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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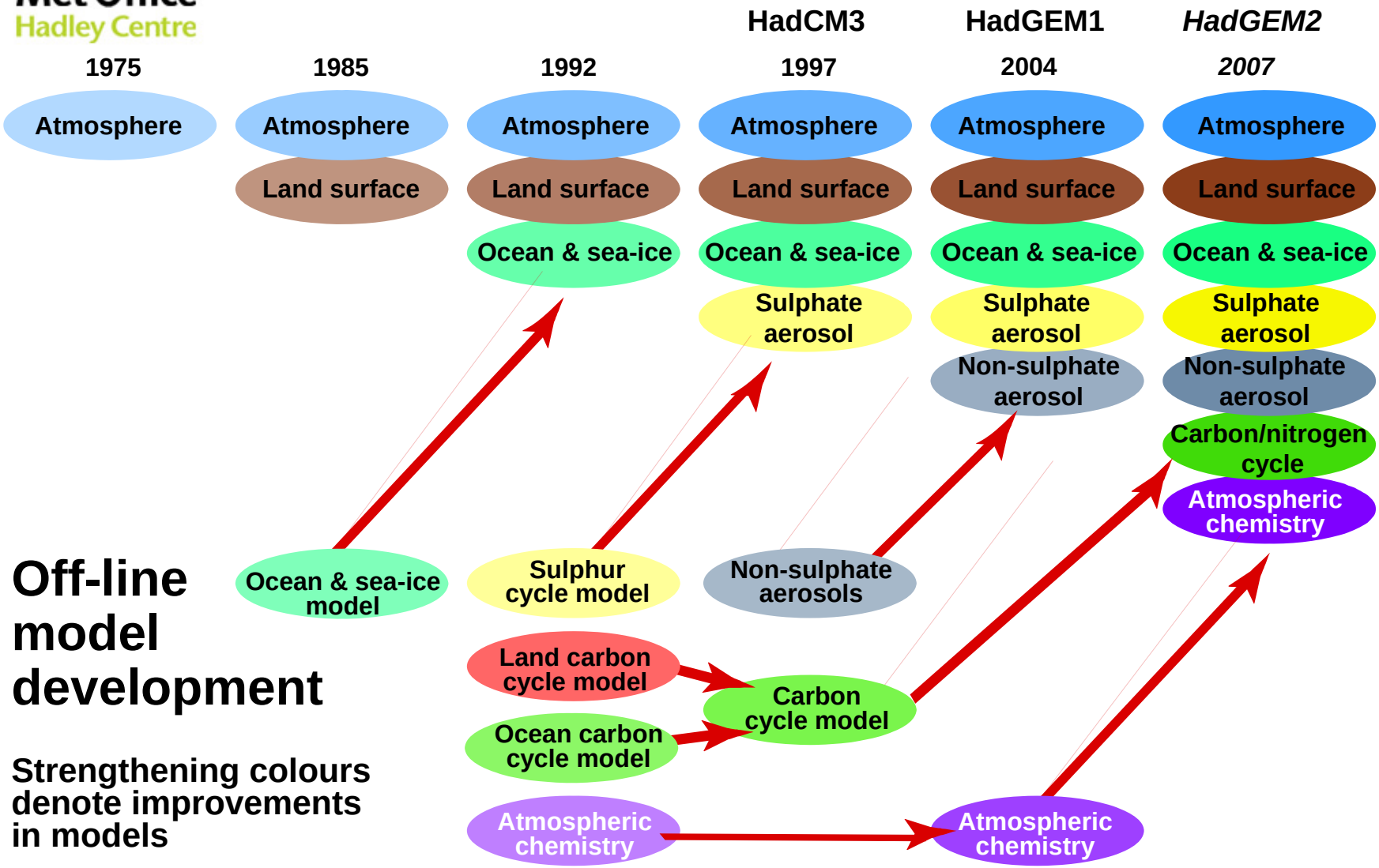
Earth System modeling at the Met Office

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

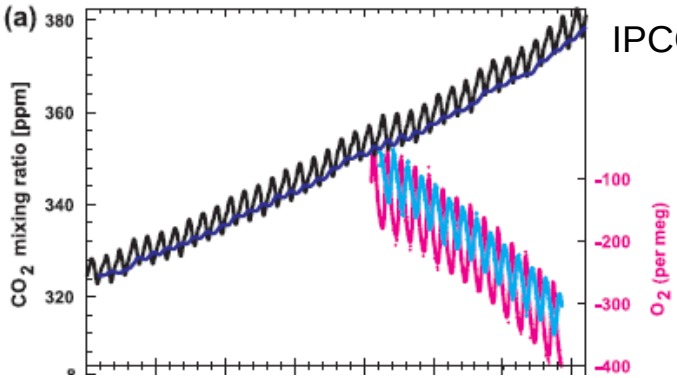
Model Evolution



Off-line model development

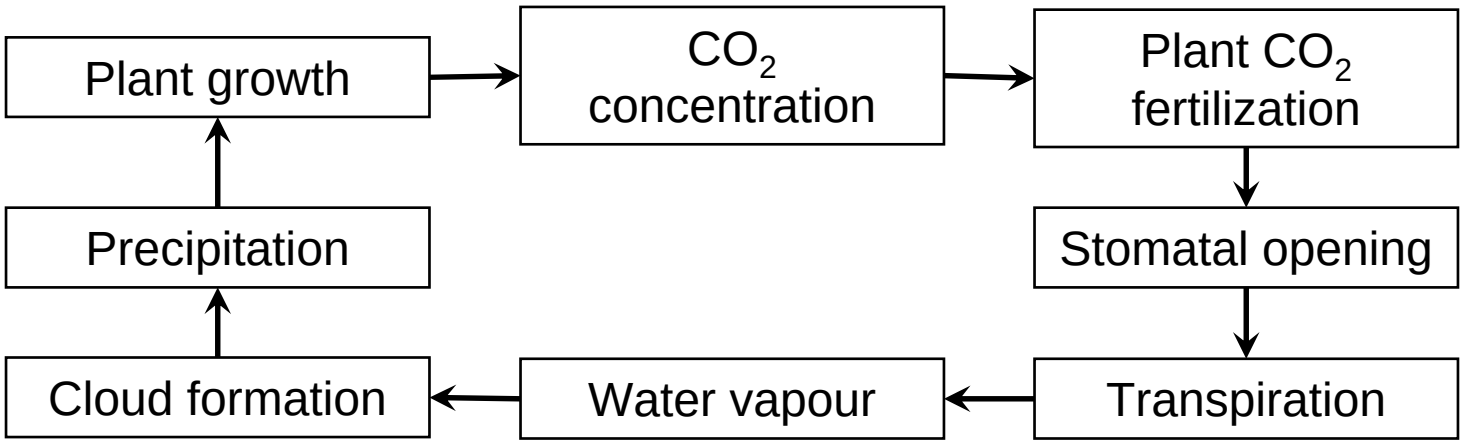
Strengthening colours denote improvements in models

A carbon cycle feedback



IPCC AR4

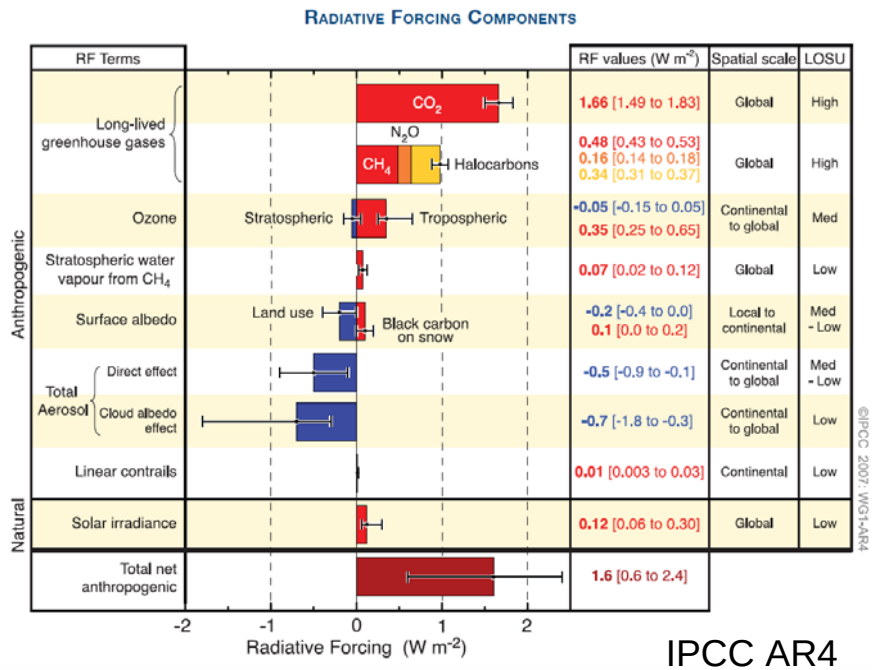
Specific to CO_2: not all greenhouse gases: beware of CO_2 equivalence!



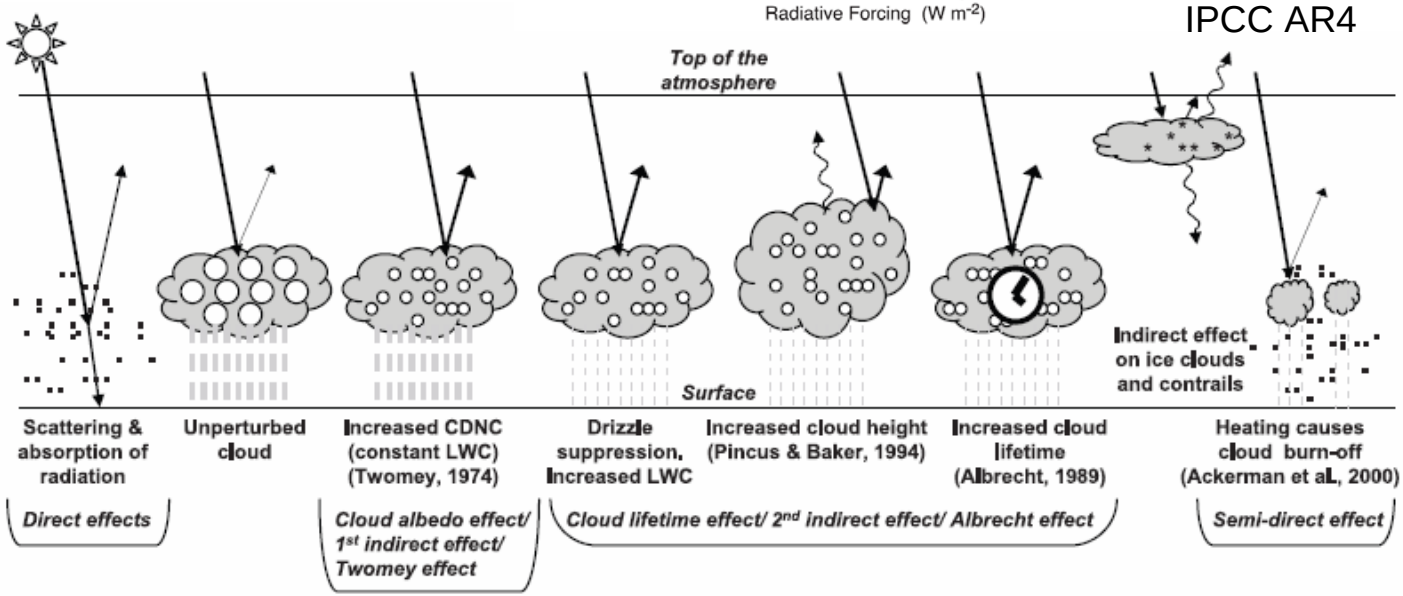
Models must be coupled to simulate feedbacks

Forcing and Feedbacks

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



IPCC AR4



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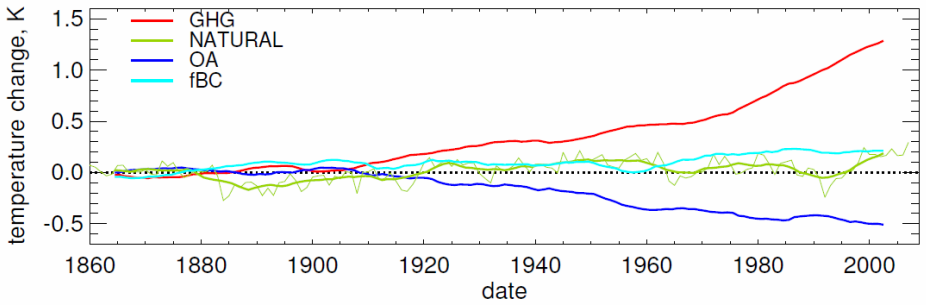
Air Quality species in a climate change context

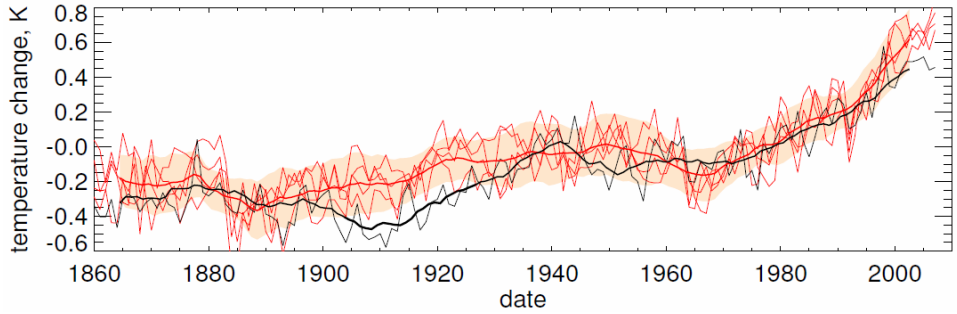
Black Carbon

- 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

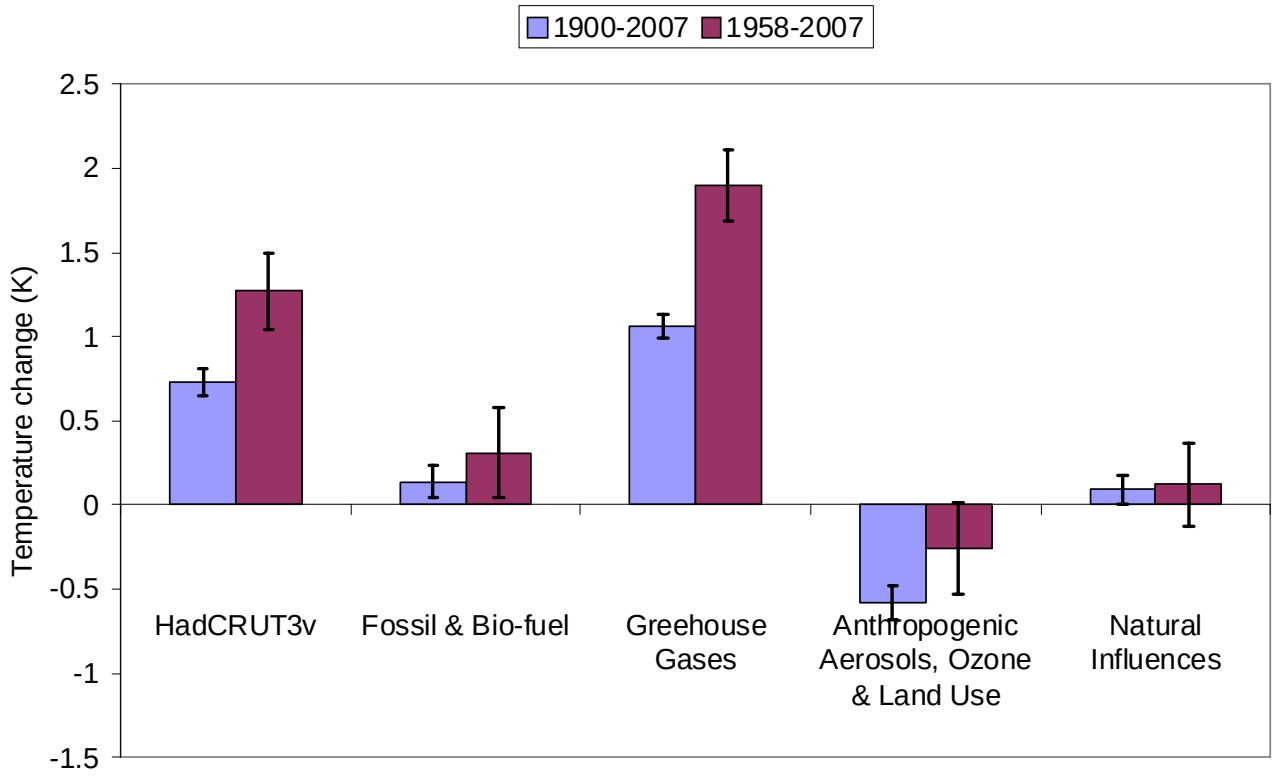
- HadGEM1 climate model over 20th century
- Multiple runs with and without black carbon components
- ‘Subtract’ control results to yield black carbon contribution
  - Detection & attribution experiment





Jones et al. Atmos. Chem. Phys. **11** 799-816 (2011)

Black carbon



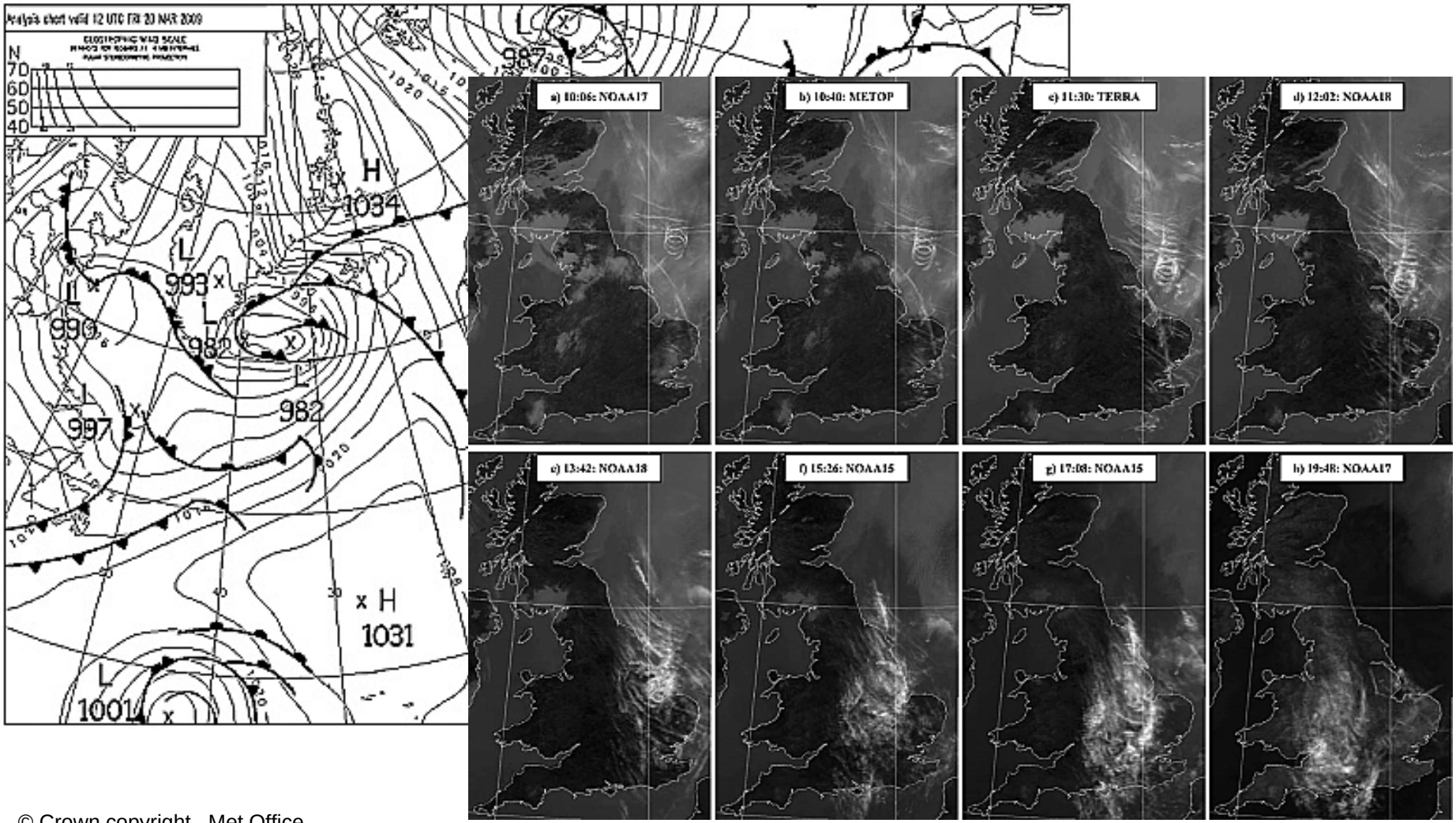
- BC has had a warming effect over the 20th century
- Does not include snow albedo effect

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…

Haywood et al. J. Geophy. Res. **114** D24201 (2009)

Contrail-induced cirrus



Contrail-induced cirrus

- Many sums later…
- This case:
  - Distance flown= ~1250 km
  - Global annual mean radiative forcing= $+2 \times 10^{-6}$ Wm^{-2}
  - Forcing per unit distance= **$+1.6 \times 10^{-9}$ $Wm^{-2}km^{-1}$**
- Whole civil fleet:
  - Distance flown= 3.3e10 km
  - Global annual mean radiative forcing= $+1 \times 10^{-2}$ Wm^{-2}
  - Forcing per unit distance= **$+3 \times 10^{-13}$ $Wm^{-2}km^{-1}$**

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 << CO_2: 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_2 and other emissions?
  - Knock-on change in scheduling affects air quality management?

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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