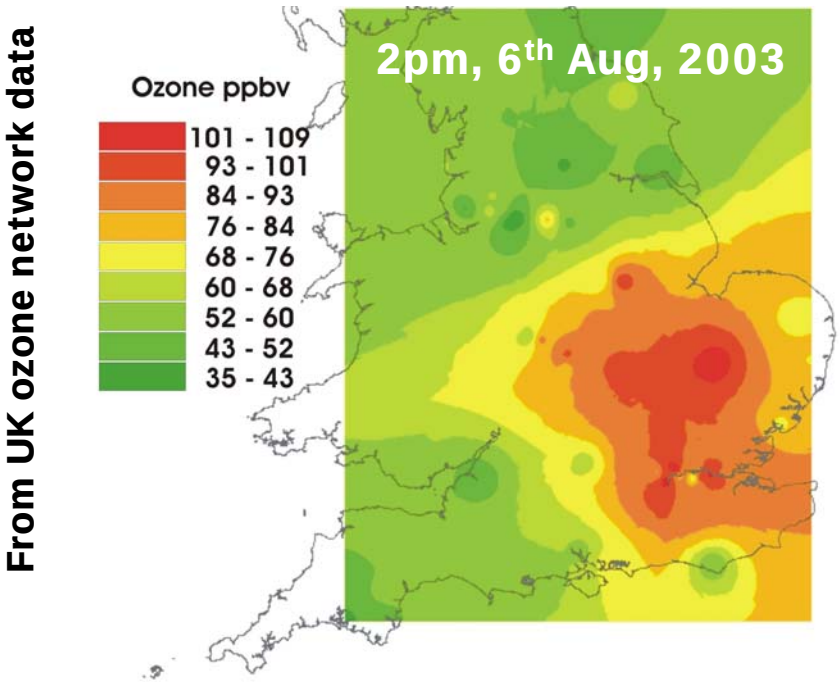
Inverse modelling of satellite observations for climate and AQ

Paul Palmer

O_3 > 100 ppb on 6 consecutive days

Extra deaths attributable to air pollution (O_3 and PM)



BBC WEATHER 2010

"Expect harmful levels of ozone and PM2.5 over the next couple of days; please keep small children and animals inside. Transatlantic pollution represents 20% of today's UK surface ozone."

General public only interested in pollution levels at 1.8m above surface

- Numerical Chemical Weather Prediction (NCWP): PM, O_3, NO_x
- Guiding AQ and Climate Policy: PM, O_3, NO_x?

Currently no strong commitment to PM2.5(!)

Annual mean stats	UK AQ strategy	EU directive
NO_2 (ann mean)	40 µg m^{-3} (21ppb)	
PM10 (ann mean)	40 µg m^{-3} (2004) 20 µg m^{-3} (2010)	40 µg m^{-3} (2004) 20 µg m^{-3} (2010)
O_3 (8-hour run. mean)	100 µg m^{-3} (50ppb) as daily max by end 2005 (max exceed 10/year)	120 µg m^{-3} (60ppb) by 2010 (max exceed <25 mean of 3 years)

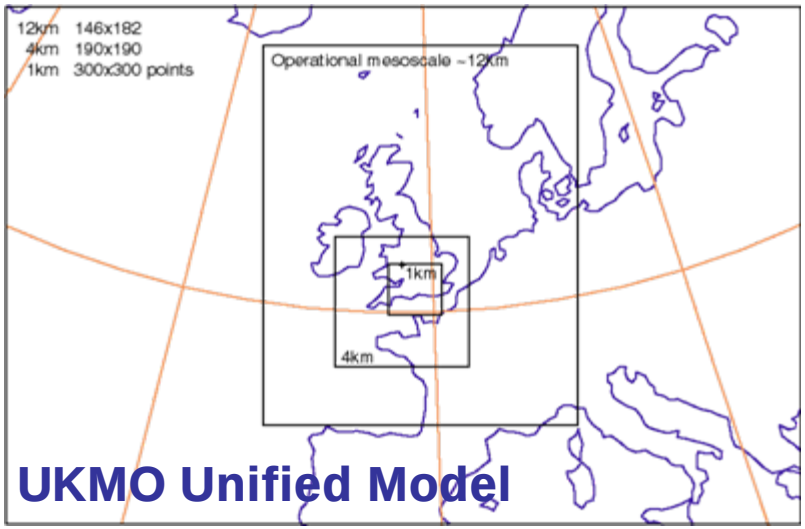
(Current instruments probably not accurate enough to monitor AQ standards)

- Some addtn science: surface fluxes, aerosol-chemistry processes, dynamics

Current Development in Modelling UK AQ

- UK currently using MODELS 3 (MM5 + CMAQ) for AQ
- Two major recent developments

1) UM mesoscale CTM



UKMO Unified Model

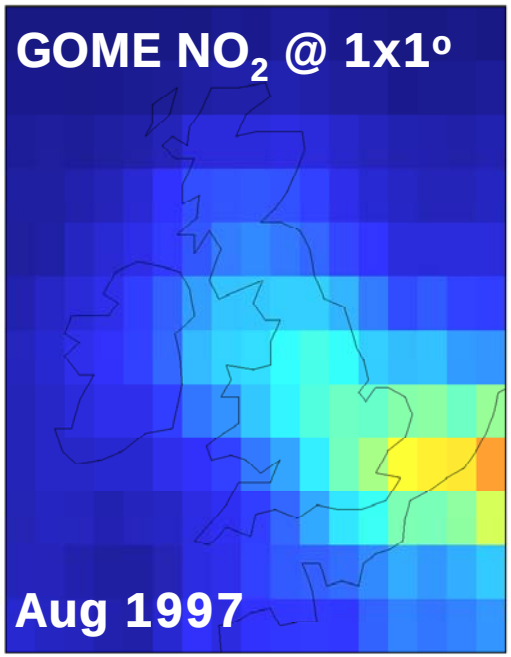
2) Unified heterogeneous chemistry scheme

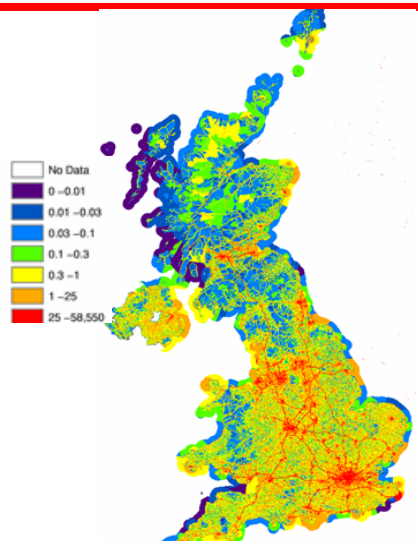
AQ Model ⟷ Chem-Clim Model

AQ-climate links

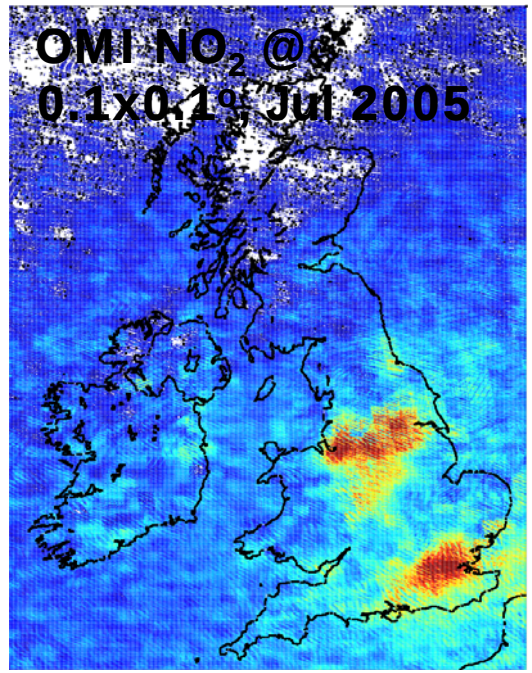
Global vs urban chemistry?
Subgrid scale processes?

Resolution of new satellite data allows study UK AQ from space





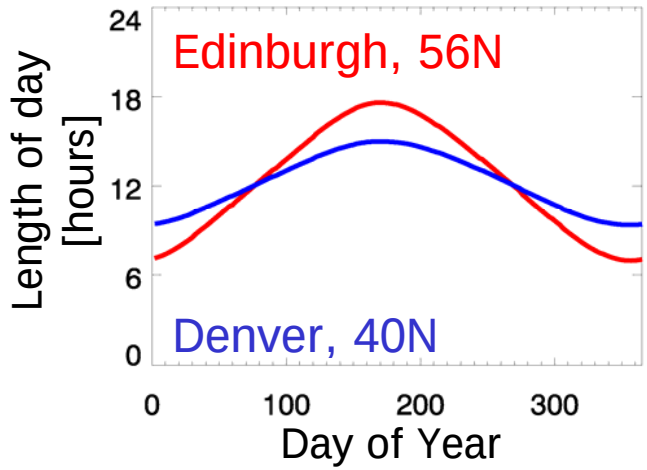
NAEI NO_X emissions as NO_2, 2002

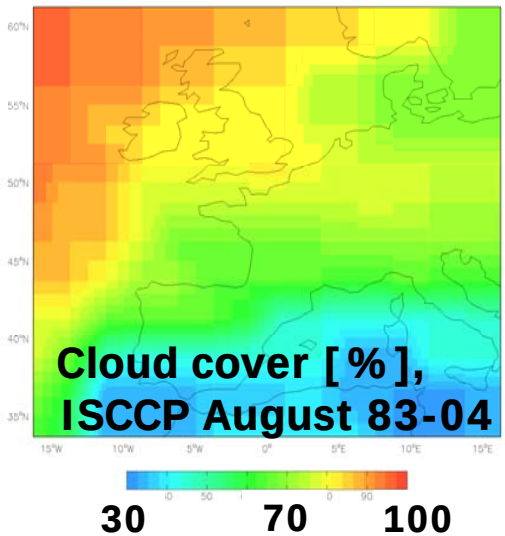


GOME and SCIA NO_2 c/o R. Martin

"Artist's impression of OMI NO2" c/o T Kurosu

Challenges...





Data Assimilation vs Inverse Modelling

•Robust way to combine a model information with irregular, noisy observations

•Similar equations for data assimilation and inverse modelling

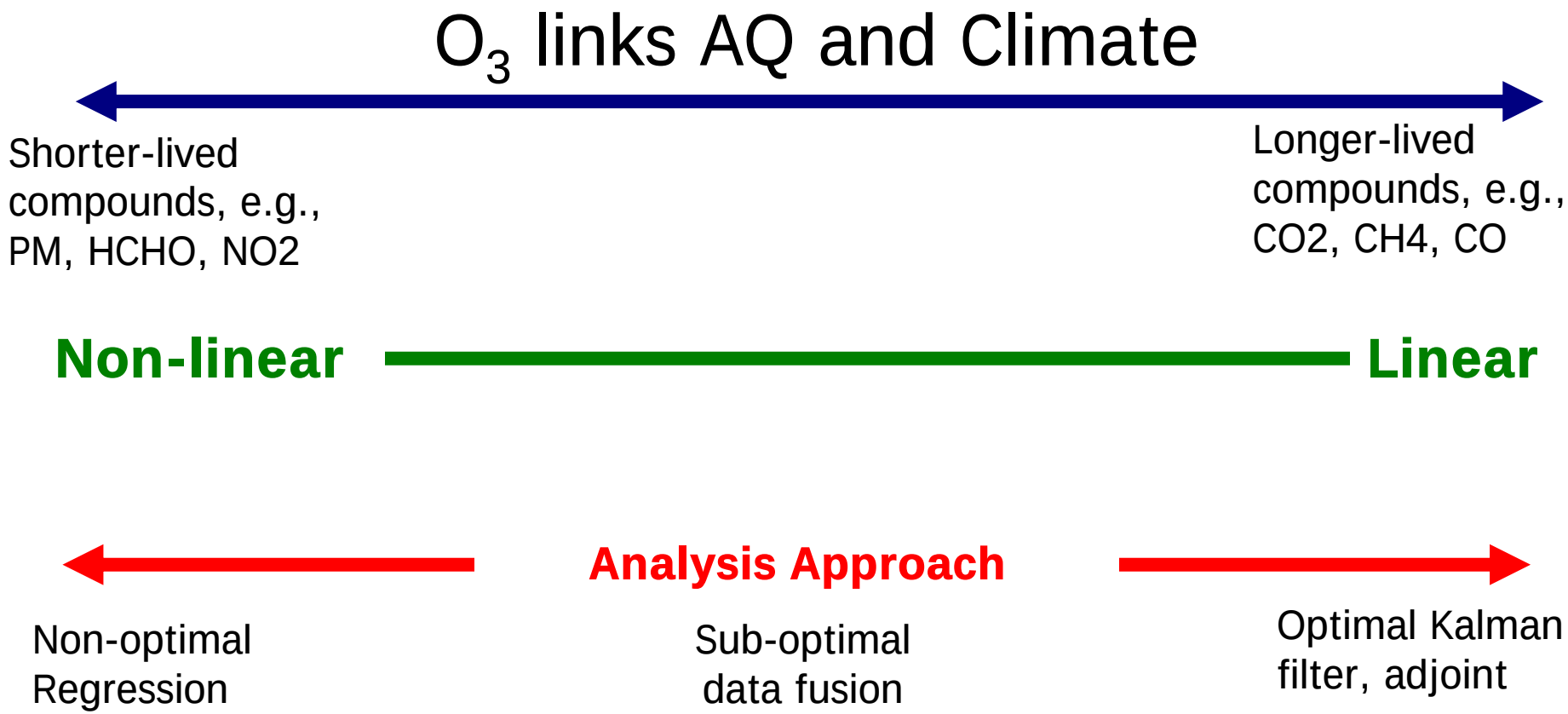
$$J(\mathbf{x}) = \tfrac{1}{2}(\mathbf{y}_o - \mathbf{H}(\mathbf{x}))^T(\mathbf{E}+\mathbf{F})^{-1}(\mathbf{y}_o-\mathbf{H}(\mathbf{x})) + \tfrac{1}{2}(\mathbf{x}-\mathbf{x}_b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b)$$

How we define error (co)variance structure?
Define $\mathbf{x}$ and $\mathbf{y}_o$?

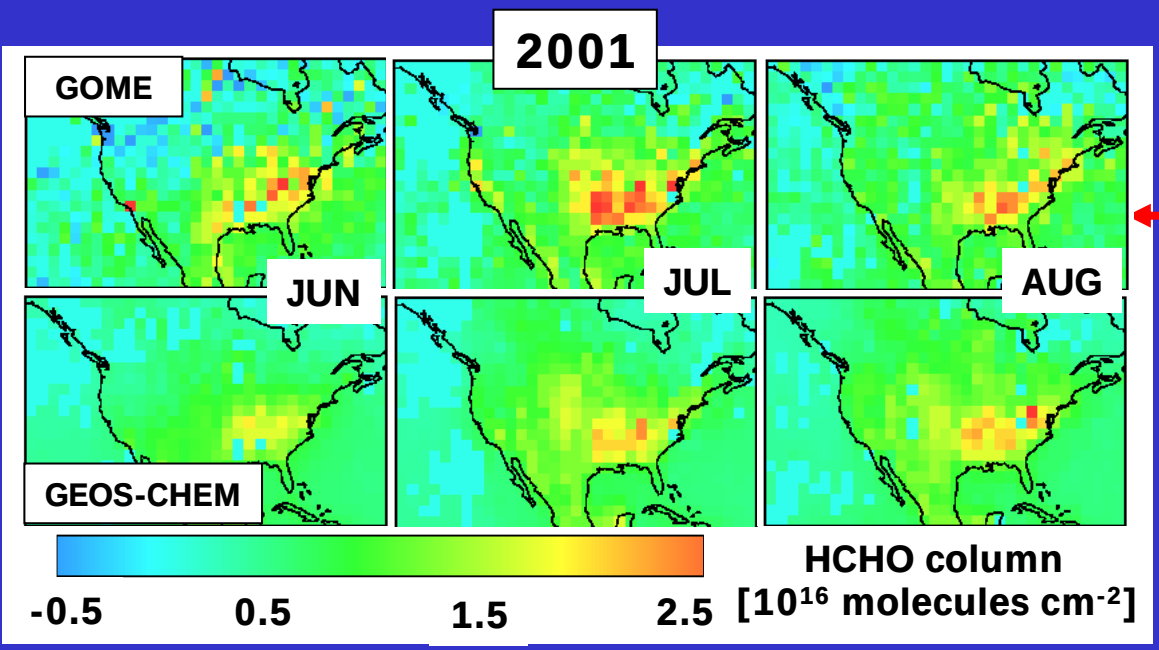
•Other important things to consider:

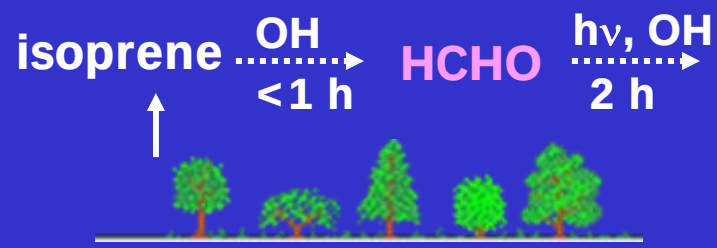
- Multi-species analyses – inter-species error covariance?
- Radiance versus retrieved products?
- Limit of linearization of non-linear oxidant chemistry?

Spectrum of methods currently used



MAPPING ISOPRENE EMISSIONS USING FORMALDEHYDE COLUMNS FROM GOME

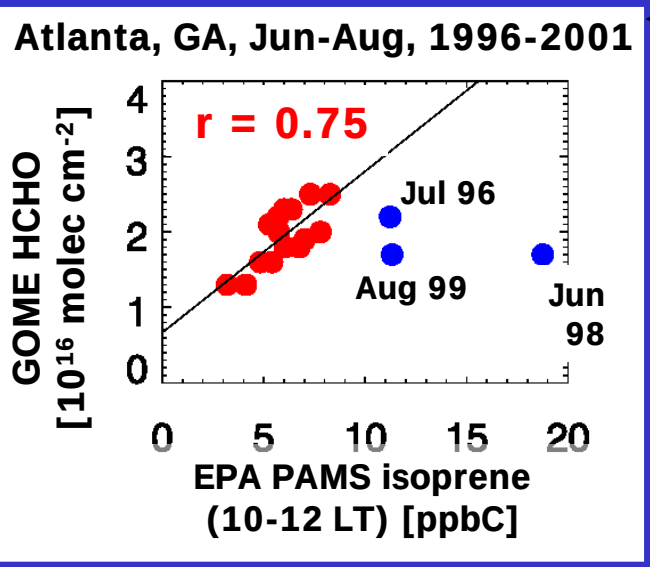


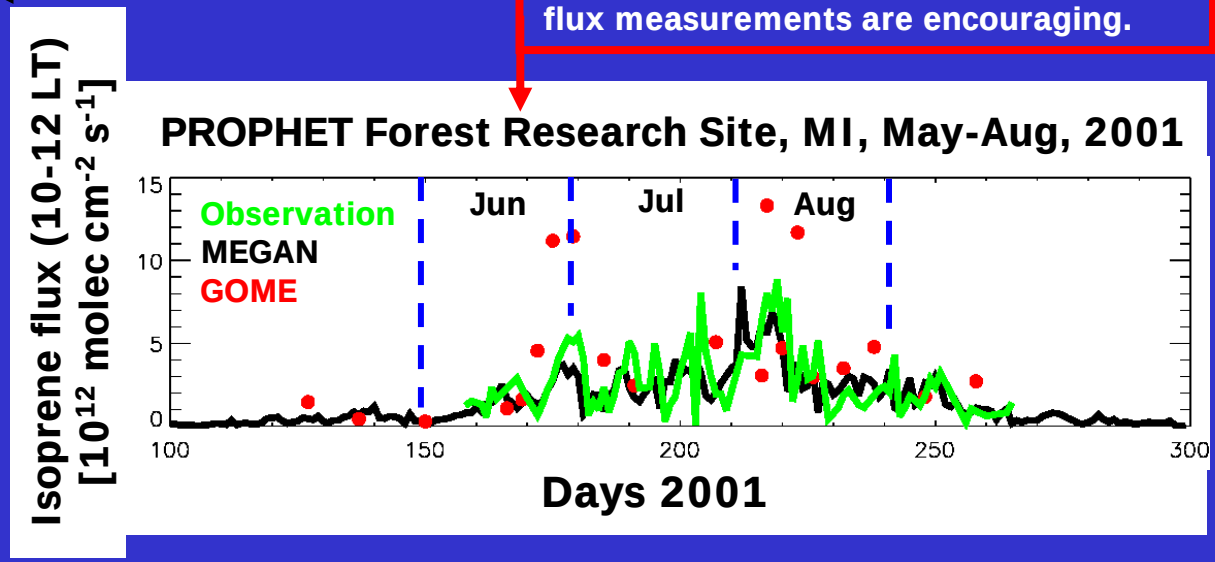


Predicted HCHO columns from the MEGAN state-of-the-art isoprene emission algorithm generally agree with GOME data. However, some aspects of the observed variability are not captured well by the model.

GOME columns over SE US during Jun-Aug 1996-2001 correlate well with *in situ* isoprene concentration data, after outliers (blue) have been removed.

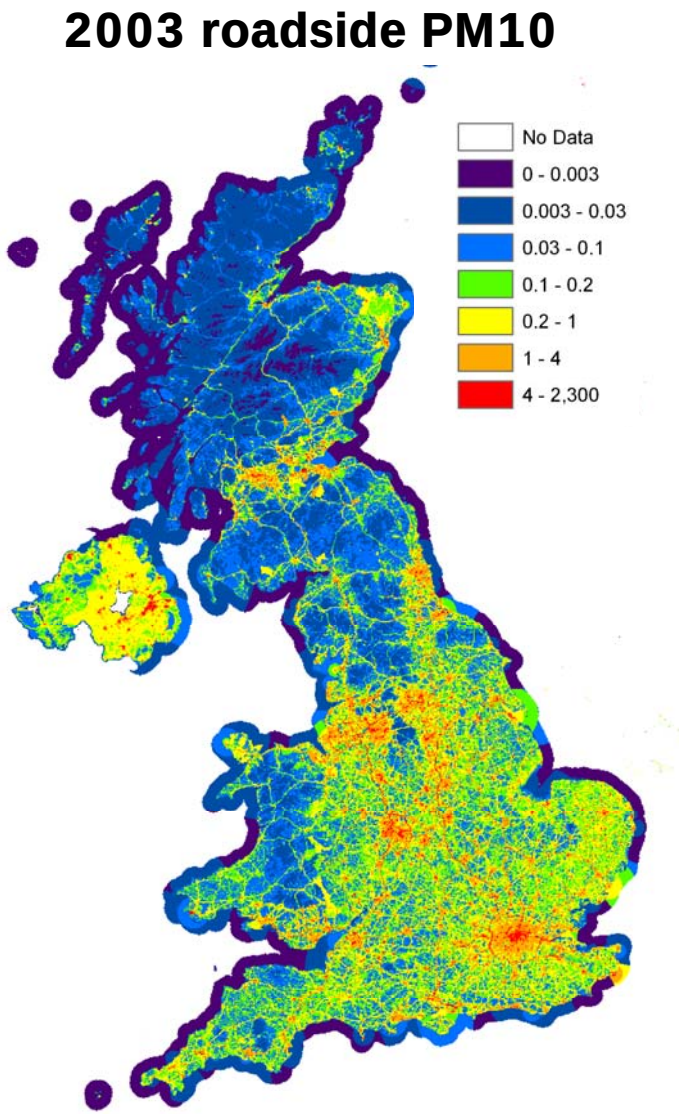
The model isoprene:HCHO regression is used to calculate GOME isoprene flux. Comparison with continuous isoprene flux measurements are encouraging.





UK PM: low-hanging fruit

- Unclear what PM characteristics affect health
- Secondary PM is formed from:
  - Oxidation of organic compounds
  - Oxidation of SO_2
  - Difficult to estimate in inventories: **need models and data**
- Also strong regional contributions to PM:
  - **Saharan desert dust**
  - **Sea salt aerosol**
  - **Secondary organic PM**
- Non-optimal data fusion methods exist



A Road Map for the Way Forward…

- Number of short, focused studies needed to:

  1) understand how we can use current data for monitoring and forecasting UK chemical weather

  2) identify future data streams are best suited for that purpose (OSSEs)

- Incremental approach: test data fusion methods (quick and dirty but easy implementation) before formal assimilation?