Meteorological Normalisation

Accounting for meteorology in trends

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LAQN Seminar, King's College London
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Outline

1 Introduction

2 Developing models

3 Examples of use

4 Concluding remarks

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Introduction

Some thoughts and questions

Importance of trends

- Important to know how concentrations change in time
- Consistent with changes in emissions?

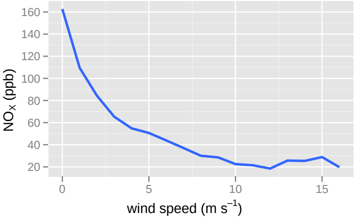
Meteorology

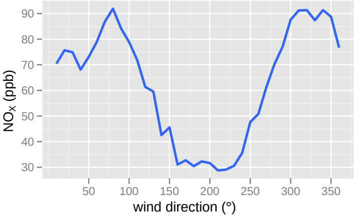
- Meteorology can falsely mask or emphasise trends
- …but meteorology is rarely taken into account in a robust way
- Often left with statements like "such and such was a 'good' or a 'bad' year"
- It would be useful if we had the same weather every year!

Effect of meteorology

Effects of wind speed and direction

- Meteorology has a strong influence on pollutant concentrations at all scales
  - Focus here is on local urban effects
- Perhaps easiest to see the effects by averaging the data

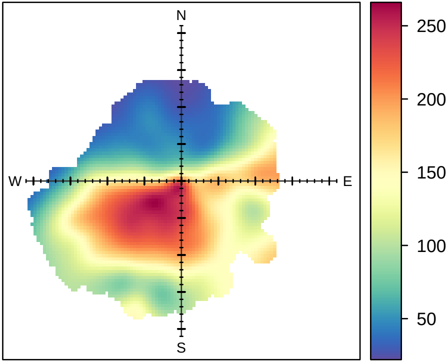




Effect of meteorology

Joint effect of wind speed and direction

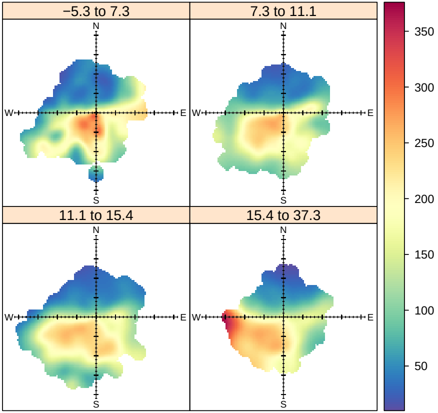
- Plot concentration as a function of wind speed *and* direction
    - Clear that the effect of wind speed is not constant with wind direction
    - Strong effect of street canyon and complex local mixing
    - There is an **interaction** between wind speed and direction



Effect of meteorology

Joint effect of wind speed, wind direction and temperature

- What about temperature?
  - Good indicator of thermal turbulence
- Concentrations depend on wind speed, wind direction **and** temperature
  - ∴ complex models are required to capture all these effects



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Model development

Type of input required for model development

The models were developed using hourly air pollution and meteorological data.

Example

A wide range of models can be developed and tested using a large range of meteorological variables and other terms to captures trends:

$$[NO_X] = \overline{u} + \phi + T_\theta + t_{hour} + t_{weekday} + t_{JD} + t_{trend} + \cdots$$

Heathrow meteorological measurements include measures of rainfall, cloud cover and type at different heights.

Modelling approach

Use of regression trees

Many different types of model could be used including linear regression and Generalized Additive Models (GAMs)

However, a **regression tree** approach is used here[1]:

Regression Trees — some modelling benefits

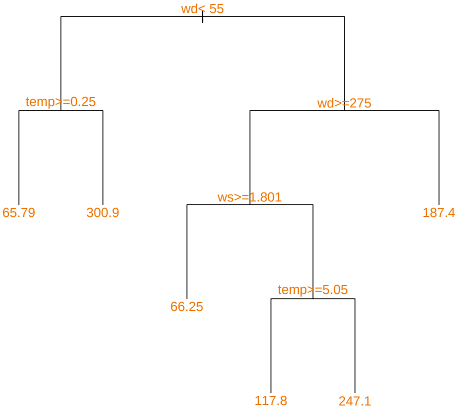
- Can model non-linear relationships
- Can take account of complex interactions
- Can model abrupt changes
- Good treatment of missing data
- Can be interpreted e.g. to check whether relationships are physically meaningful

[1] Carslaw and Taylor (2009) Analysis of air pollution data in a mixed source location using boosted regression trees. *Atmos. Env.*, in press.

Modelling approach

Predicting concentrations of NO_X at Marylebone Road

- Simplified model with wind speed, wind direction and temperature
  - Aim to predict hourly NO_X concentrations
- Interpretation
  - Output looks like a 'tree'
  - Actual models are considerably more complex



Modelling approach

Predicting meteorologically-averaged concentrations

How are concentration predictions made?

Modelling steps

- Develop and test good explanatory model(s)
  - Test models on data independent of that used to develop the models
- Make new predictions with:
  - Randomly sample meteorological data from whole time series (100s of times) and average the results
  - Randomly sample from a particular year — addresses the question as to what trends would look like with 2007 meteorology throughout, for example

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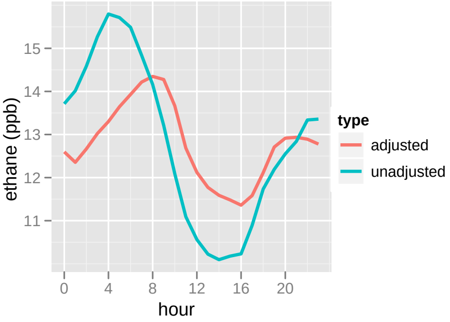
Example 1

Accounting for meteorological variation for a ‘tracer gas’

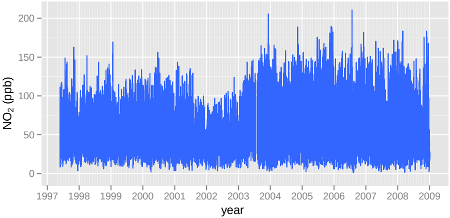
- Ethane concentrations are dominated by natural gas leakage
    - Acts as a tracer gas
    - Strongly influenced by ‘bulk’ meteorological processes e.g. wind speed, boundary layer height
- However . . .
    - Road vehicles are also an important source



Example 2

NO_2 at Marylebone Road

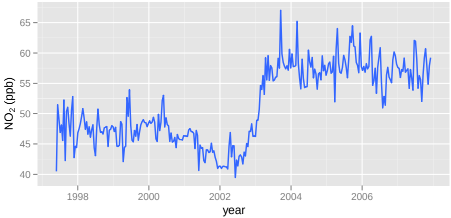
- Hourly concentrations of NO_2 are highly variable
- If the meteorological signal is removed:
  - Should look more like the trend in NO_2 emissions
  - Can compare these results with independently estimated f-NO_2 trends
  - Ratios of pollutant concentrations are invariant to meteorology (when close to a single source)



Example 2

Meteorologically-averaged NO_2 at Marylebone Road

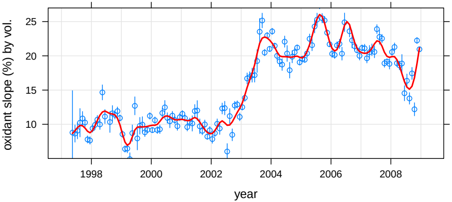
- Accounting for meteorology shows a clear trend:
  - Relatively stable until 2003 and relatively stable afterwards
  - How does this compare with estimated trends in f-NO_2?



Example 2

Trend in f-NO_2 at Marylebone Road

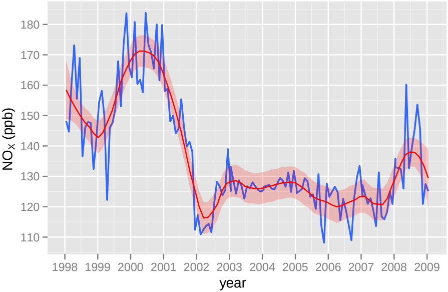
- Trend in f-NO_2 shares many of the characteristics with the previous plot
    - Shows how these techniques can say something about emissions



Example 3

NO_X at Marylebone Road

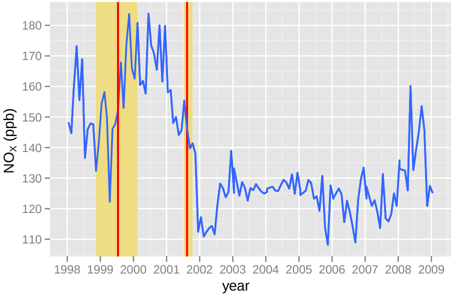
- Trend in NO_X concentrations have clearly not been smooth and may even have been *increasing*
- What could explain this type of trend?



Example 3

NO_X at Marylebone Road

- Run a change-point analysis[a]
- Two change-points detected
  - July 1999 (95% confidence interval Nov. 1998 – Feb. 2000)
  - August 2001 (95% confidence interval July – October)
- Bus lane started operation in August 2001.

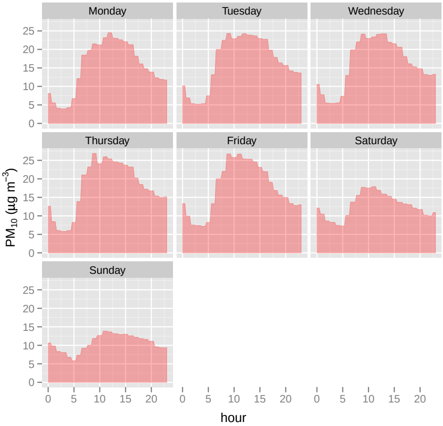


[a] Carslaw et al. (2006) Change-Point Detection of Gaseous and Particulate Traffic-Related Pollutants at a Roadside Location. *Environ. Sci. Tech. Vol. 40. Issue 22. 6912-6918.*

Example 4

Potential to make direct comparisons with emissions data

- Emissions of traffic-related pollutants vary in important ways
  - There are considerably fewer heavy vehicles at weekends
  - Diurnal variation in traffic differs by vehicle type
- Accounting for meteorology offers the potential to compare like with like
  - Can provide insights into what vehicle type(s) control concentrations and trends



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Summary points

1. Meteorological variation can frustrate the analysis of trends
2. Explanatory models can be developed to explain the variation in hourly concentrations
   - Can calculate new time series with average meteorology
   - 'Modern' statistical models capture much of the complex variation in concentrations
3. These models allow us to get closer to changes in emissions rather than meteorology
   - Better indication of long-term trends
   - Detection of changes due to interventions
   - Provision of data that can be strongly linked with emissions analysis (like Sean has said)

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Questions?

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