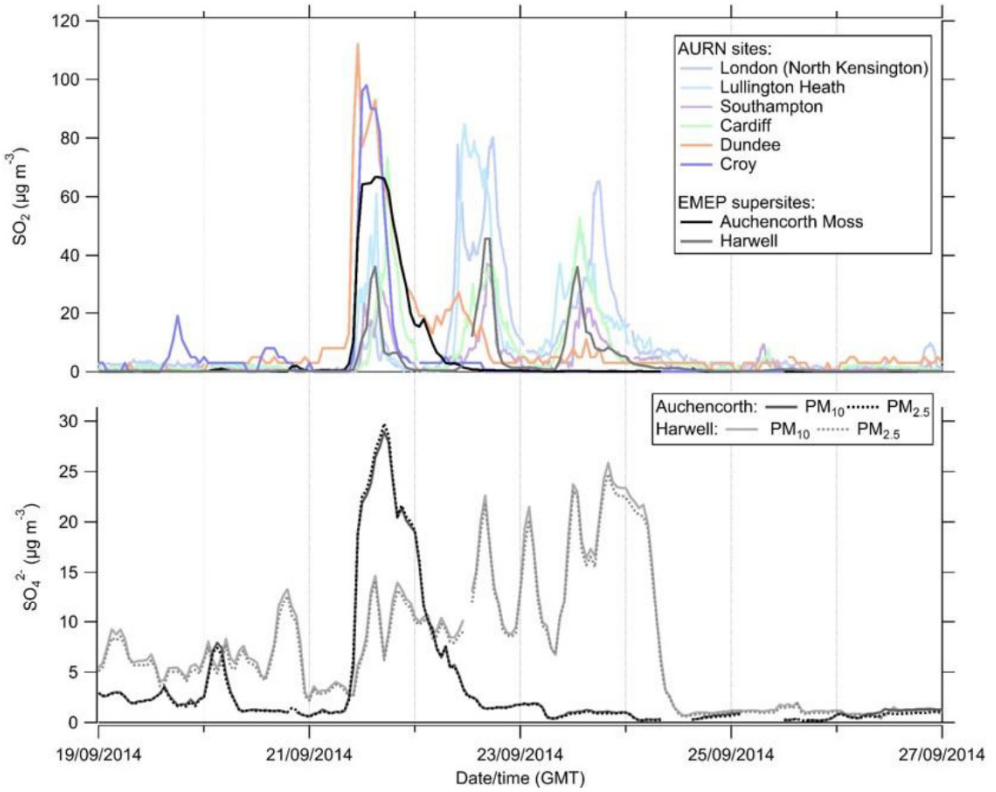
2014 Icelandic volcano eruption





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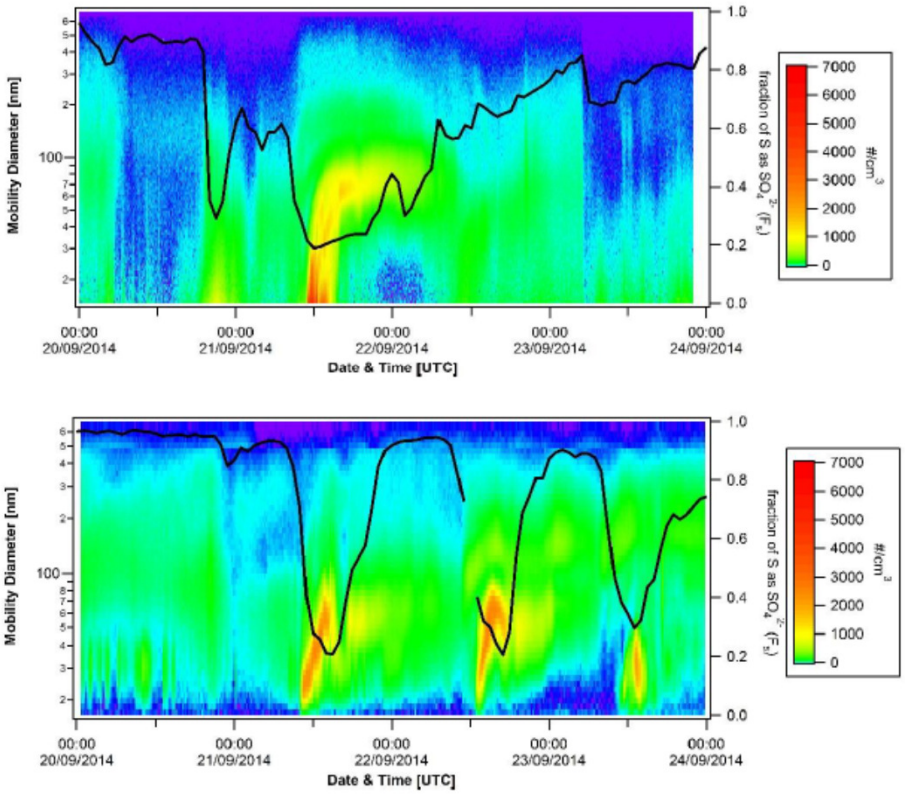
Watching the volcano plume in high resolution



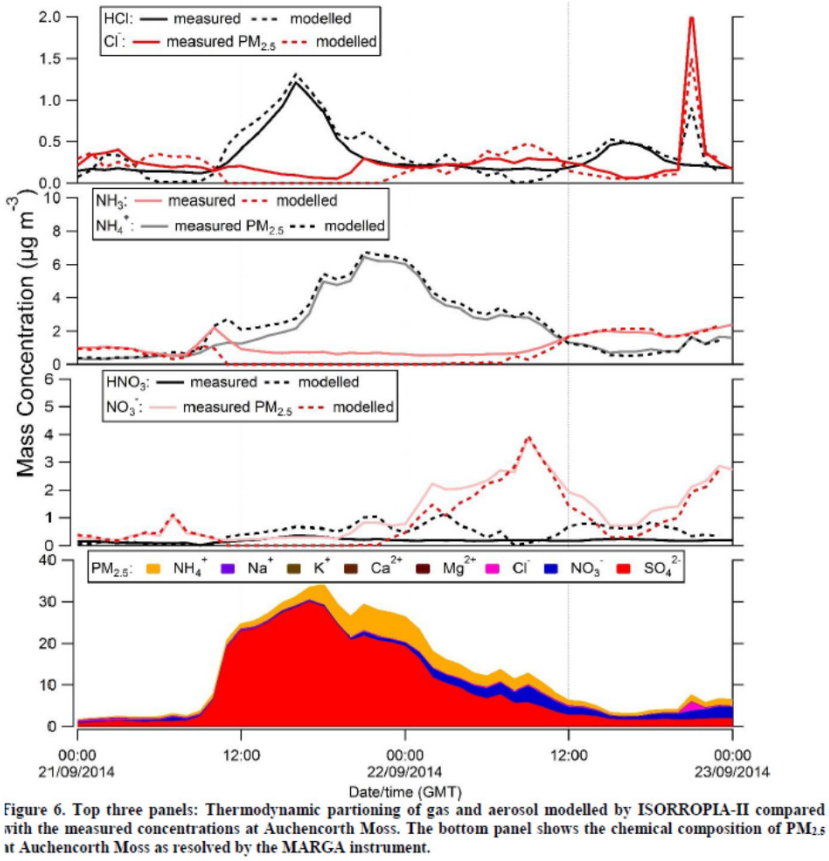


Figure 6. Top three panels: Thermodynamic partioning of gas and aerosol modelled by ISORROPIA-II compared with the measured concentrations at Auchencorth Moss. The bottom panel shows the chemical composition of $PM_{2.5}$ at Auchencorth Moss as resolved by the MARGA instrument.

Particle growth

Acid displacement of HCl by sulfuric acid

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Other applications: particulate matter March/April 2014 episode

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2 April 2014 Last updated at 15:28

Air pollution: High levels to spread across England

The pollution has caused a thick layer of dust to form on cars and buildings, as Pallab Ghosh reports

People with health problems are being warned to avoid strenuous activity after forecasts that air pollution will reach high levels in parts of England.

Defra issued warnings as high pollution levels were recorded on Tuesday.

The pollution - a mix of local and European emissions and dust from the

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London smog warning as Saharan sand sweeps southern England

Strong winds and desert storms deposit fine dust on UK streets amid fears of high air pollution levels in capital

Mark Tran

@marktran

Tuesday 1 April 2014 10.01 BST

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London skyline through fog and haze over the Thames last month: the prime minister's car at Downing Street was covered in a layer of dust overnight. Photograph: Guy Corbishley/ Guy Corbishley/Demotix/Corbis

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Sahara desert dust brings smog to Britain

By ASSOCIATED PRESS

PUBLISHED: 18:22, 2 April 2014 | **UPDATED:** 18:23, 2 April 2014

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LONDON (AP) — European pollution and dust swirling in from the Sahara created a "perfect storm" of smog in Britain on Wednesday, prompting authorities to warn people with heart or lung conditions to cut down on tough physical exercise outdoors.

Air pollution in some areas reached the top rung on its 10-point scale, the environment department said.

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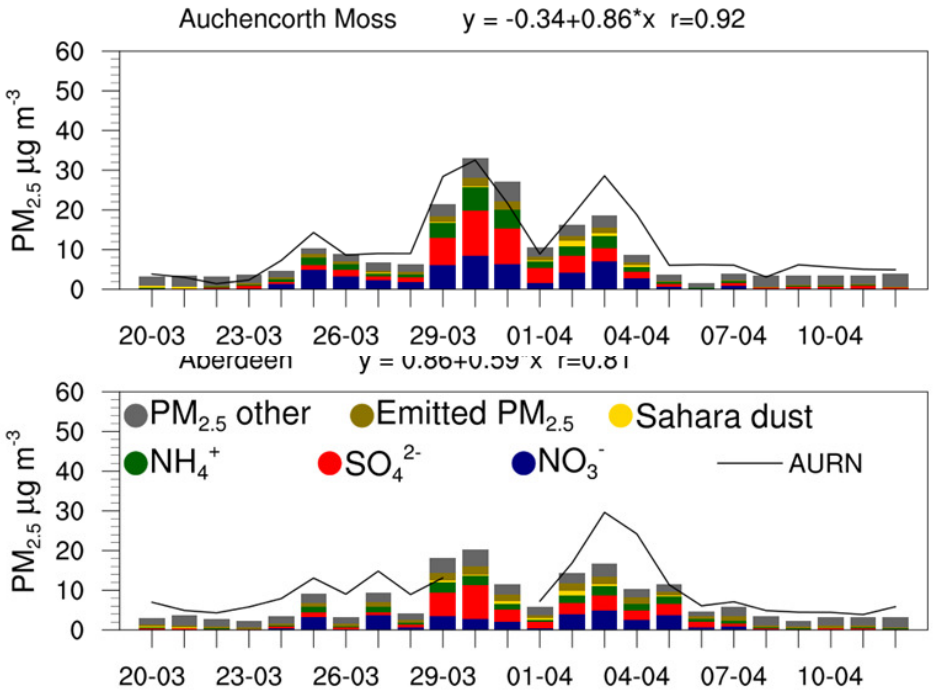
- An air pollution event of elevated particulate matter occurred in the UK between 26 March and 8 April 2014.
- Observations from UK air quality monitoring networks showed markedly elevated PM surface concentrations across the majority of the country during this time.

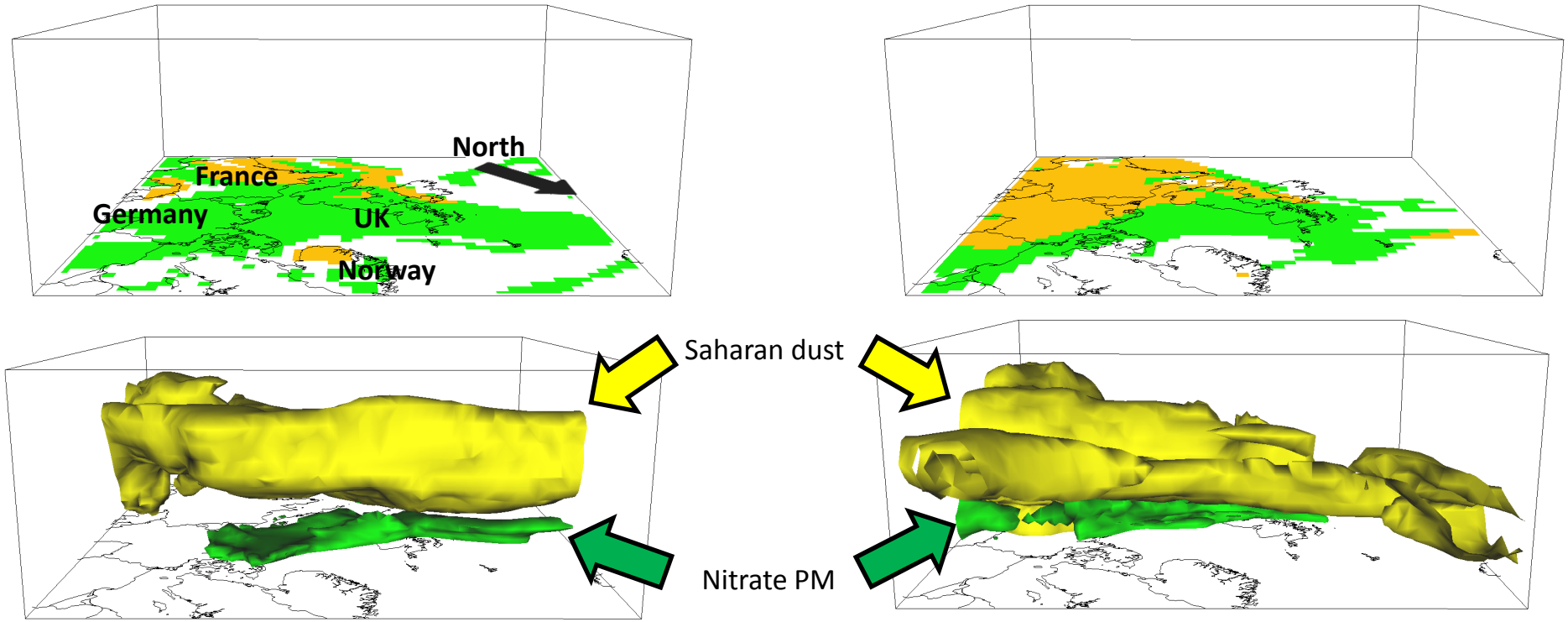


Where is the dust? Cars and other surfaces were covered with dust?!

Yellow Saharan dust (>1 µg m^{-3})
Green Nitrate PM (>1 µg m^{-3})

12:00 on the 30th March 2014

12:00 on the 4th April 2014



3D iso-surface (5 µg m^{-3})

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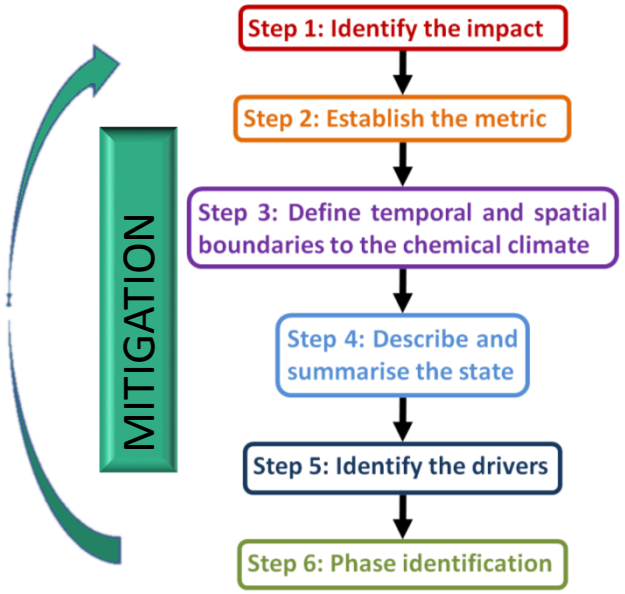
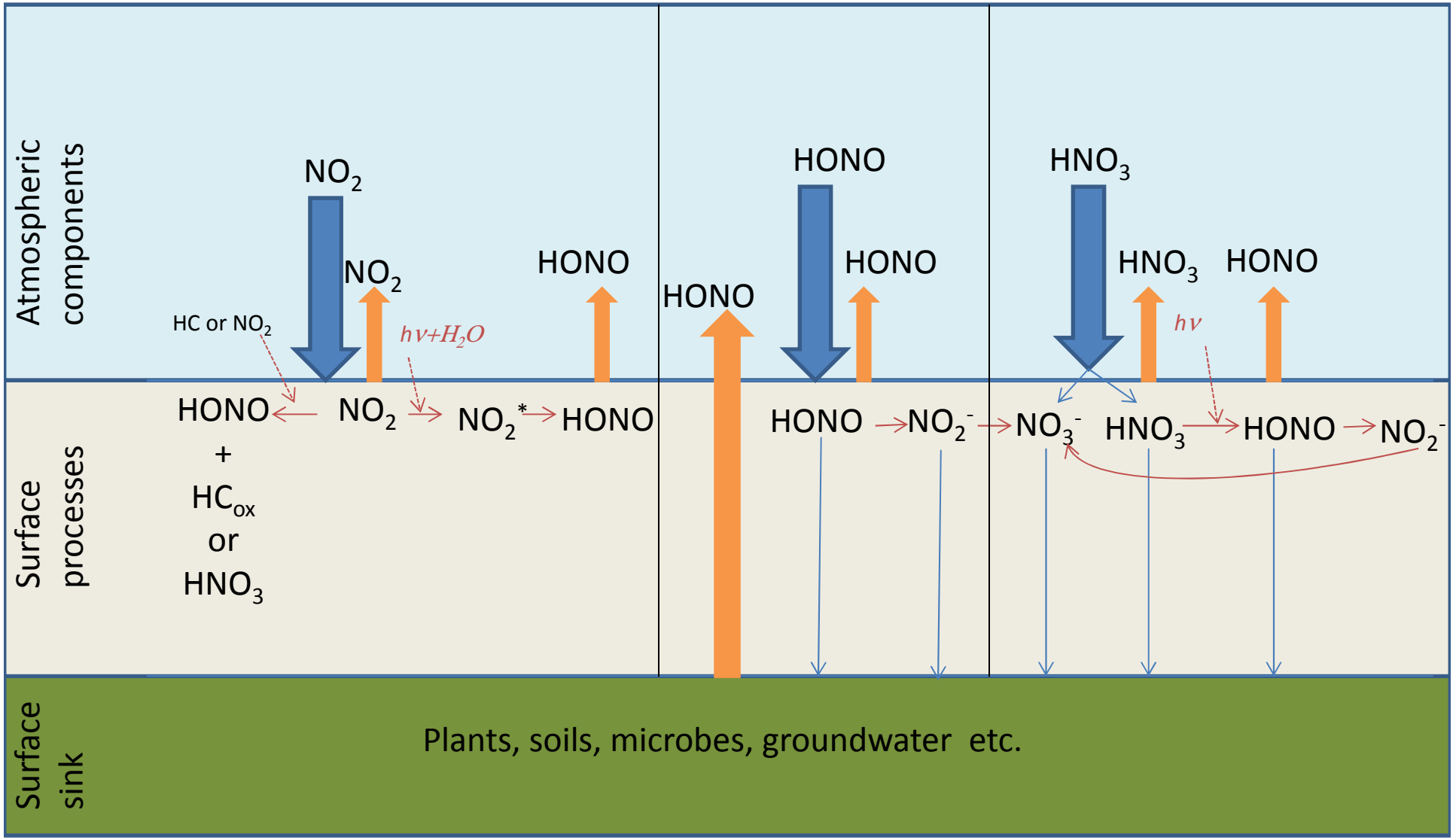
The future for background air quality



- **Identifying impacts:** Are we measuring the correct chemicals with the correct impact metrics?
- **Identifying the state:** gas phase and PM composition – are we measuring all the correct species?
- **The mixture effects:** organic/ inorganic /biological chemicals
- **Mitigation:** background vs local emissions; emission reduction strategies

Underpin science and policy with consistent measurement, integrated across scales

Identifying state and Impacts: oxidised N deposition/emission possibilities



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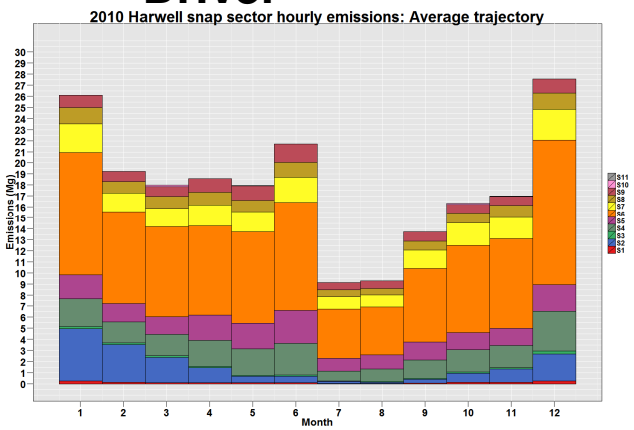
The mixtures: VOCs

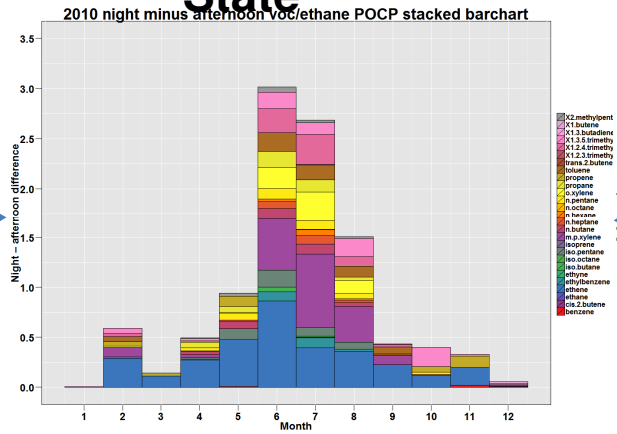
Malley, C. S., Braban, C. F., Dumitrean, P., Cape, J. N. & Heal, M. R. The impact of speciated VOCs on regional ozone increment derived from measurements at the UK EMEP supersites between 1999 and 2012. Atmos. Chem. Phys. (2015).

- Current monitoring allows relationship between VOC cycling and ozone formation to be found.
- Ethene and m+p-xylene show largest photochemical cycling.
- 33 % of UK total emissions emitted as one of 27 measured VOCs.
  - Lots of unmonitored VOCs (ethanol, acetone, methanol) and biogenic VOCs.

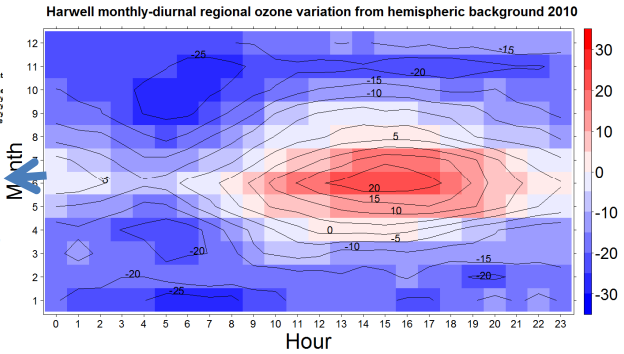
Driver



State



Impact



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THE UNIVERSITY of EDINBURGH

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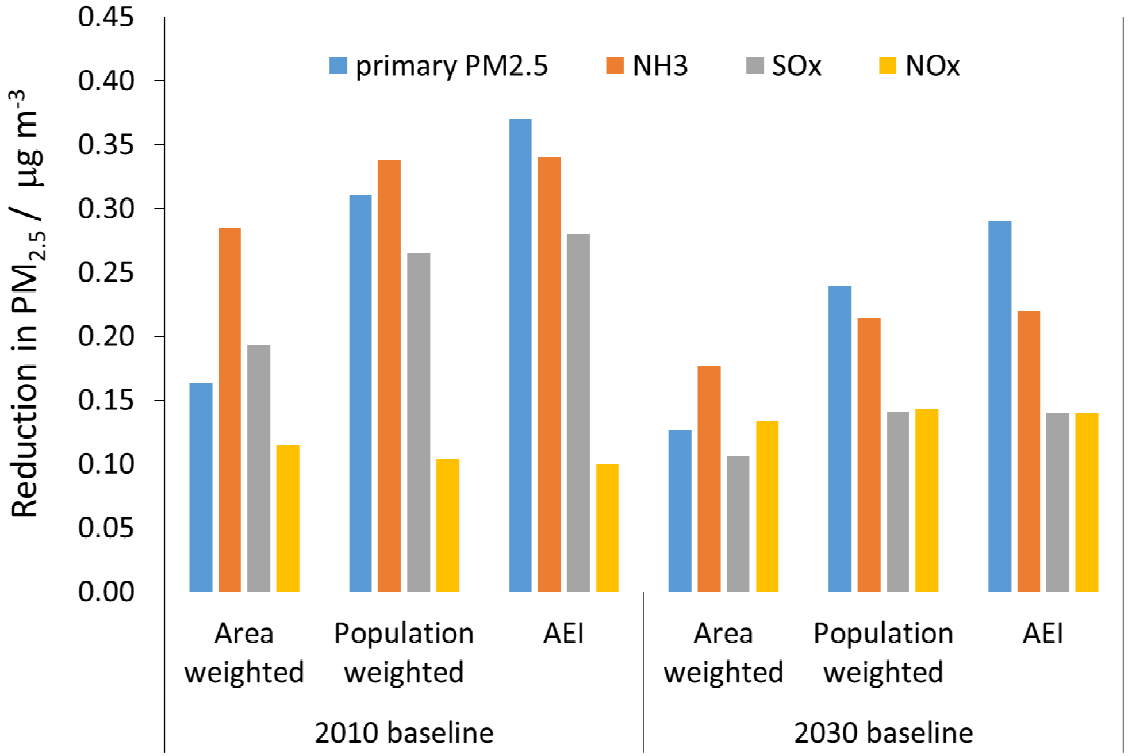
Mitigation: AQEG - PM2.5 analysis

The impact of 30% UK terrestrial emissions reductions in primary $PM_{2.5}$, NH_3, SO_x and NO_x (individually) on total $PM_{2.5}$



Area weighted; population weighted; and the average for the 45 model grids containing the monitors used to calculate the UK PM2.5 Average Exposure Indicator (AEI)

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Vieno et al. Atmos. Chem. Phys., 16, 265–276, 2016
www.atmos-chem-phys.net/16/265/2016/ doi:10.5194/acp-16-265-2016

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Conclusions

- Background air quality at both high and low resolution used to monitor the chemical status across Scotland
- Changes can be observed and publically accessible data can be used to understand the processes
- Future challenges are to understand the complexity of the atmosphere... and whisky:

Acknowledgements:
With thanks to all site operators and field teams across Scotland keeping the measurements going!

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