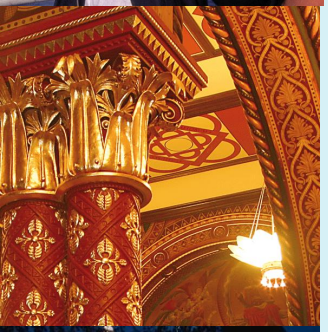
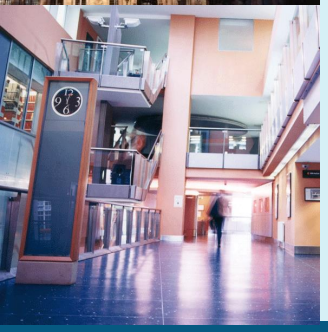




Wood burning PM in the UK

Gary Fuller, Anja Tremper, Timothy Baker- King's College London

(gary.fuller@kcl.ac.uk)

Karl Espen Yttri – NILU

David Butterfield - NPL

Contents

Background

Assessments using two methods

- **Levoglucosan**
- **Aethalometer**

Results from two studies

- **London in winter 2010**
- **Mainland UK 2009 to 2011**

Conclusions

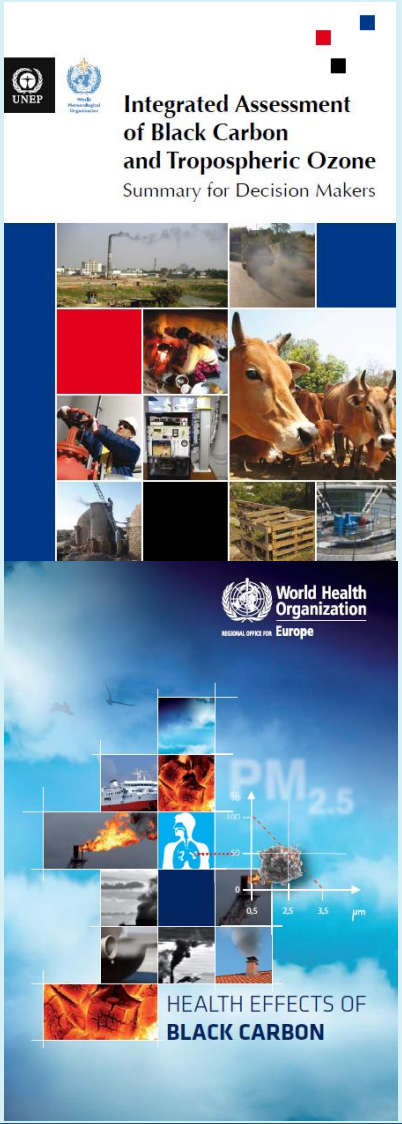
Footnote (If there's time) – results from a quick home experiment

Why are we concerned about black carbon and PM from wood burning?

Background – black carbon

Black carbon is a short-term climate forcer as highlighted by recent UNEP assessment (UNEP, 2011; Shindell et al 2012; Shine et al 2007).

Black carbon has been shown to be a better predictor of short-term air pollution health effects than PM mass metrics (Janssen et al 2011; 2012 - for WHO)



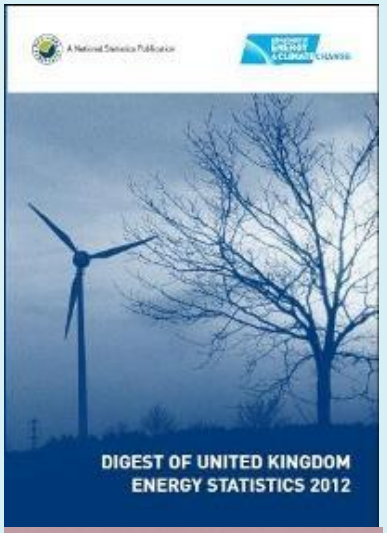
Background – wood burning

European energy projections also point to 50 - > 100% increase in biomass energy from 2010 to 2020 (IIASA, 2010)

Current UK wood heating is thought to be small but there has been recent concern over increasing amounts of wood being burnt in existing fire places and future widespread installation and use of biomass boilers.

Assessments in Berlin, Paris and London have shown wood burning to account for 0.8 and 2.3 µg m^{-3} to annual mean PM_{10} and up to 13 µg m^{-3} daily (Fuller et al 2013).

UK Renewable Heat Incentive is likely to be a big driver (700,000 new biomass burners 2010 to 2020 (Klevnäs and Barker 2009) in addition to UK planning guidance for 10% on-site renewable energy in new non-residental buildings (Merton, 2012).



Method 1
Levoglucosan

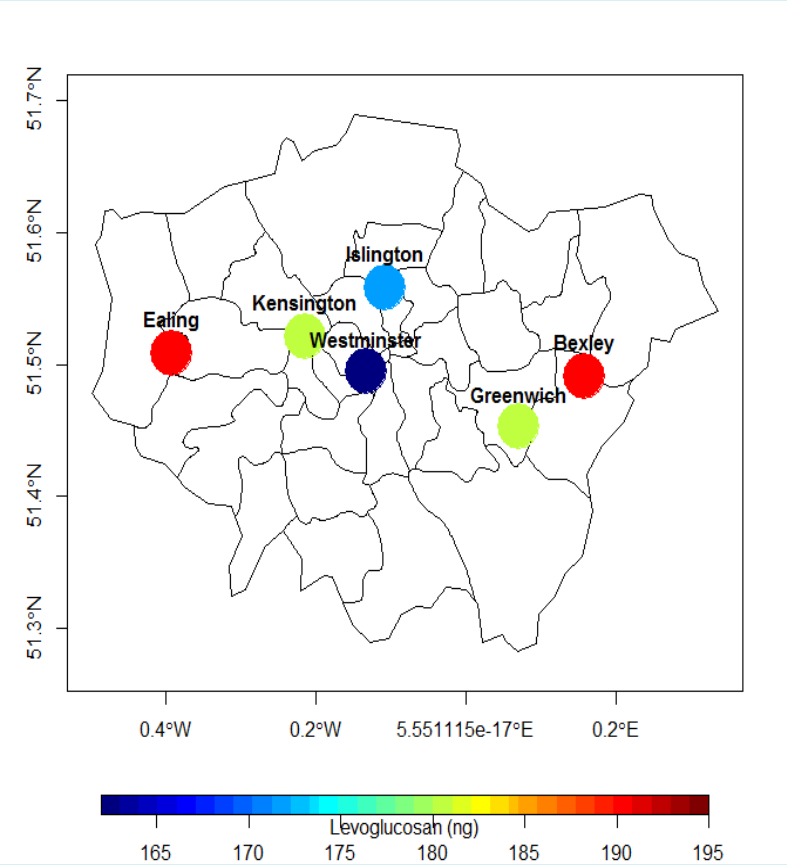
Levoglucosan

Yttri et al. (2005); Simoneit et al., (1999); Fine et al., (2004) and others.

- PM from cellulose (wood and paper) combustion is associated with emissions of levoglucosan (a sugar).
- Emitted in high concentrations and not present in vapour. Can therefore be considered a good tracer for wood combustion PM. (New evidence of OH^- degradation in summer but less so in winter Hennigan et al 2010)
- Emission rates depend on type of wood.

Levoglucosan -partisol sampling

~6 weeks in middle of heating season 2010, 38 km transect



Mean = 176 ng m^{-3} *cf* 15 European studies 60 - 900 ng m^{-3} (Szidat et al 2009)

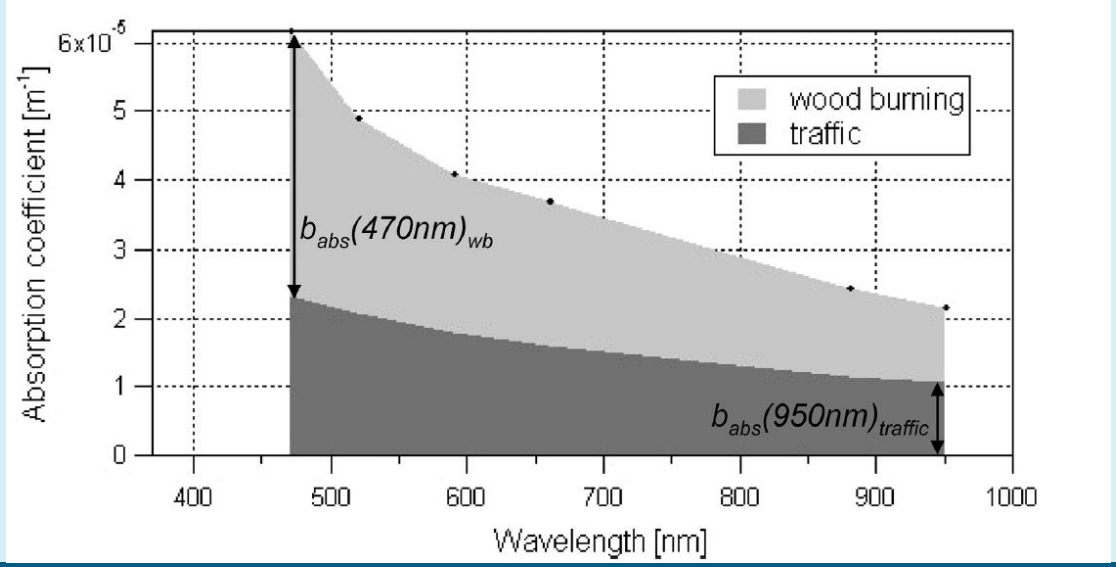
Suburbs minus central = 30±26 ng m^{-3} (k=2, ~2σ) or 19±16% of the inner London concentration.

Similar gradients between suburbs and central city were found in Berlin by Wagener et al 2012.

Method 2
Aethalometer

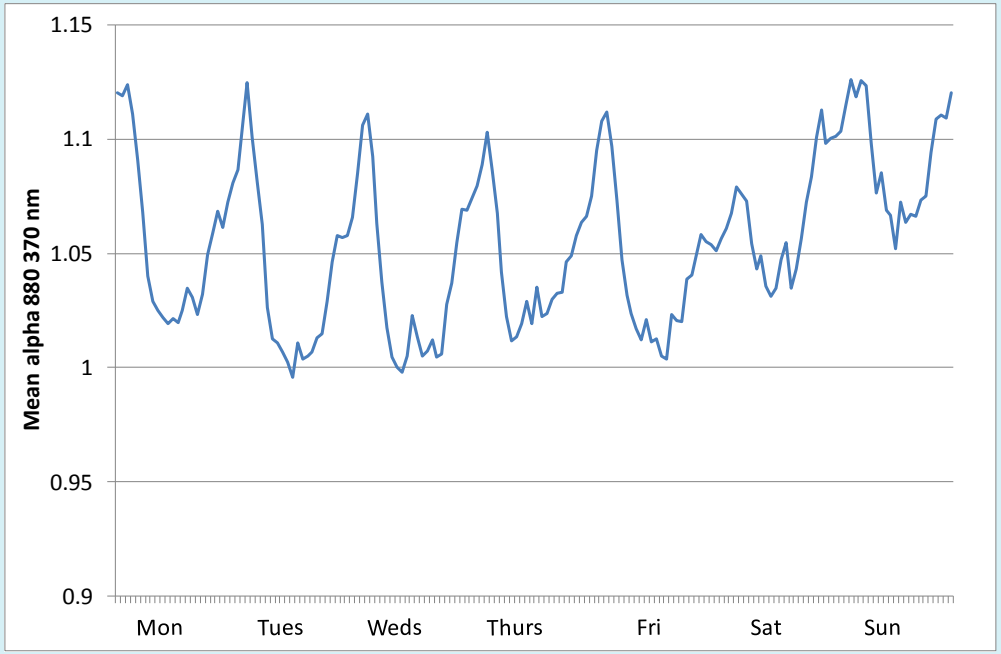
Aethalometer method

- Aethalometers used in UK (two in London, 18 across UK) as part of Defra black smoke network - UV 370nm and IR 880nm wavelengths
- Measure eBC
- Can be used to detect PM from wood smoke (Favez et al., 2009, 2010, Sandradewi et al., 2008a, 2008b, Sciare et al 2011 and others)
- Depends on the assumed α for fossil (traffic) and wood



Determining $\alpha_{traffic}$ and α_{wb}

- $\alpha_{traffic}$ can be obtained from the data used for climate change models assuming it to be similar to black carbon eg Bond and Bergstrom (2006) Aerosol Sci and Tech 40:27–67



- or experimentally at the very busy traffic / roadside canyon site eg Marylebone Road.

- Suggests $\alpha_{traffic}$ ~1.0

Determining $\alpha_{traffic}$ and α_{wb}

- α_{wb} can only be determined experimentally.

- Ambient value of 2.0 suggested from literature (Favez et al., 2009, 2010, Sandradewi et al., 2008a, 2008b, Sciare et al 2011, Kirchstetter et al 2004 and others).

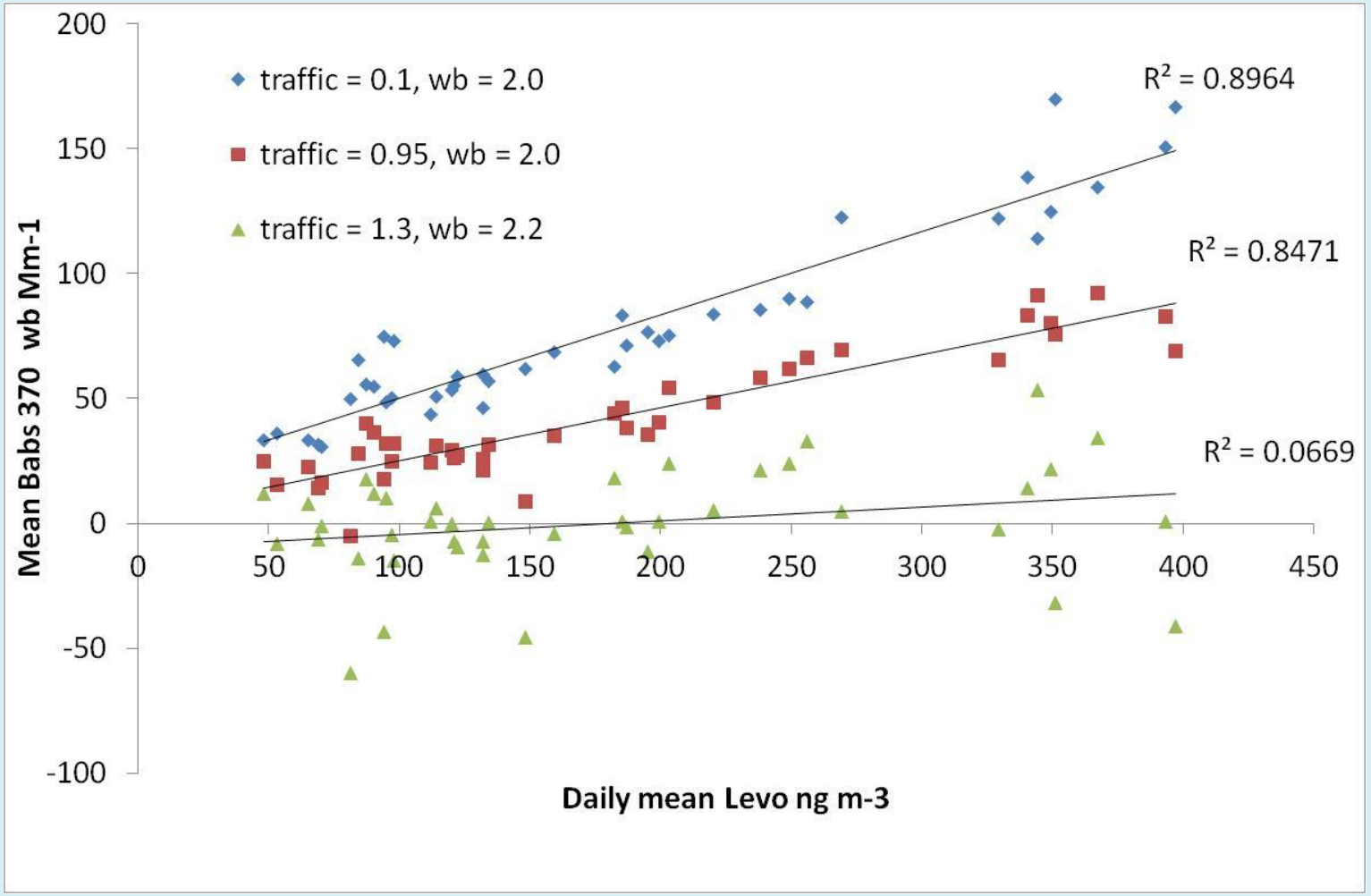
- Is this sensible? – UK α almost never bigger than 2.1 except for a couple of spikes.

Determining $\alpha_{traffic}$ and α_{wb}

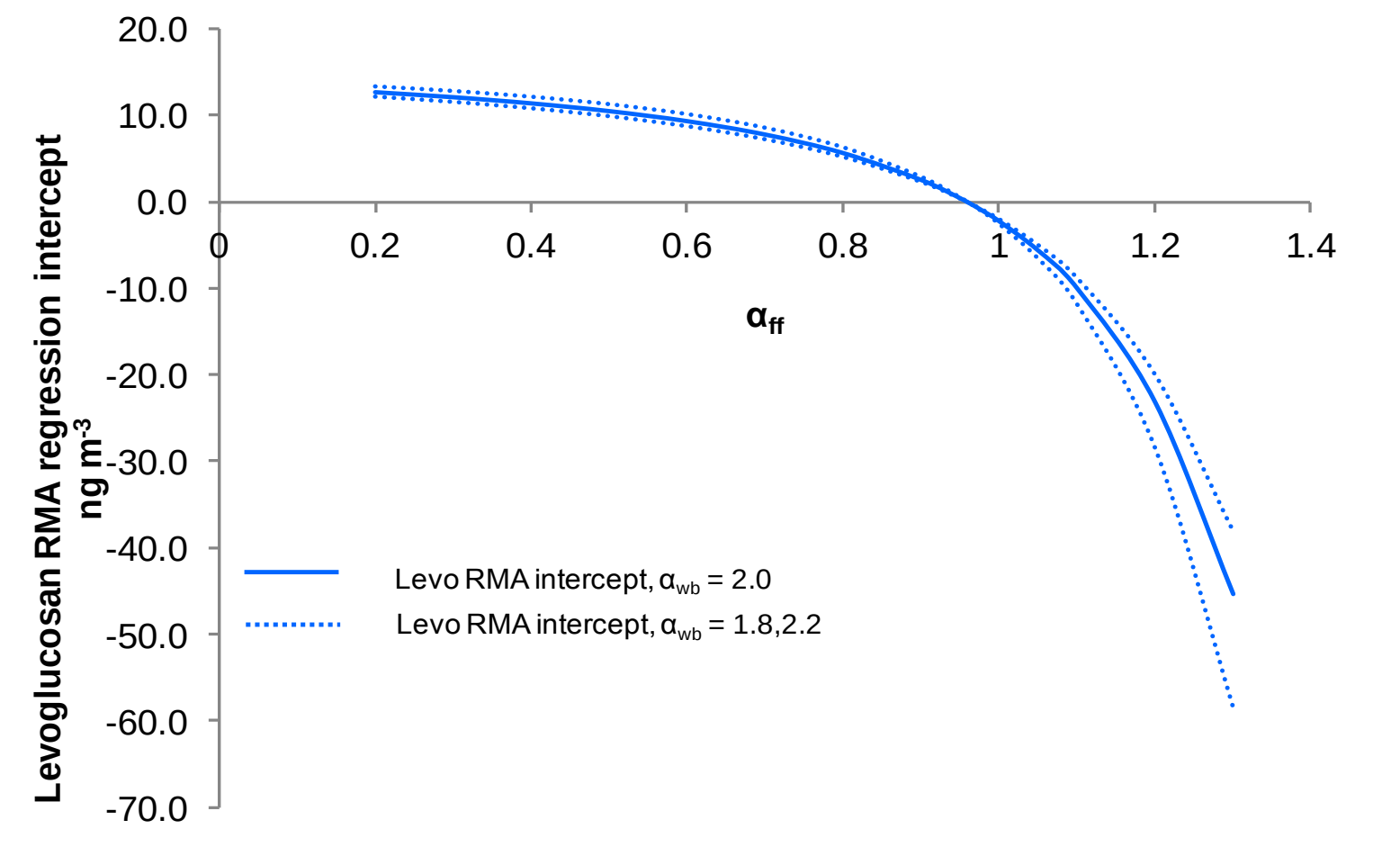
- But how sensitive is the aethlameter wood burning model to the different assumptions about $\alpha_{traffic}$ and α_{wb} ?

- Can the levoglucosan measurements be used to further constrain the model and test the sensitivities to $\alpha_{traffic}$ and α_{wb}?

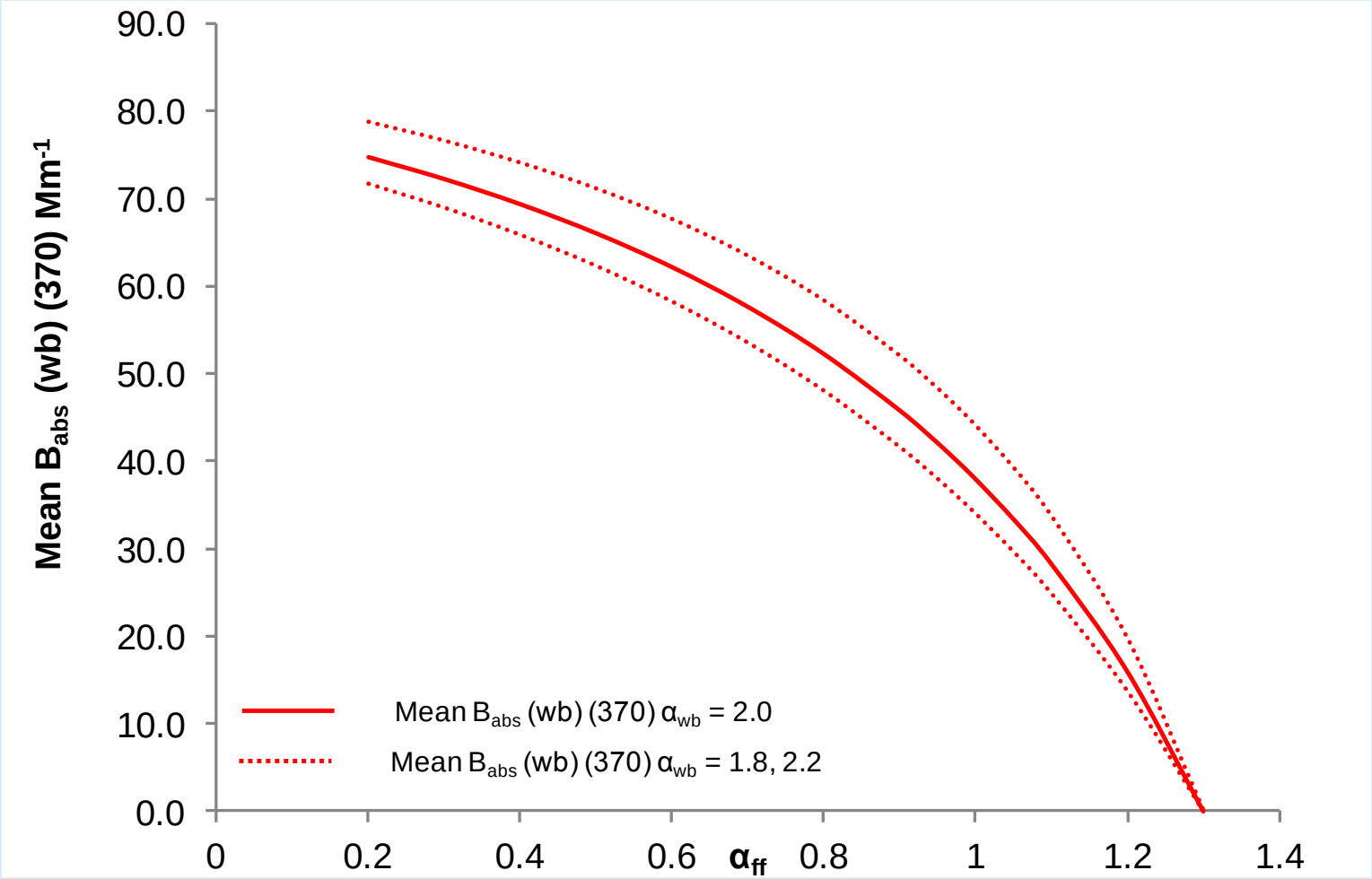
Determining $\alpha_{traffic}$ and α_{wb}



Determining $\alpha_{traffic}$ and α_{wb}



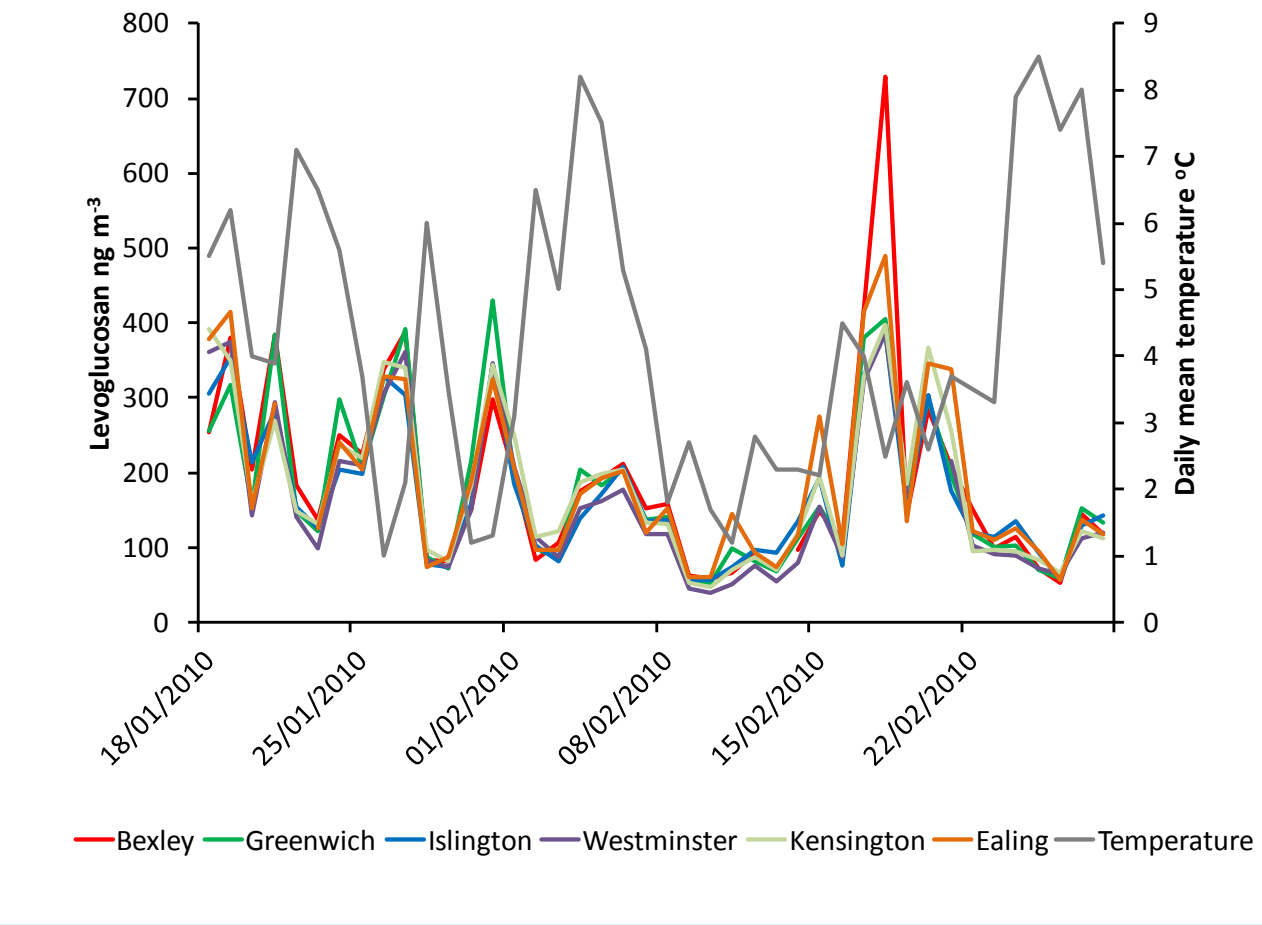
Determining $\alpha_{traffic}$ and α_{wb}



Results

Where's it coming from? Levoglucosan

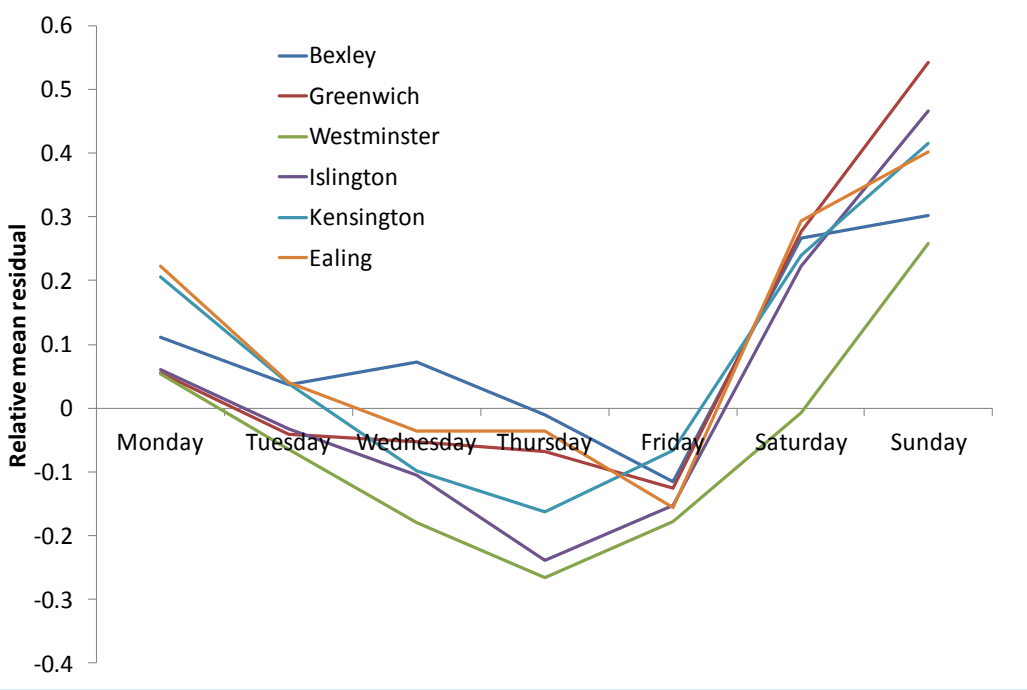
Temperature and levoglucosan badly correlated, R^2 ranging between -0.15 and -0.22



Where's it coming from?

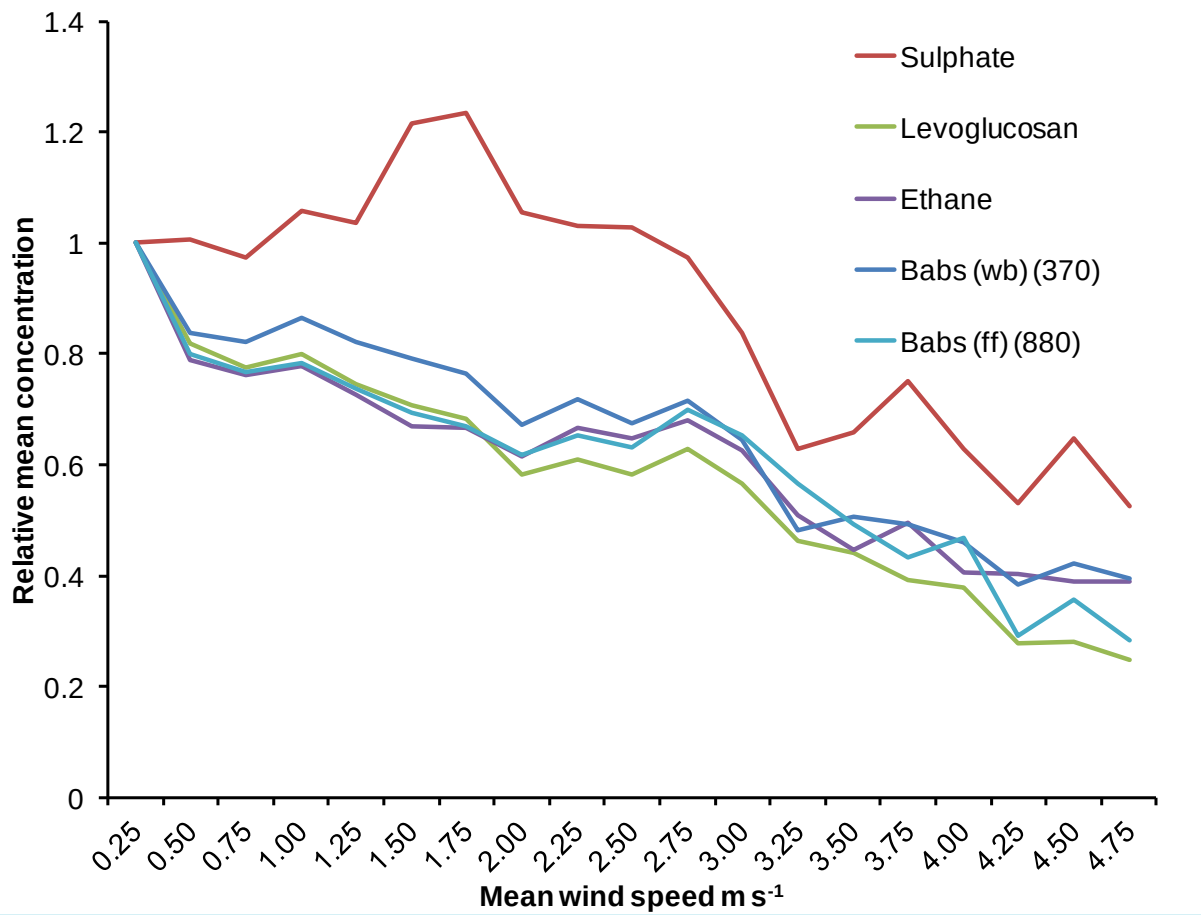
Levoglucosan

Can we say something about day of week variation?
Residuals from simple regression model with ethane
(ethane has a fixed emission rate from natural gas leakage)



Where's it coming from?

Variation with wind speed along with tracers for urban and long-range sources



Estimating eBC and PM concentrations from wood burning

Levoglucosan PM: PM emission rates depend on wood type.

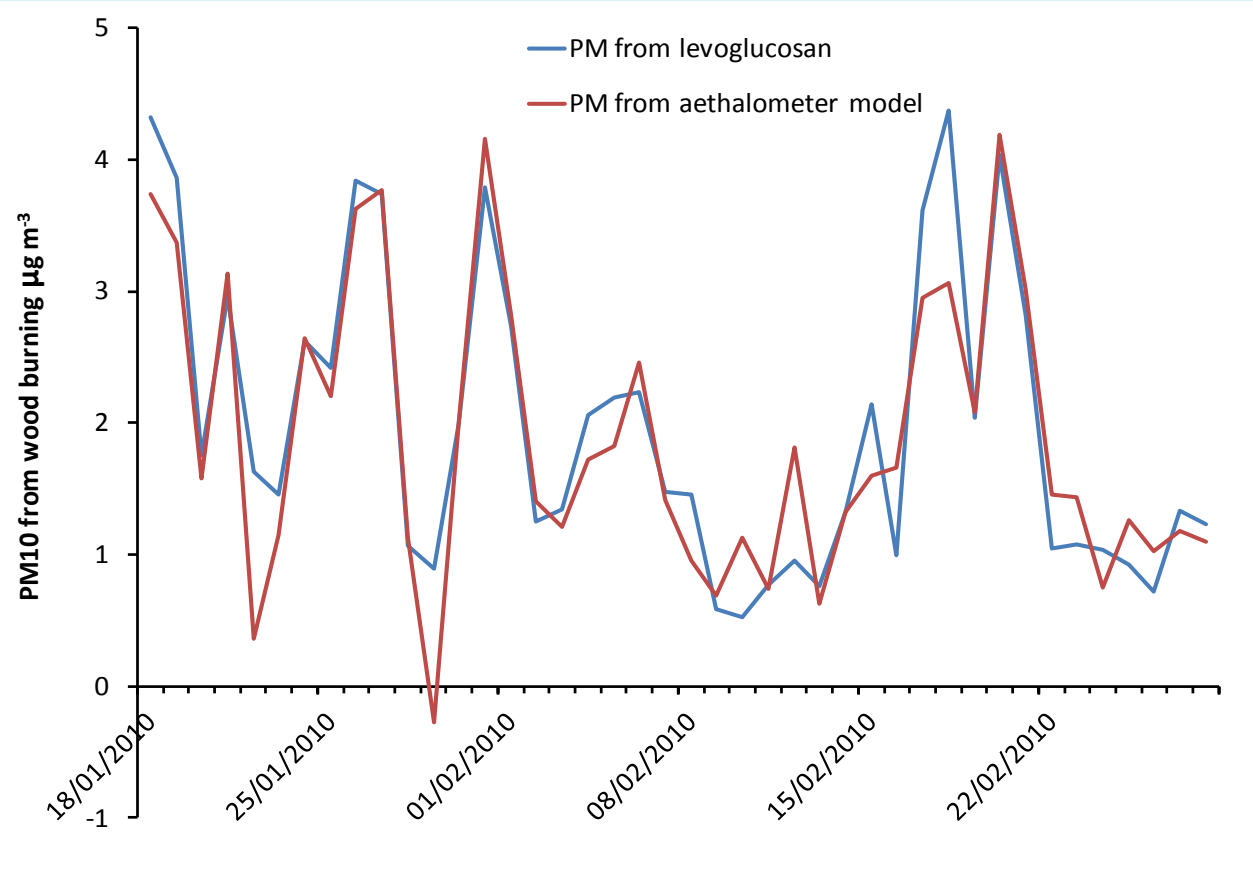
- Puxbaum et al., (2007) suggested 7.35 and an OC to OM factor 1.4 and levoglucosan to EC of 0.9. Implies Levoglucosan to PM ratio of 10.
- Within the range suggested by Szidat et al., (2009) of 5.5 to 14

Black carbon: from apportioned absorption in the IR wavelength and the aethalometer default mass absorption co-efficient, assuming this applies to BC from all sources.

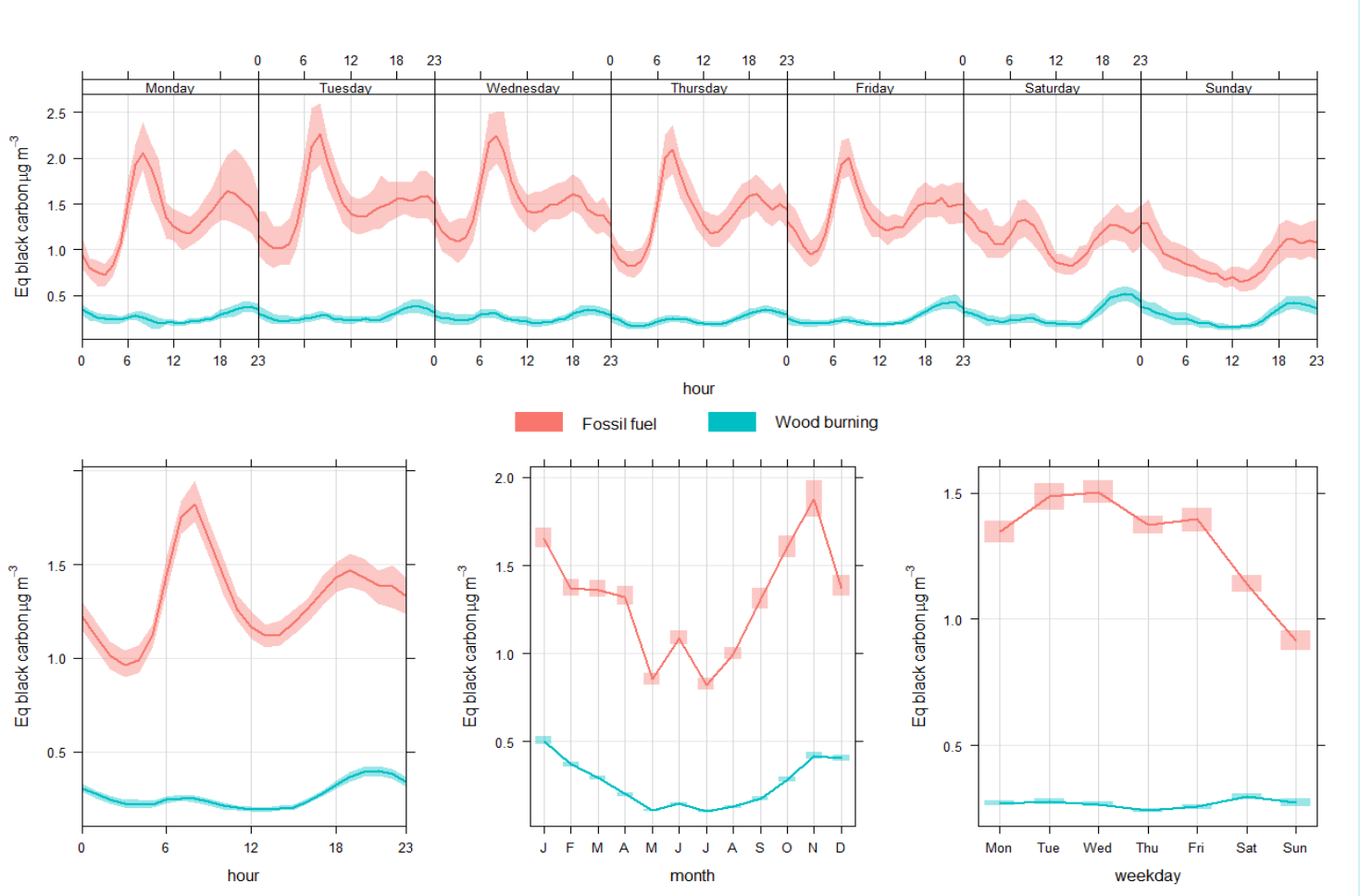
Aethalometer PM: Literature factors from multiple linear regressions with EC and OM. Favez et al., (2009, 2010), Sandrewi (2008), Sciare et al., (2011), Harrison et al., (2012).

Estimating concentrations

[PM wood Aethalometer] = (0.95 ± 0.0) [PM wood levo] + (0.06 ± 0.14), r = 0.92 n= 42

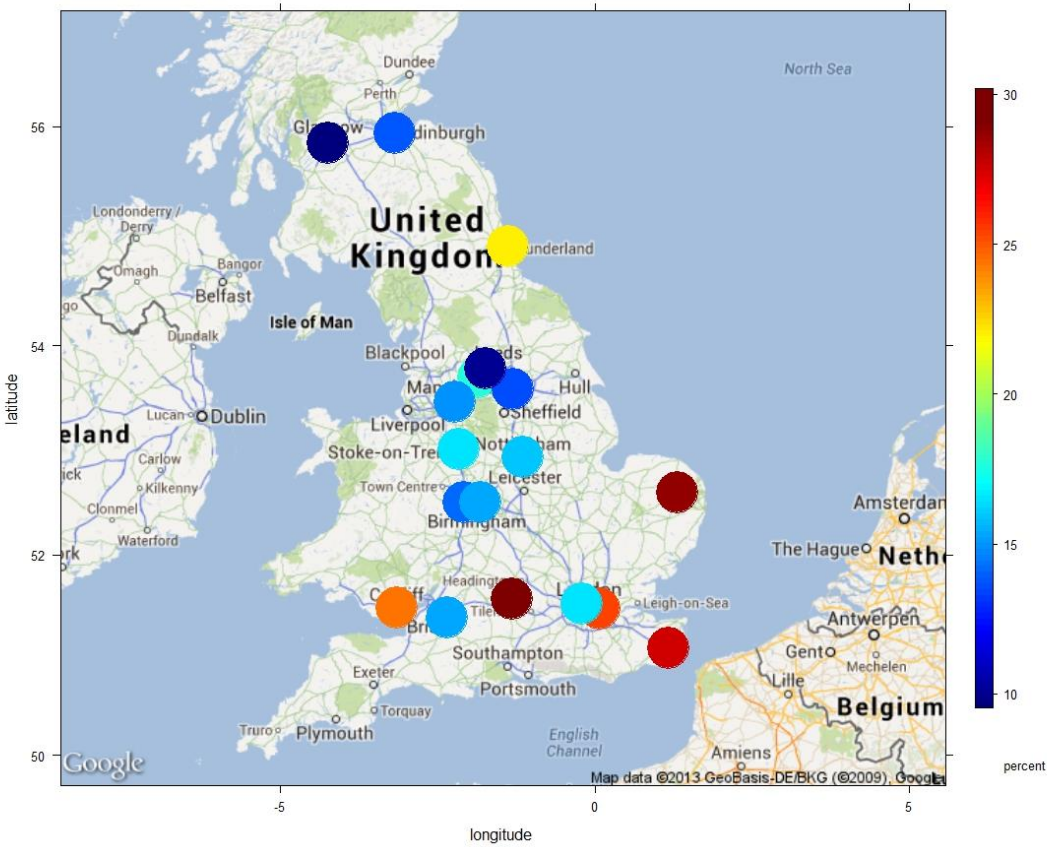


Equivalent black carbon – central London



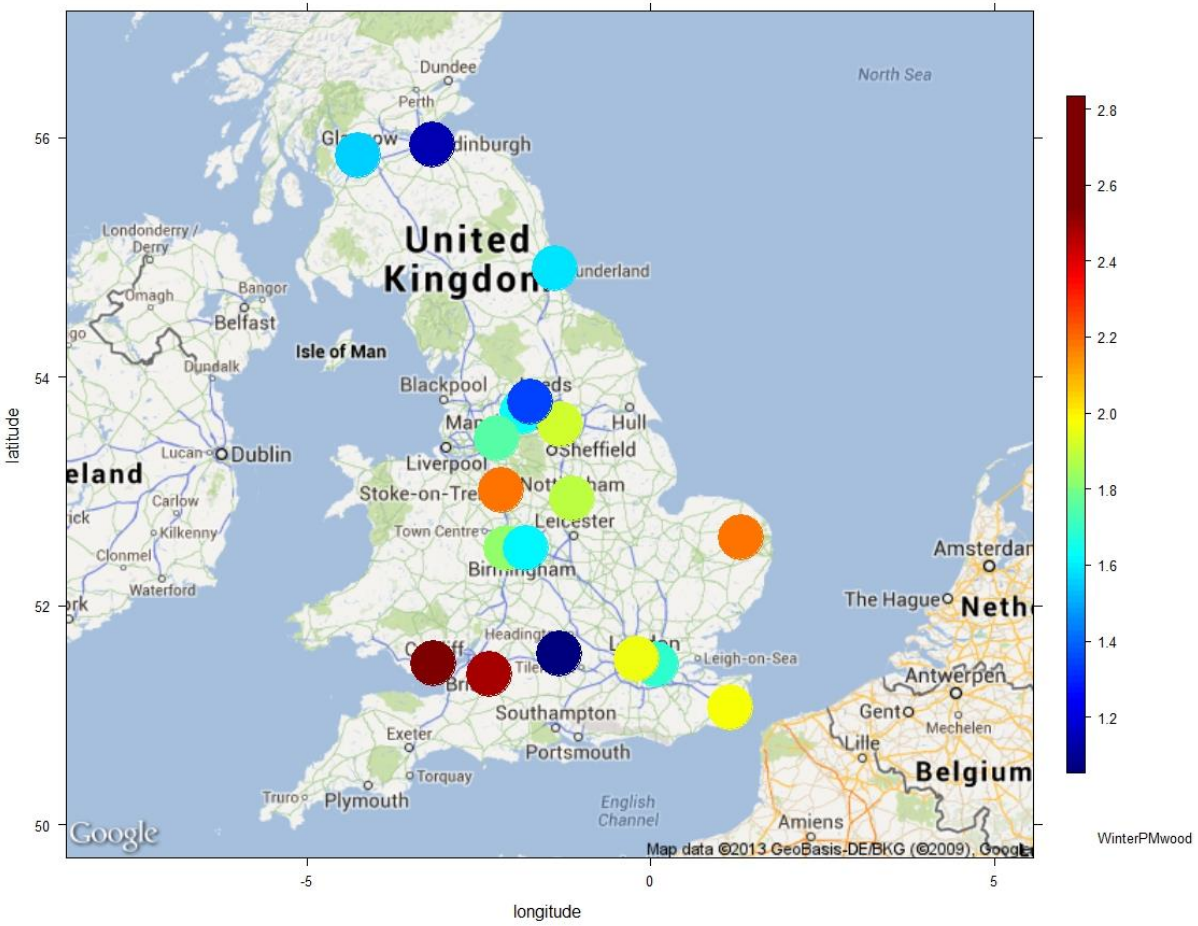
UK mainland (aethalometer)

% equivalent black carbon from wood burning



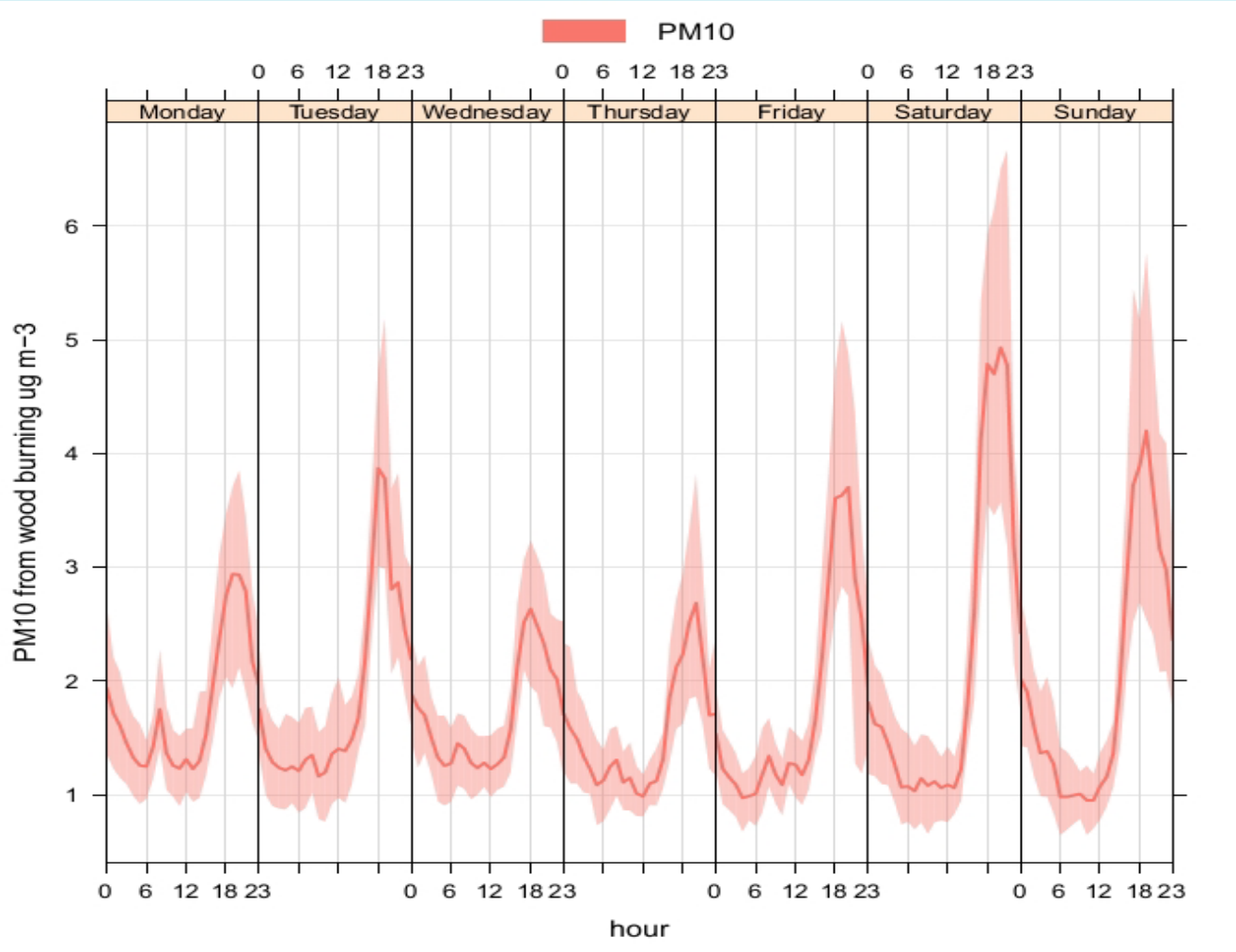
UK mainland (aethalometer)

winter time PM from wood burning (µg m-3)



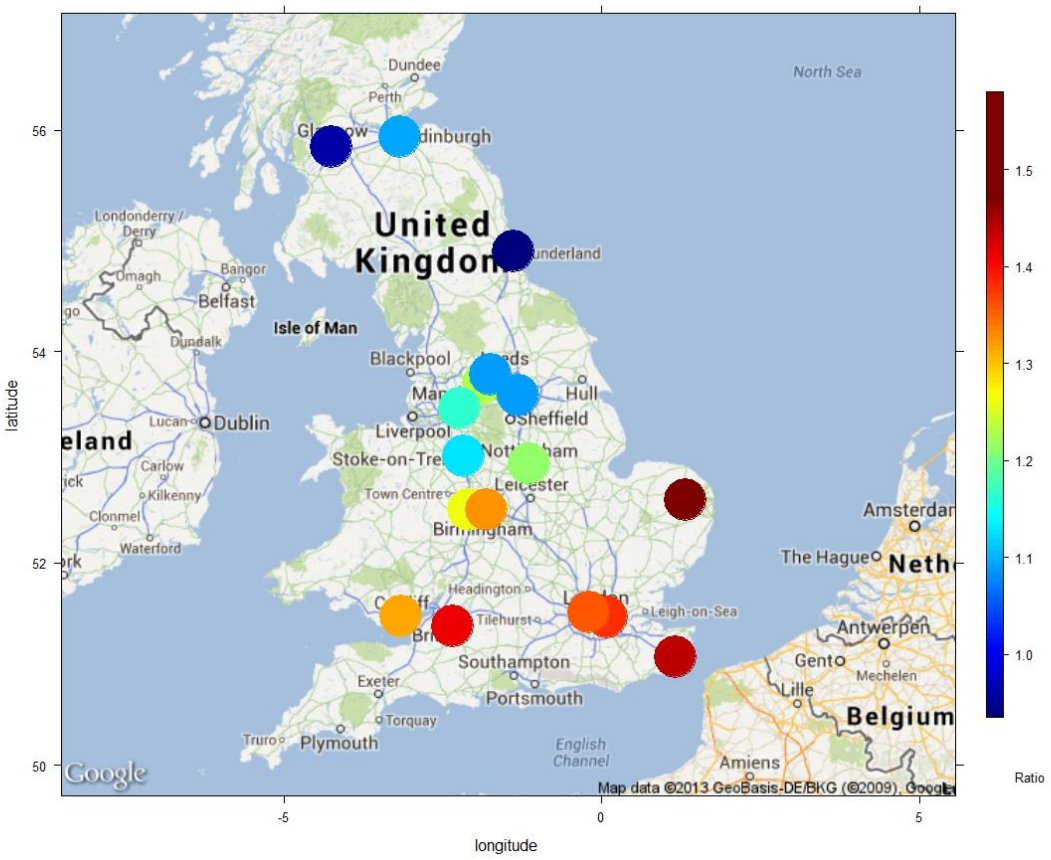
UK mainland (aethalometer)

Winter time PM from wood burning (µg m-3) in Norwich



UK mainland (aethalometer)

Winter evenings weekend / weekday



Conclusions

Conclusions

Good agreement between levoglucosan and aethalometer methods (not shown but in recent experiments aethalometer also seems to agree well with AMS wood burning factor). Using levoglcosan to constrain aethalometer model a **α(ff) = 0.96 was found** consistent with literature values and validating the methods. A **±10 %** change in **α(wb)** varied the estimates of wood burning PM by **-10% and+16%.**

Wood burning is mainly **winter** source. Mean **wintertime PM** from wood between **1.1 and 2.5 µg m-3**. Across ten UK cities **wood burning** comprised **~2 - 7 %** of **annual mean PM10 and 3 - 13% in wintertime.**

PM wood in London comes from **within the city** and is greatest at **weekends and in the evenings** suggesting that wood burning is a **secondary domestic heating** source. Similar patterns across the **southern half of England**.

Likely that PM from wood burning is mainly from **domestic wood burning in existing fire places** (NB: no incremental levo at Islington Arsenal next to modern wood burner but little wind from the right direction!)

Smoke control legislation in London and other cities (like Bath) isn't working

Year on year changes hard to determine from three years (!) but more likely to be an increase than decrease (wood smoke will be almost all PM2.5 – exposure reduction)

Thanks…

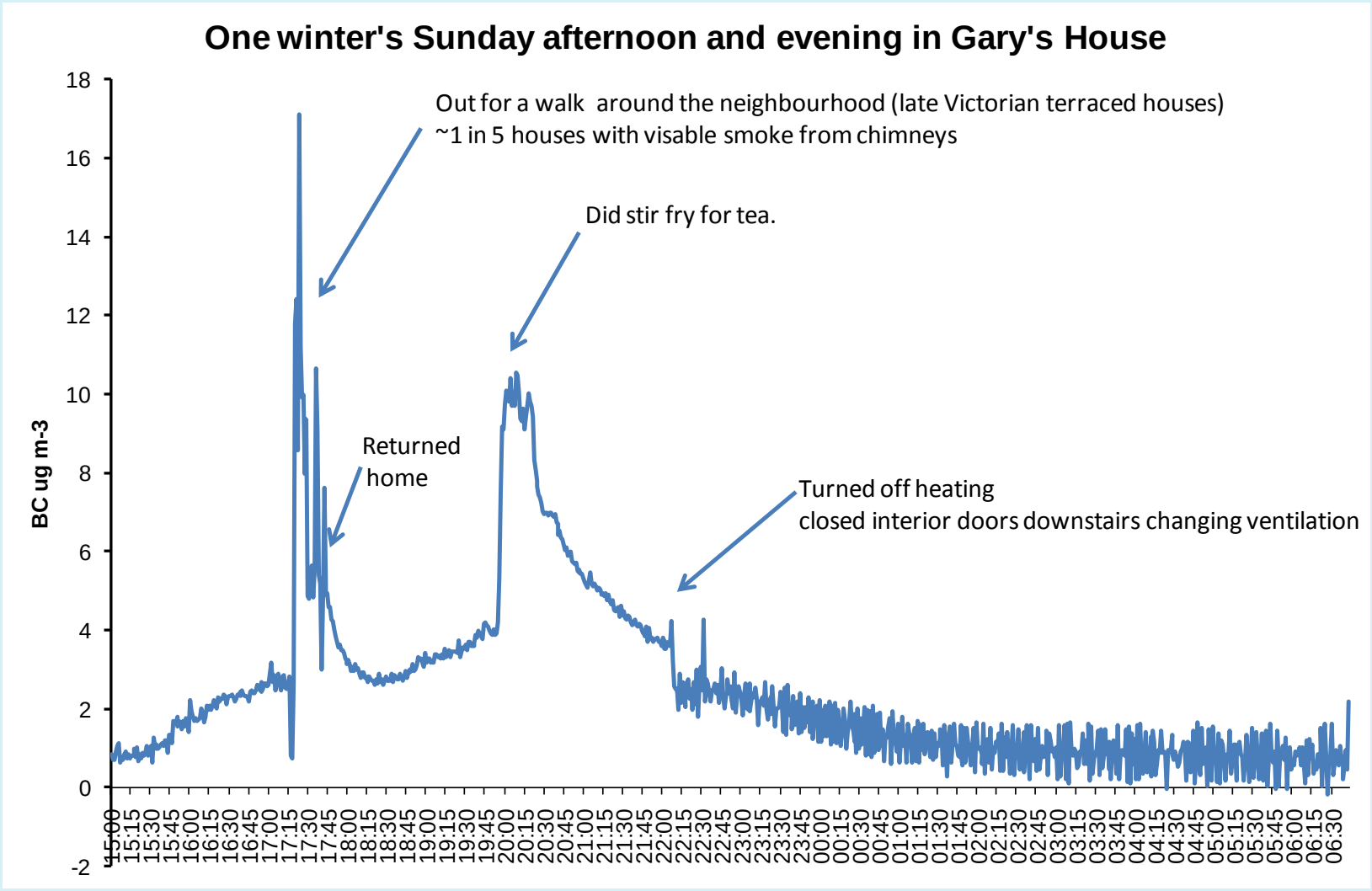
London boroughs of Greenwich, Bexley, Central London cluster group and defra for having the foresight to fund the Levoglucosan measurements and Ealing for hosting 2010 sampling.

Jean Sciare,Oliver Favez, Phil Hopke, Grisa Mocnik and Tony Hansen for enjoyable and helpful discussions.

Defra and our NPL partners (especially David Butterfield) in the black smoke network for the absorption measurements.

Karl Espen Yittri for levoglucosan analysis and comments on the project.

Footnote


One winter's Sunday afternoon and evening in Gary's House
BC ug m-3
Out for a walk around the neighbourhood (late Victorian terraced houses)
~1 in 5 houses with visable smoke from chimneys
Did stir fry for tea.
Returned home
Turned off heating
closed interior doors downstairs changing ventilation