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# From Air Quality to Climate Change- a switcher's perspective

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# Why this talk?

- **Last time at the AAMG...**

- Measuring Ultrafine particles
- Part of a broader effort to understand PM
- Supporting policies to manage local and regional and local air quality

- ***This time at the AAMG...***

- Still interested in PM (and trace species more generally), but...
- ...in the context of climate change and its impacts, specifically air quality globally in 50-100 years.



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# Earth System modeling at the Met Office

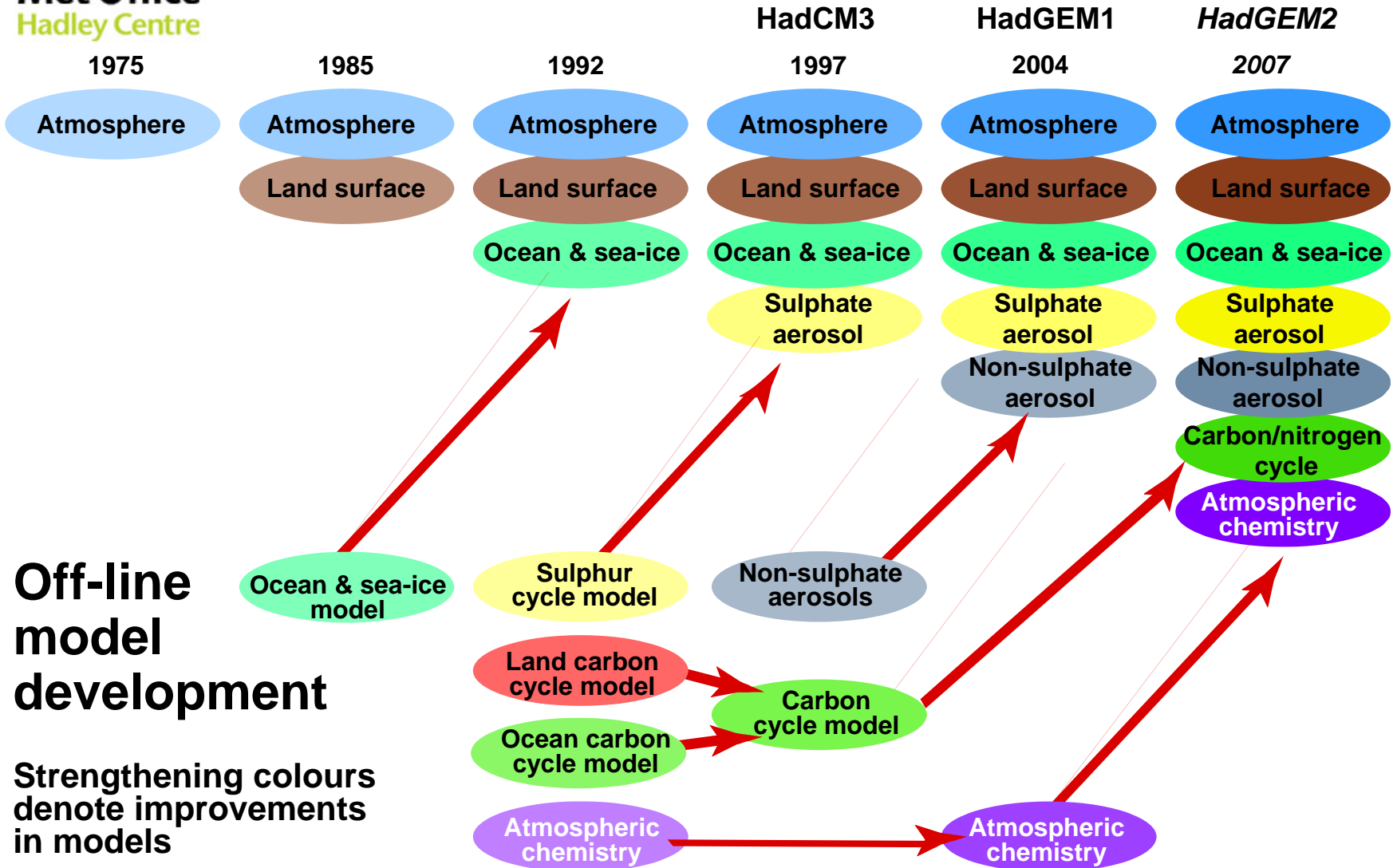
# Earth System Modelling

- Model the Earth as a complete system
  - Atmosphere, land surface, oceans
- Investigate the effects *of* the climate and the effects *on* the climate
  - Feedbacks and forcings
- Model complexity and resolution has grown with computer power

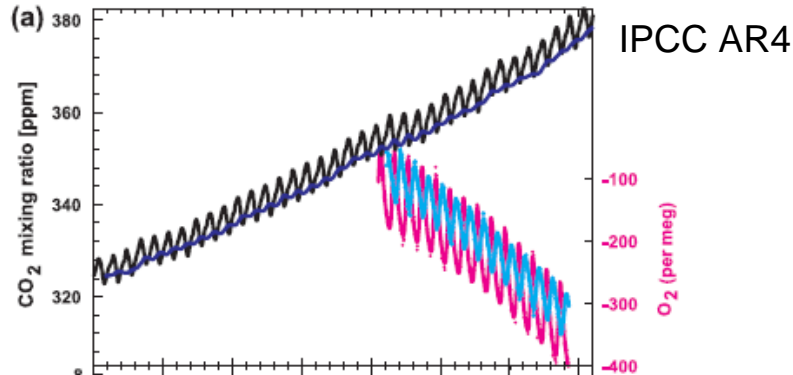


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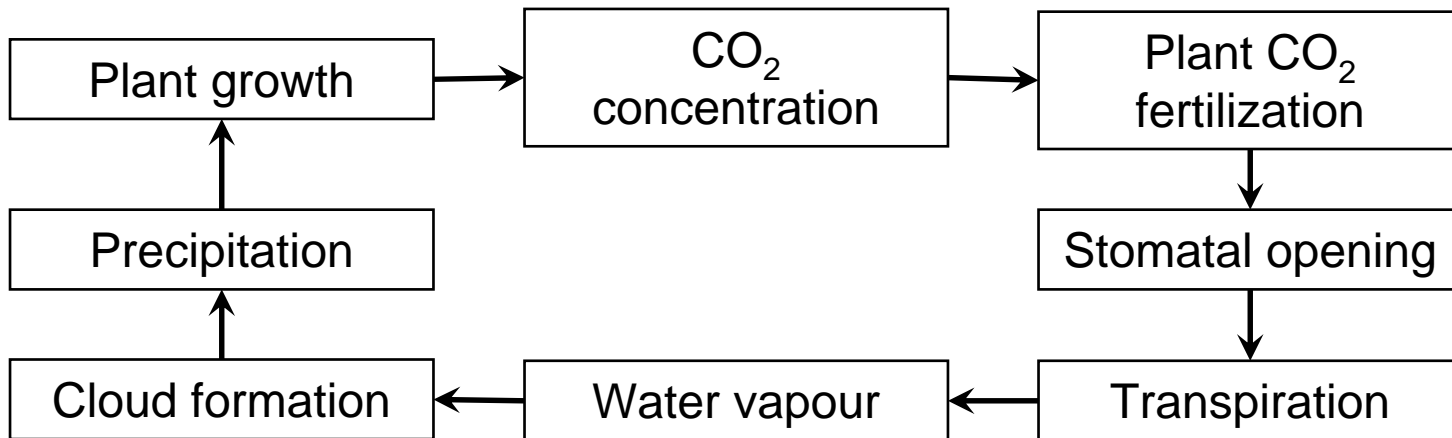
# Model Evolution



# A carbon cycle feedback



Specific to CO<sub>2</sub>:  
not all greenhouse  
gases: beware of  
CO<sub>2</sub> equivalence!



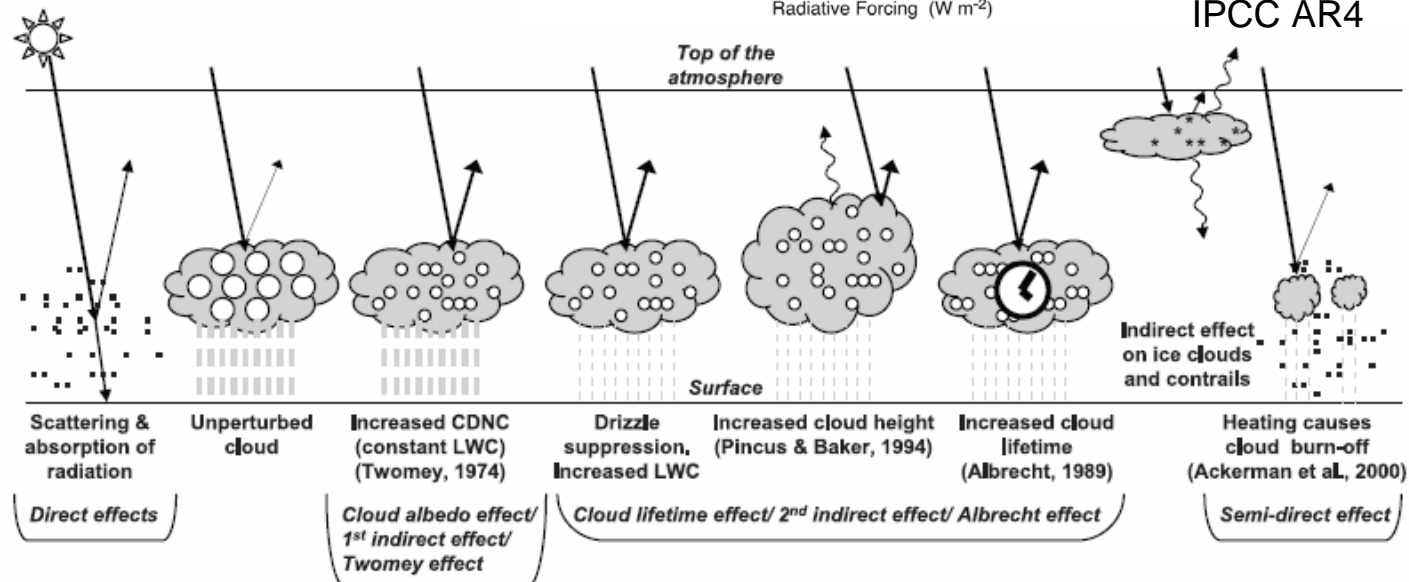
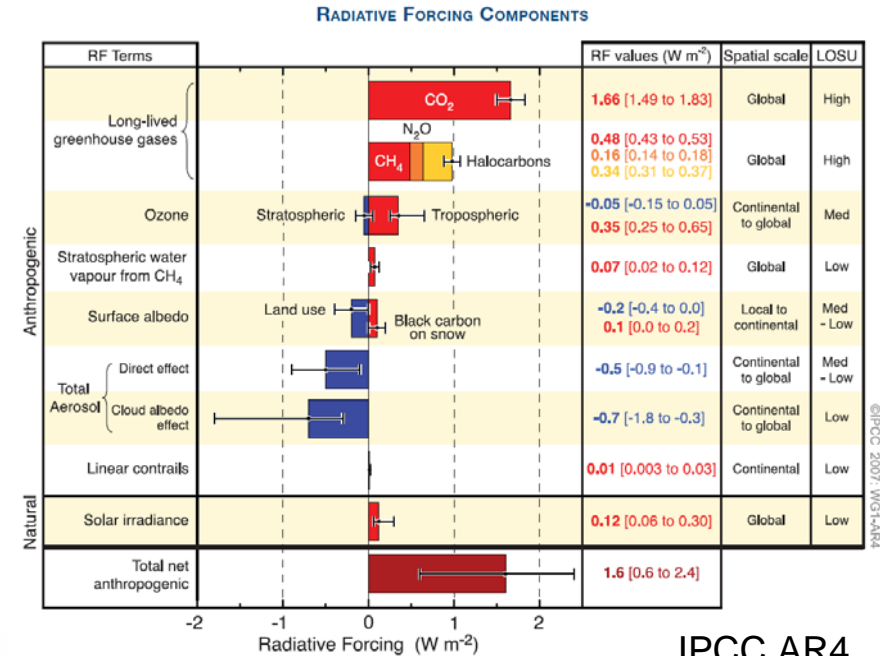
Models must be coupled to simulate feedbacks



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# Forcing and Feedbacks

- Forcings can be thought of as instantaneous feedbacks
- AQ-relevant species take part





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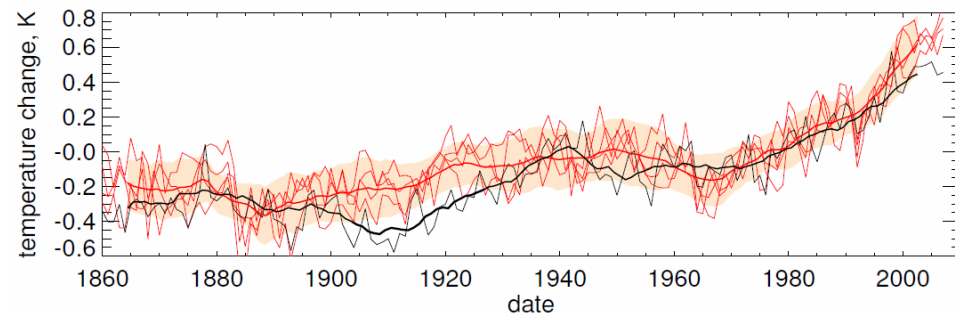
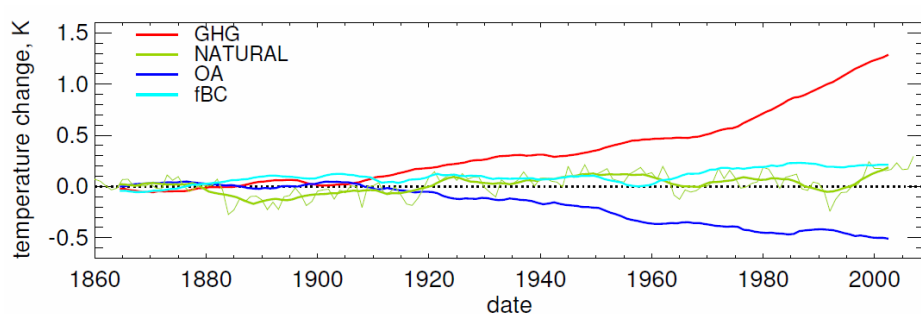
# Air Quality species in a climate change context

# Black Carbon

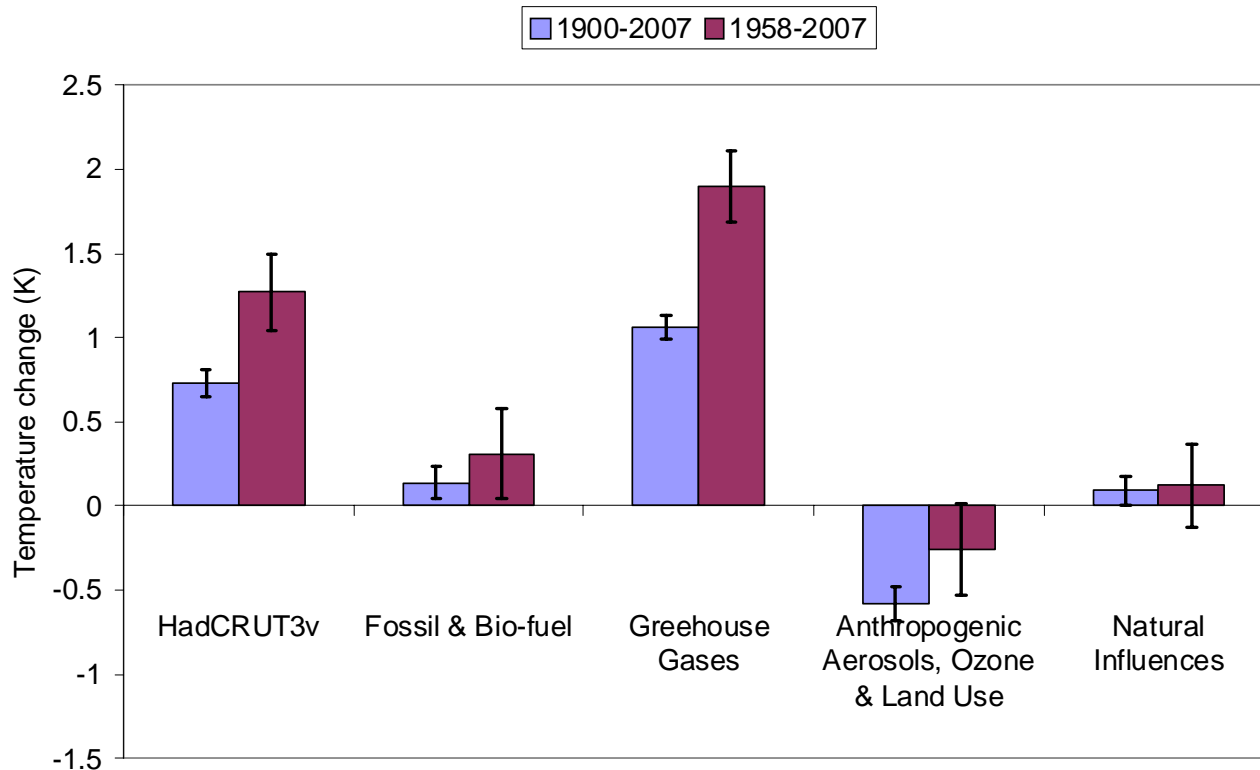
- Radiatively absorbing
  - Reduces downward shortwave (UV) radiation
  - Re-emits longwave (IR) radiation
- Deposition
  - Changes surface albedo
- Both warming and cooling
- Does black carbon mitigate or promote climate change?
  - *Do we want more or less of it?*

# Black Carbon

- HadGEM1 climate model over 20<sup>th</sup> century
- Multiple runs with and without black carbon components
- ‘Subtract’ control results to yield black carbon contribution
  - Detection & attribution experiment



# Black carbon



- BC has had a warming effect over the 20<sup>th</sup> century
- Does not include snow albedo effect

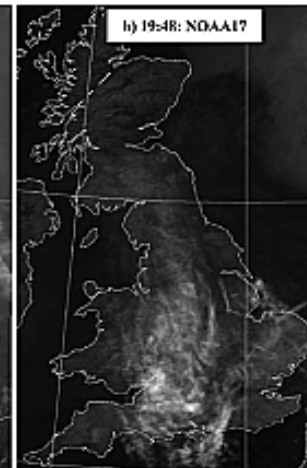
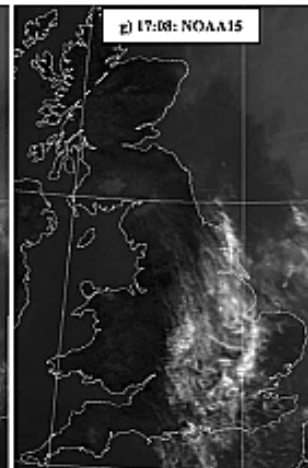
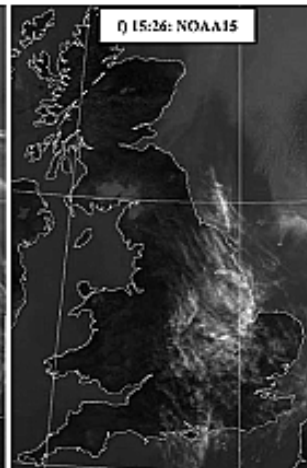
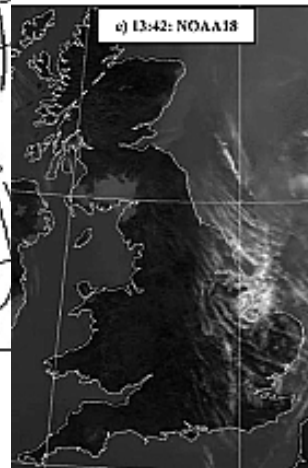
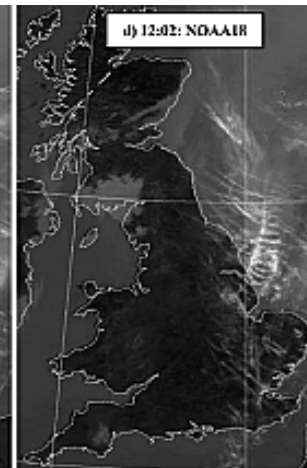
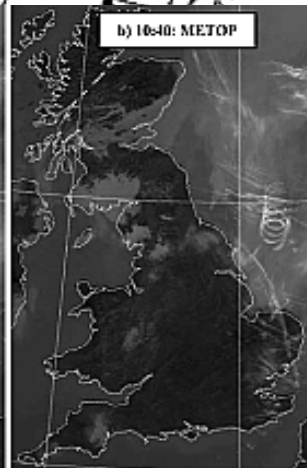
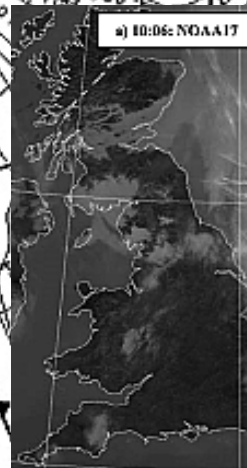
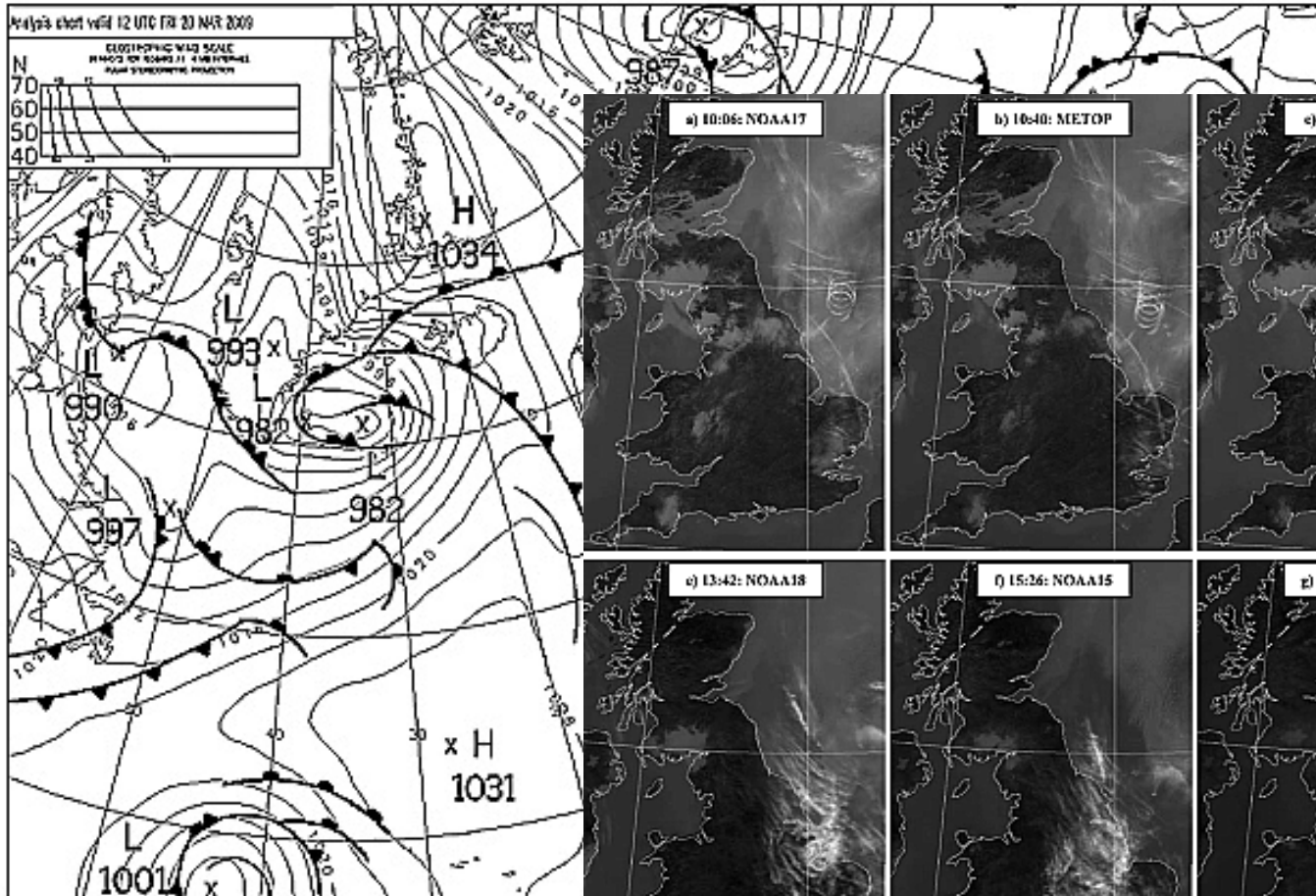
# Contrail-induced cirrus

- Non-trivial but uncertain contributor to radiative balance
- Two mechanisms:
  - Contrail dispersion
  - Aerosols acting as condensation nuclei
- Can be both cooling and warming:
  - Reflect shortwave radiation back up to space
  - Reflect longwave radiation back down to Earth
- March 2009 provides a case study...



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# Contrail-induced cirrus



# Contrail-induced cirrus

- Many sums later...
- This case:
  - Distance flown= ~1250 km
  - Global annual mean radiative forcing=  $+2 \times 10^{-6} \text{ Wm}^{-2}$
  - Forcing per unit distance=  **$+1.6 \times 10^{-9} \text{ Wm}^{-2}\text{km}^{-1}$**
- Whole civil fleet:
  - Distance flown=  $3.3 \times 10^{10}$  km
  - Global annual mean radiative forcing=  $+1 \times 10^{-2} \text{ Wm}^{-2}$
  - Forcing per unit distance=  **$+3 \times 10^{-13} \text{ Wm}^{-2}\text{km}^{-1}$**

# Contrail-induced cirrus

- ~5000 such events a year to reach the global annual mean
  - Or ~7% of the diurnally-averaged forcing
- Atmospheric conditions appear to have a huge effect on the contribution of contrail-induced cirrus
- How typical are these events?



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# The meeting of two worlds?

Co-benefits and trade-offs

# Some assumptions...

- Air quality: Mitigate the impact of emissions
  - Cost-effective emission reductions
- Climate change: Mitigate and/or adapt
  - Mitigation: Reduce greenhouse gas emissions
  - Adaptation: Minimise the *negative* impacts of climate change

# Co-benefits

- Black carbon
  - Reductions are good for air quality and mitigating climate change
  - Lifetime of black carbon  $\ll$  CO<sub>2</sub>: quick win for climate
- Contrail-induced cirrus
  - Reductions are good for mitigating climate change
  - Avoid favourable conditions to minimise formation

# Trade-offs

- Black carbon
  - Reduction in one emission leads to an increase in another?
- Contrail-induced cirrus
  - Re-routing increases CO<sub>2</sub> and other emissions?
  - Knock-on change in scheduling affects air quality management?



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# Making decisions (I)

- AQ policy/legislation is well established in the developed world and making a difference:
  - Local measures have local impacts
  - Measureable impacts over a few years
- CC policy is still developing:
  - Global agreements required
  - Measureable impacts over decades
- Different stakeholder (funding?) groups?

# Making decisions (II)

- Weigh up the impacts of different decisions, eg
  - Air quality: Health, vegetation damage
  - Climate change: Health (eg heat stress), food, water, ecosystems, landscape, natural disasters, energy, transport... ..air quality
- How do we measure these impacts on the same scale?
  - Lives? £s? Polar Bears?
- What is the global optimum atmospheric policy?
  - Who decides?



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# Conclusions

# Conclusions

- Earth system modelling is starting to consider air quality-relevant species in a useful way
- Good for climate change may not be good for air quality: co-benefits and trade-offs
  - Measuring the physical changes is hard; their impacts harder
  - Comparing air quality and climate change impacts on the same scale is *really* hard!
- Climate change and air quality stakeholders share the same atmosphere, but policies may not be mutually beneficial
- Despite ‘switching’, my day job is still to try and *measure* things in a meaningful and useful way



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# Questions and answers

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