The importance of linking air quality and climate change

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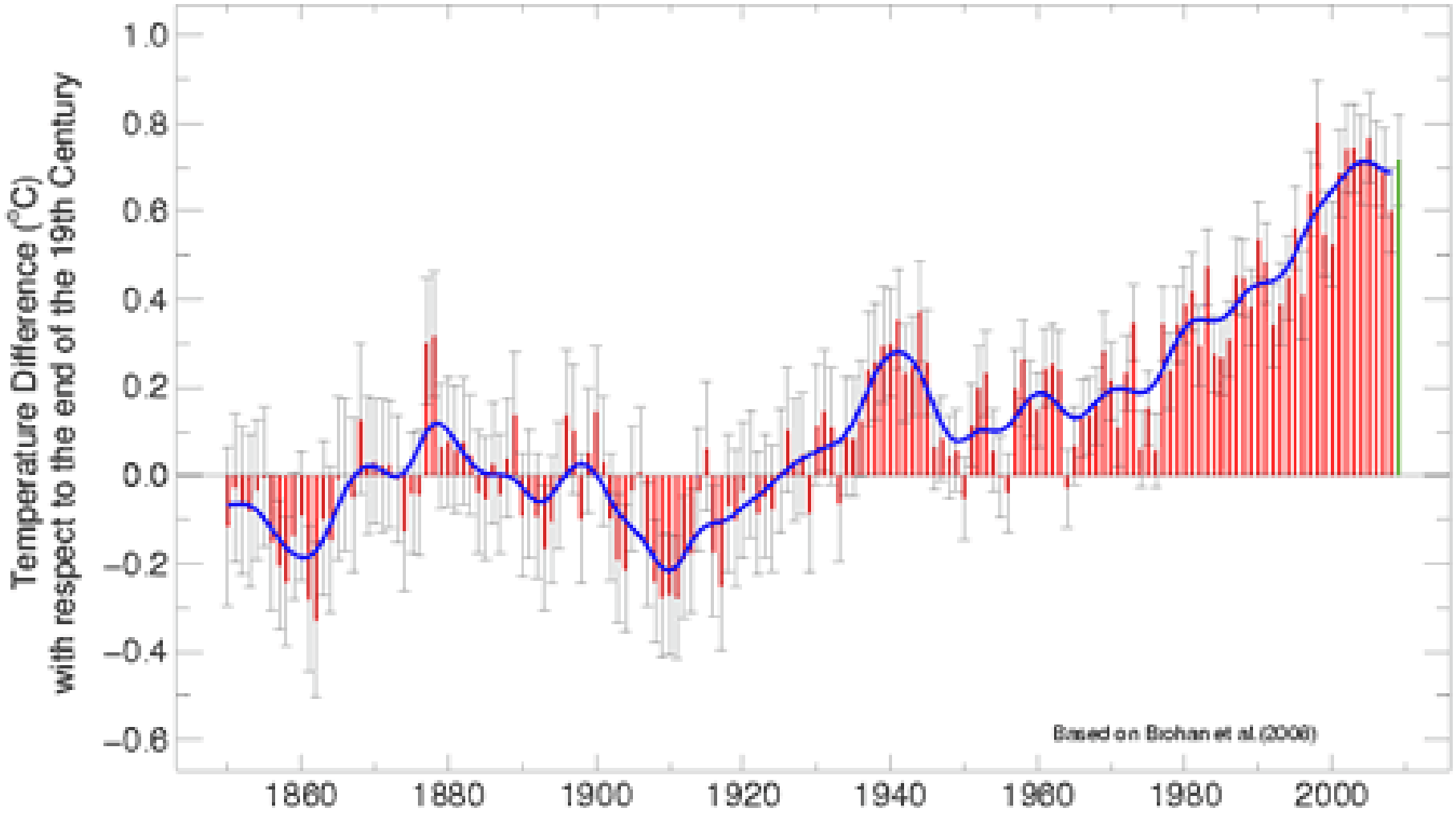
Met Office Hadley Centre – Atmospheric Composition and Climate

Outline

1. Climate Change
2. Effects of climate change on air quality
3. Effects of air quality pollutants on climate change
4. Summary

Climate Change

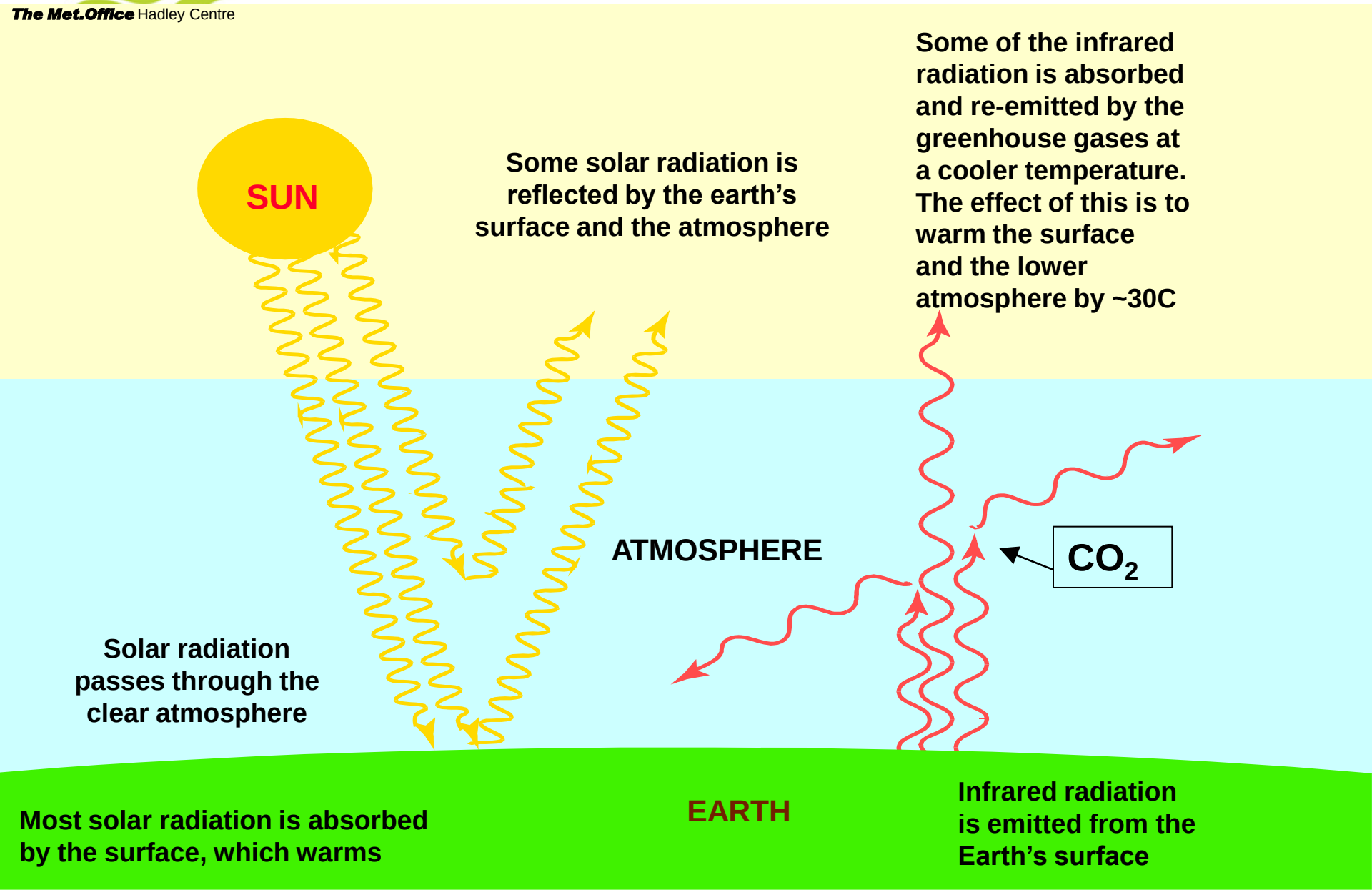
How has climate changed?



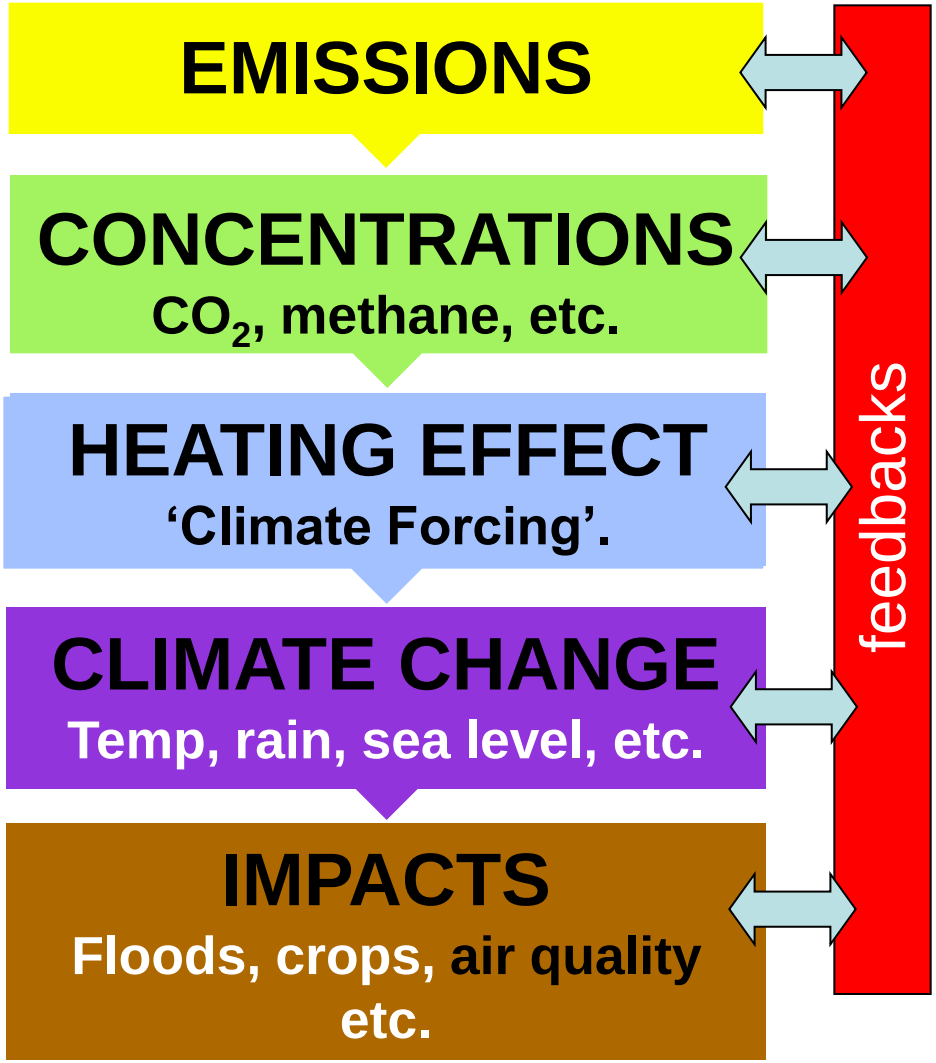
GJJ1999

THE GREENHOUSE EFFECT

The Met.Office Hadley Centre



Stages in predicting climate change



Scenarios from population, energy, economics models

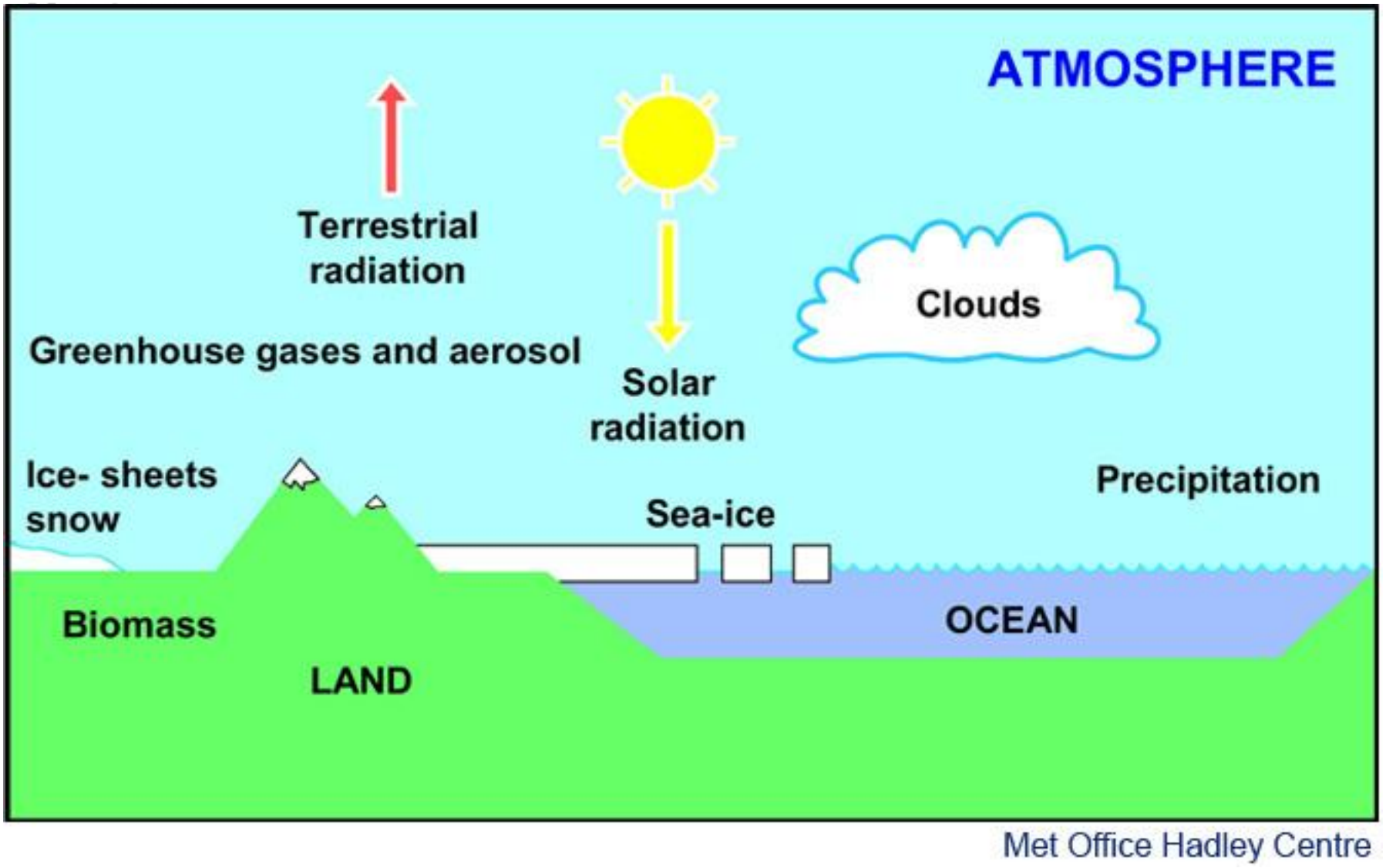
Carbon cycle and chemistry models

Gas properties

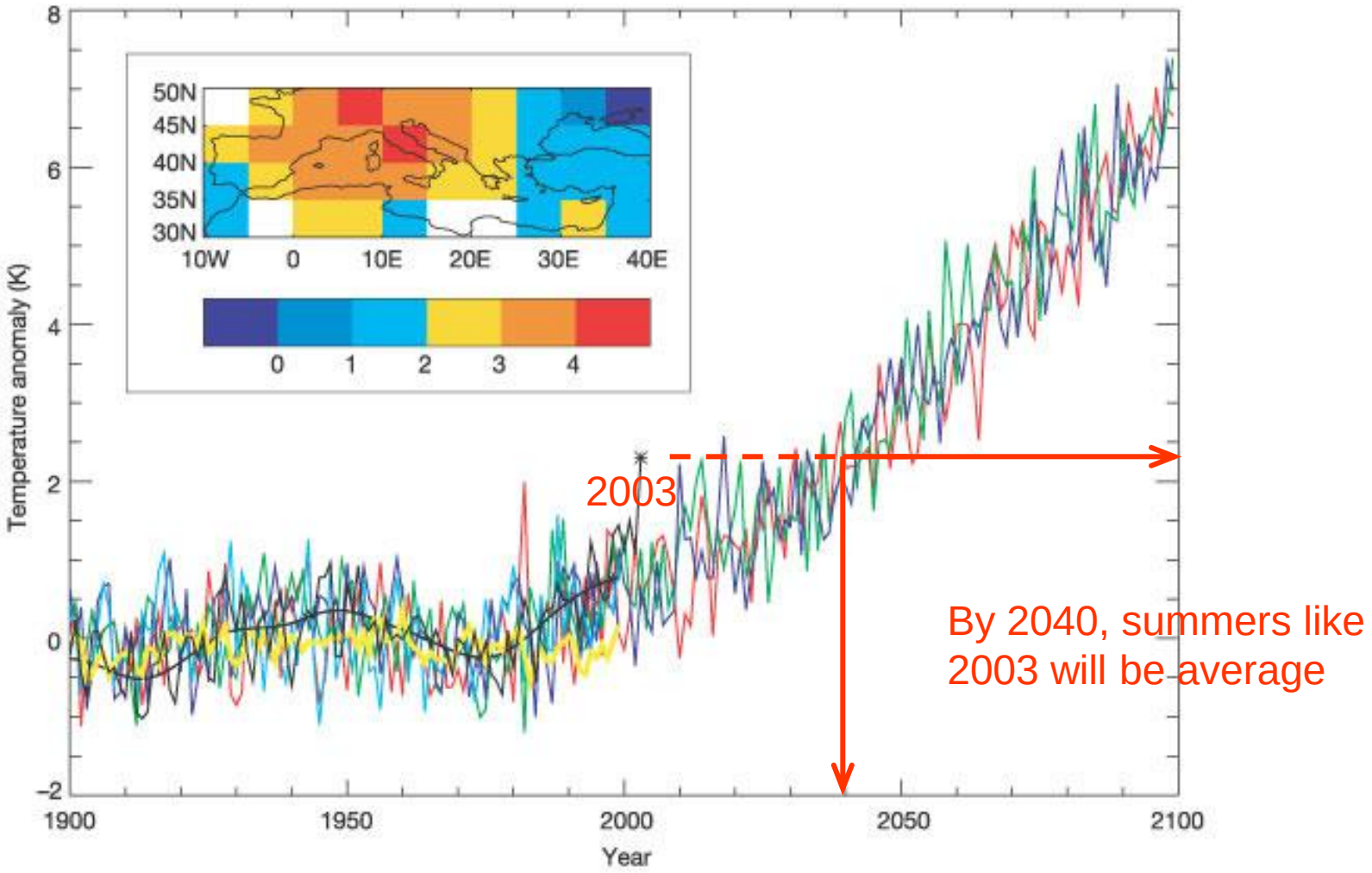
Coupled climate models

Impacts models

The climate system



Climate change in Europe



21-38% of excess deaths in UK due to August 2003 heatwave were due to increased air pollution (ozone and particulate matter) – Stedman 2004

Effect of climate change on air quality

Importance of climate change

- Climate change is not just about temperature change, there are also changes in:
  - Humidity (specific)
  - Clouds and precipitation
  - Winds
  - others…

How climate affects air quality

- Air quality is affected by many factors
  - Emissions – temperature dependence
  - Transport – winds
  - Chemistry – temperature and humidity
  - Deposition – precipitation

- All these are in turn affected by a changing climate

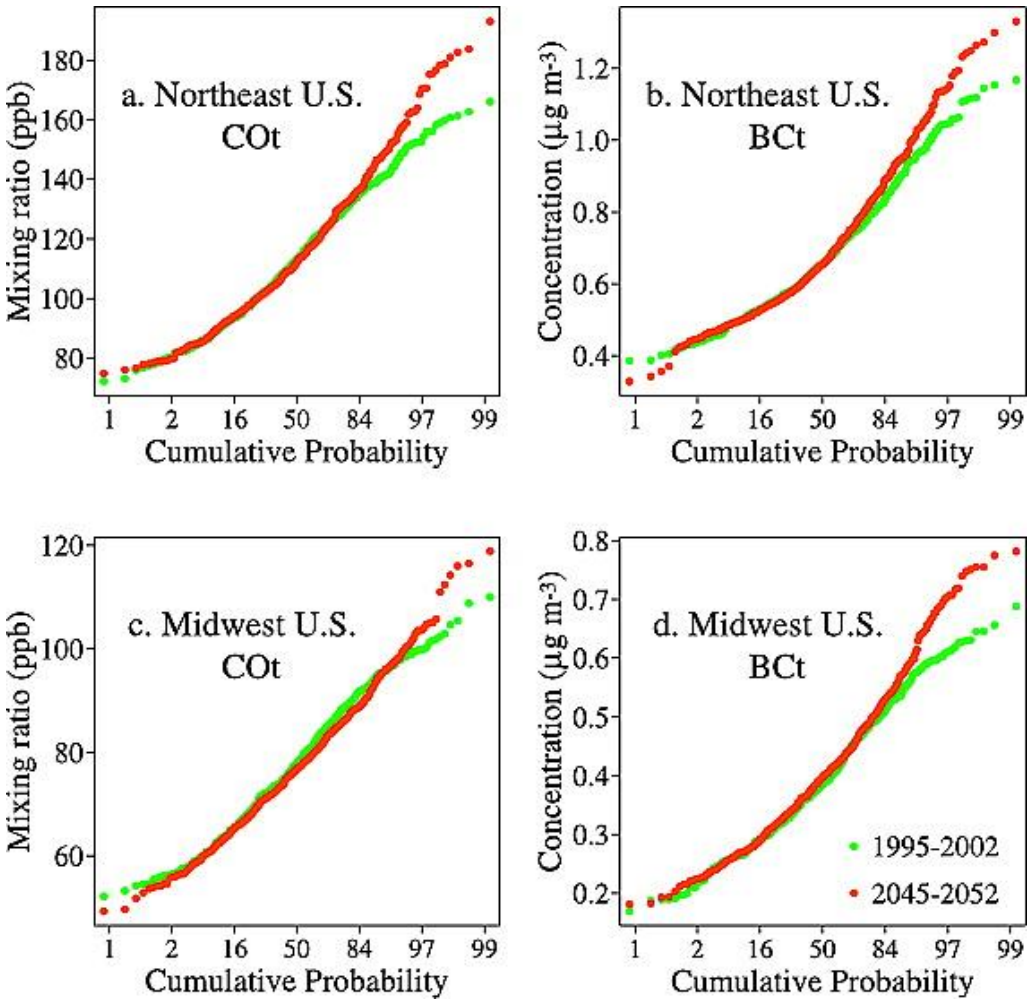
Effect of climate change on transport

Climate change can impact on the likelihood of pollution events e.g.

- Number and strengths of summer highs
- Number and duration of calm winter days

- Mean concentrations the same

- Higher chance of extreme concentrations

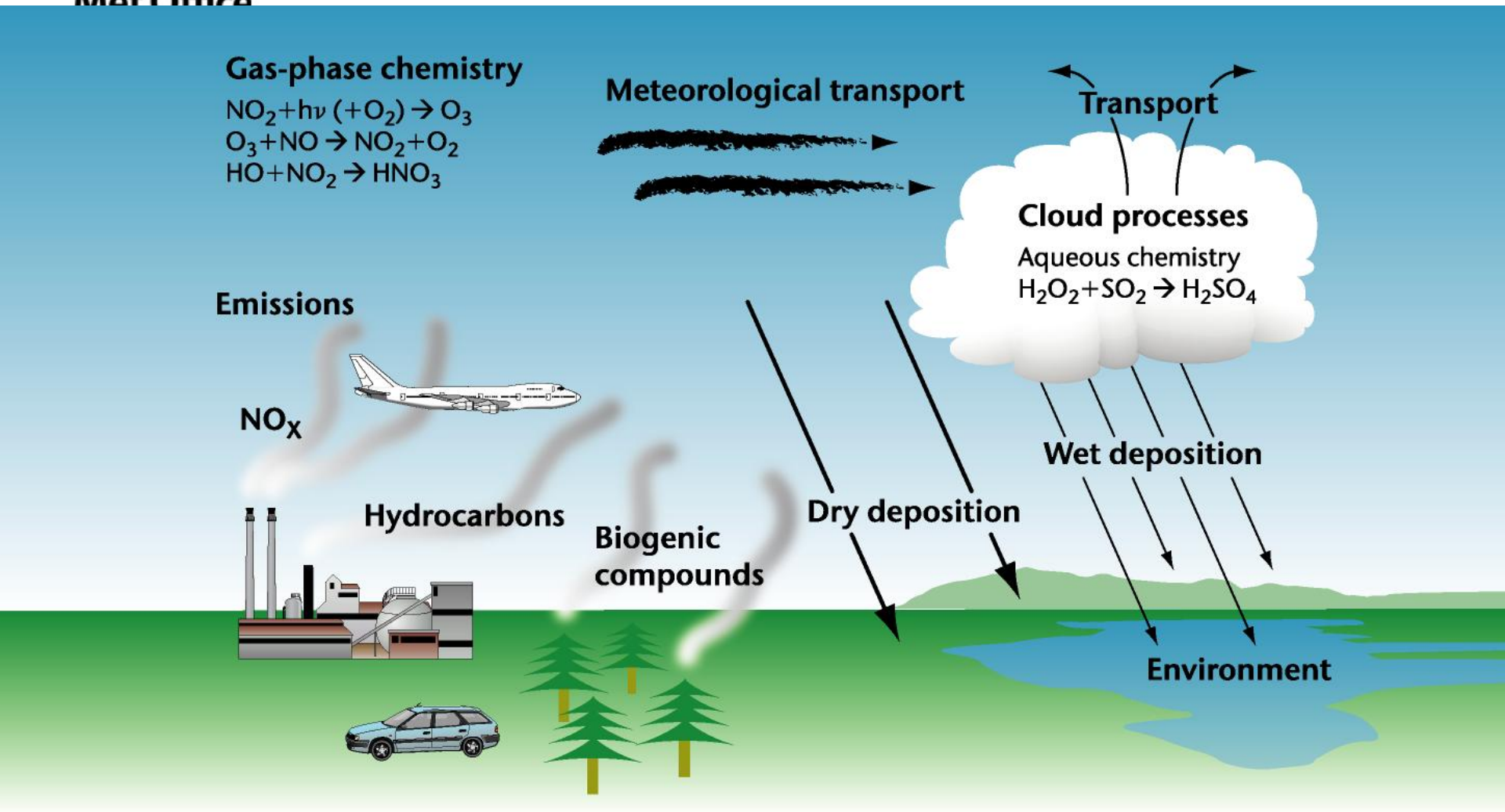


Mickley et al. 2004 GRL doi:10.1029/2004GL021216

Chemistry

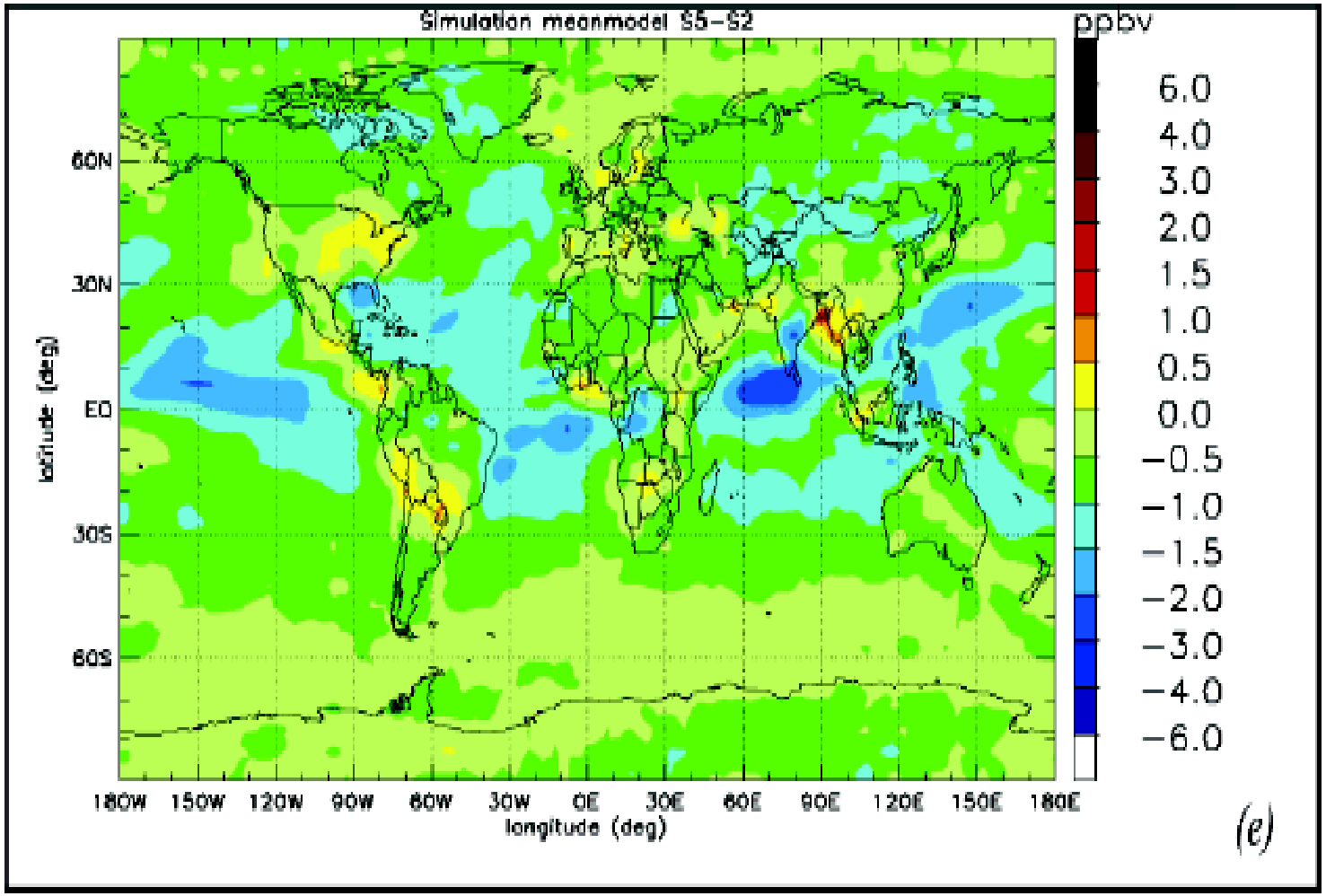
- Focus on surface ozone:
  - Damaging to human heath, and to crop yields
  - **Produced by**: Oxidation of hydrocarbons in presence of NO_X
  - **Destroyed by**: UV light in presence of water, and deposition to the surface
- Ozone will change in future
  - Changes in emissions of man-made pollutants
  - Changes in climate
- Increased humidity (water vapour)$\rightarrow$ Destruction of ozone
- Increased tropospheric temperature$\rightarrow$Production of ozone

Modelling atmospheric chemistry



Impact of climate change on surface ozone

Effect of 2030 climate change



Climate change affects emissions and deposition

- Emissions
  - Anthropogenic – changes in consumption, volatilisation of pollutants
  - Wild fires – soil moisture
  - Lightning – convective clouds
  - Vegetation and soils – temperature, sunlight
- Deposition
  - Removal by precipitation
  - Removal at the surface – vegetation and soils

Volatile organic compounds (VOCs)

Stevenson et al. JGR 2006	Man – made	Vegetation (isoprene)	Vegetation (terpenes)	Biomass burning
VOC emissions	116 Tg	580 Tg	295 Tg	31 Tg

"*Approximately 80% of our air pollution stems from hydrocarbons released by vegetation, so let's not go overboard in setting and enforcing tough emission standards from man-made sources*.", Ronald Reagan, *Sierra Magazine*, Sep. 10, 1980

"*[research does] not provide any evidence that responsibility for air pollution can or should be shifted from humans to trees.*", Purves et al., *Global Change Biology*, 2004

Coupling chemistry to ecosystems

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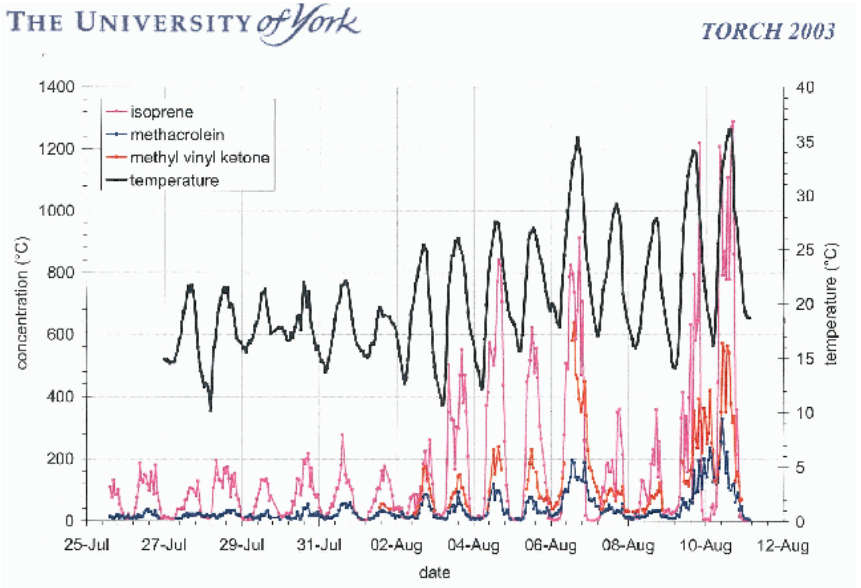
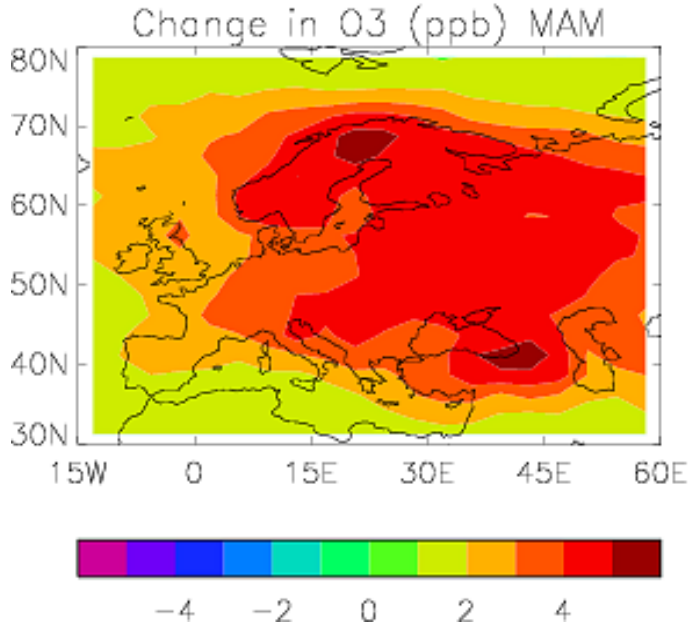
Emissions

- Increasing temperature increases hydrocarbon emissions from vegetation e.g. isoprene



Deposition

- Doubling CO_2 causes leaf stomata to open less
  - Less uptake of ozone
  - Higher ozone concentrations at ground level
  - Good for plants, bad for people



Summary – effects of climate change on air quality

- Increased humidity reduces tropospheric background ozone. Increased temperature increases local ozone production – which wins?
- Need to look at impact on biospheric emissions/deposition
- Changes in transport could be important
- Effect of climate change is likely to increase air pollution
- Studies have focussed on global-scale pollution, need to look at urban-scale
- Still large uncertainties

Effects of air quality pollutants on climate change

Man-made greenhouse gases dominate the change in climate forcing

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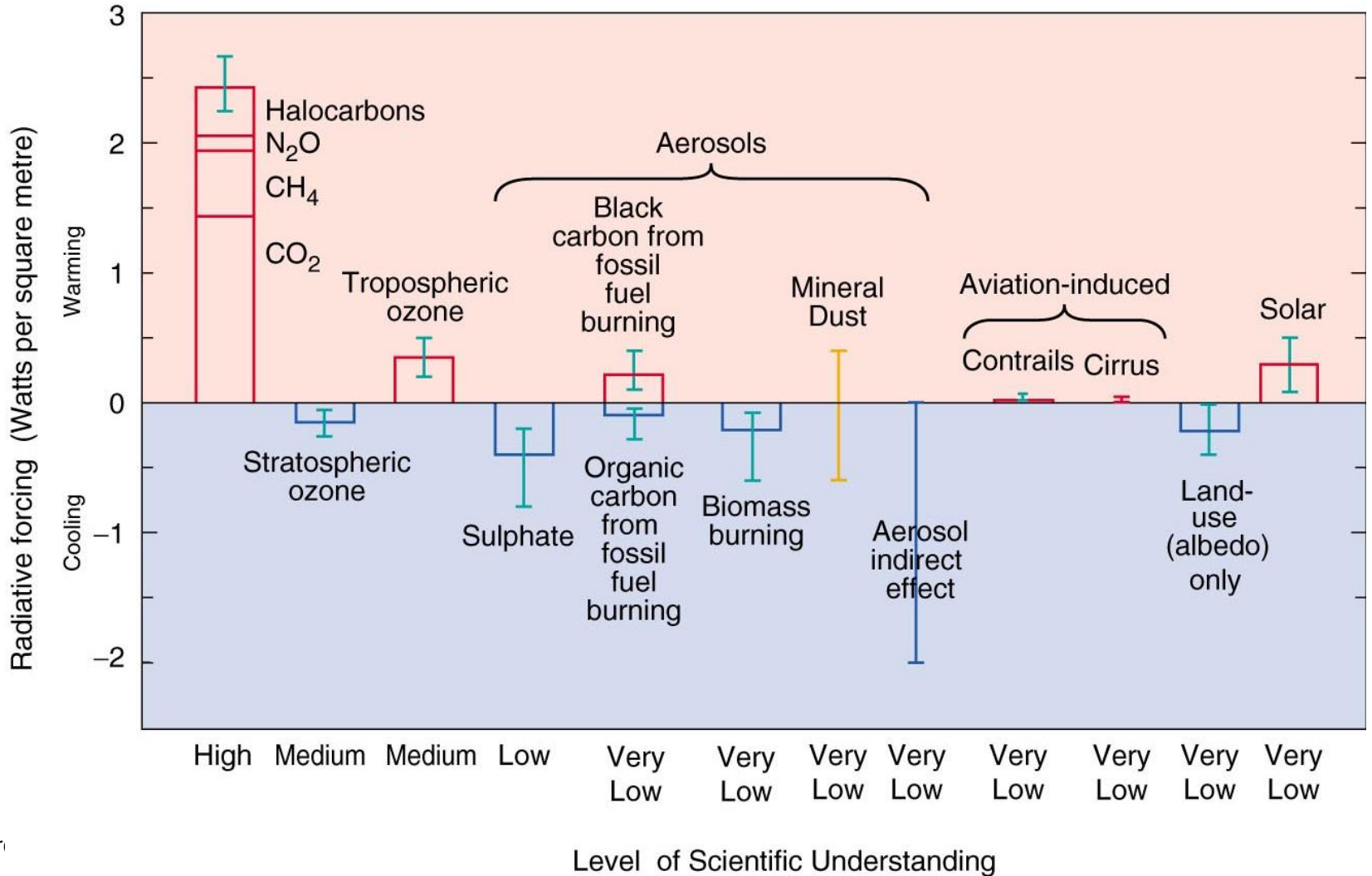
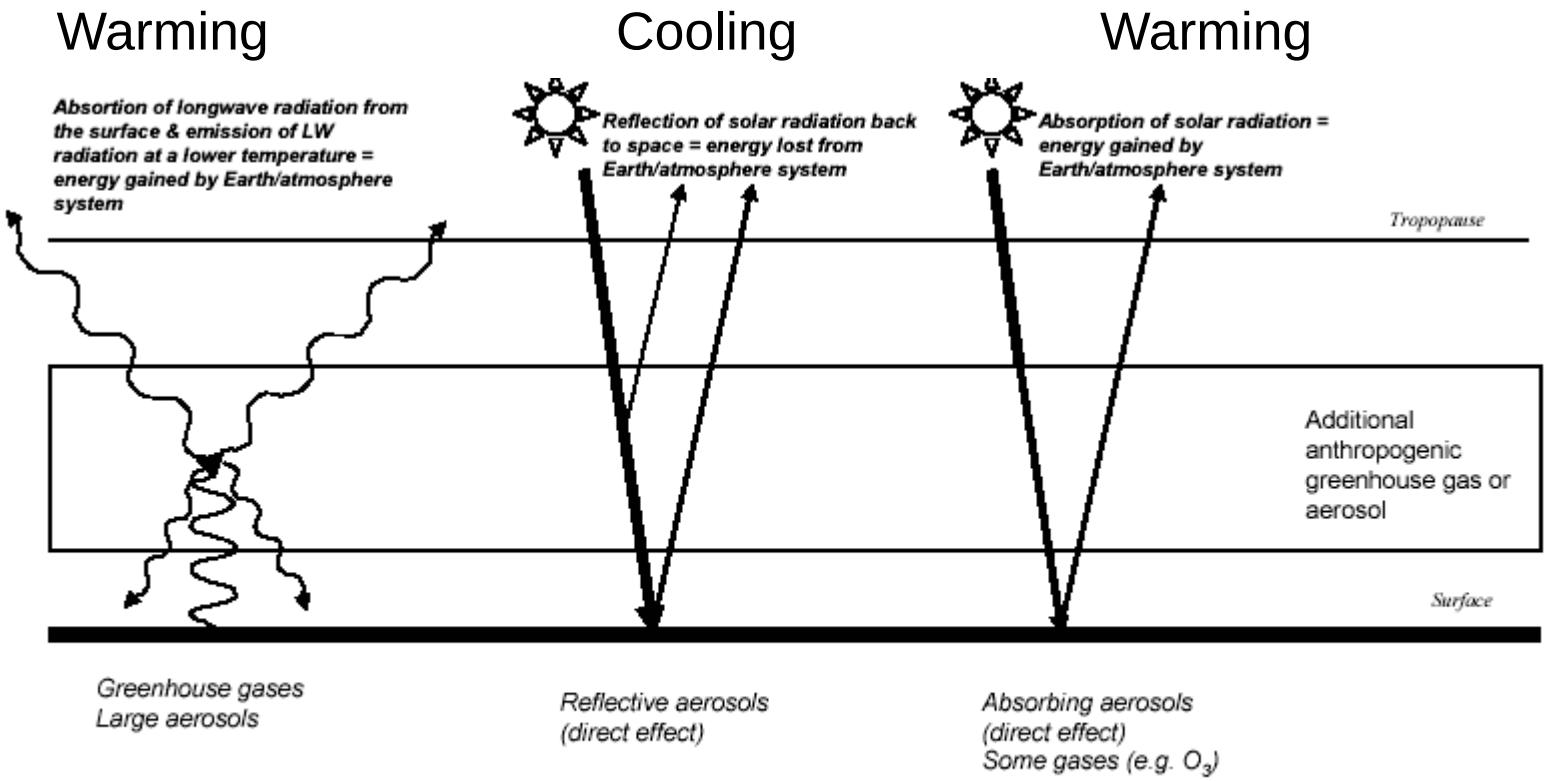
Change between 1750 and 2000



Effect of air quality constituents on climate change



CO_2, **methane**, **ozone,** N_2O, Halocarbons

Sulphate, nitrate, ammonium, organic carbon

Black carbon (soot), organic carbon

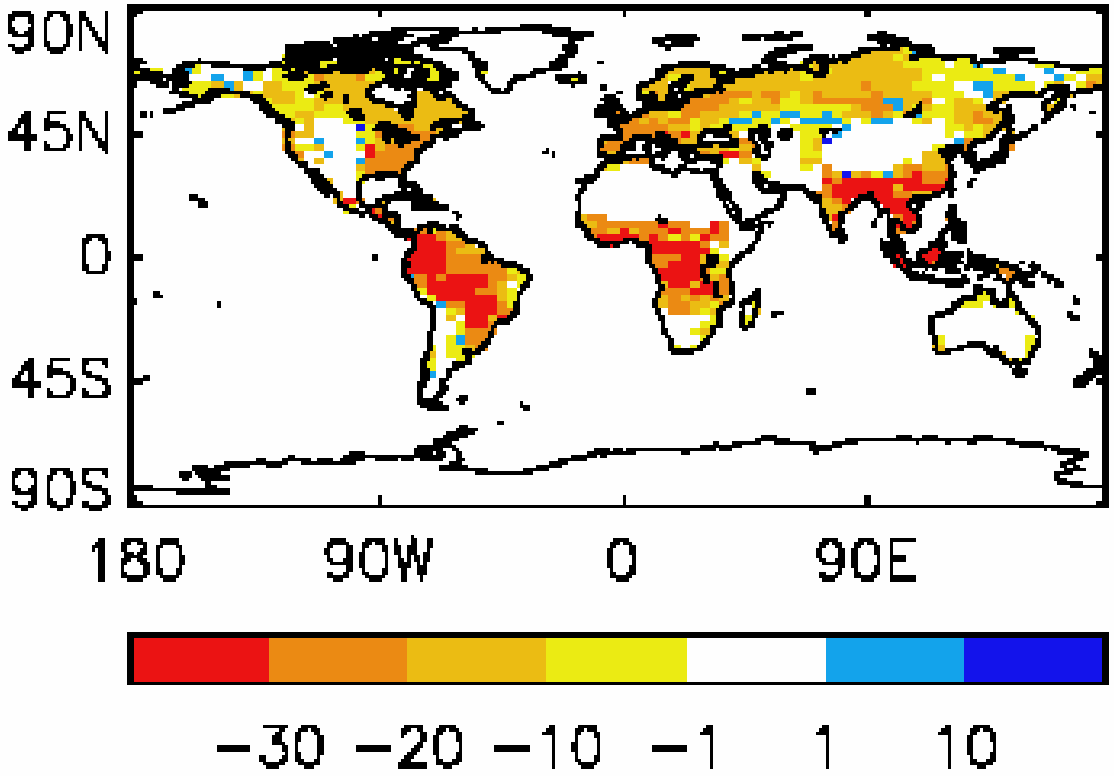
Consequences of pollutant emissions

- Methane – Fossil-fuel combustion, agriculture, land-fill, natural
  - Direct greenhouse gas - warming
  - Reacts to produce ozone - warming
- NO_x ($NO+NO_2$) – FF combustion, natural
  - Reacts to produce ozone – warming
  - Reacts to produce nitrate aerosol – cooling
  - Reacts to increase methane removal – cooling
  - Overall net cooling
- Volatile Organic Compounds – industry, natural (major source)
  - React to produce ozone – warming
  - React to decrease methane removal – warming
  - React to form organic carbon aerosol – cooling
  - Overall net cooling (depends on species)
- SO_2 – coal-fired power stations, shipping, natural
  - Reacts to produce sulphate aerosol – cooling
- Ammonia – industry, agriculture, natural
  - Reacts to produce ammonium aerosol – cooling
- Black carbon – FF combustion, natural
  - Direct warming effect – warming

Indirect climate effects

- Ozone is poisonous to plants, hence reduces CO_2 uptake
- Climate effect of ozone on CO_2 is approximately equal to direct warming from ozone

Sitch et al. Nature 2007



% change in Gross Primary Productivity due to ozone changes from 1860-2100

Quantifying the effects on climate

- **Radiative Forcing** is a measure of the change in radiative balance for a change in the concentration of an atmospheric constituent.
- **Global Warming Potential** is the time integrated RF (usually over 100 years) due to the emission of 1kg of a substance, relative to the emission of 1kg of CO_2.
  - Substances with lifetimes shorter than 100 years have lower GWPs
  - For substances that are not well-mixed (lifetimes less than a few weeks) the GWP depends on where the pulse is emitted from.
- **Global Temperature Potential** is the change in global surface temperature (usually after 100 years) due to the emission of 1kg of a substance, relative to CO_2.
- None of these take into account that for short-lived species the change in surface temperature may vary considerably across the globe.

Air Quality – climate change: win-win and trade-offs

- Conservation and efficiency improvements
  - Win-win – For climate, CO_2 dominates co-emitted species
- Abatement measures -(flue gas desulphurisation, catalytic converters, particle filters)
  - Improve air quality, but mostly increase CO_2 through decreased efficiency (but new catalyst technologies may allow more efficient vehicle engines)
  - Removing aerosol precursors (eg. SO_2, NO_X) can warm climate further.
  - Removing black carbon particles cools climate
  - Catalytic converters can generate N_2O
- Fuel switching (eg. Petrol to diesel)
  - Less CO_2, but more black carbon (GWP 680, Bond and Sun 2006)
  - Bad for AQ, but what is the net effect on climate?

Summary of effects of air pollution on climate

- Non-CO_2 pollutants can have a warming or cooling effect on climate
- Co-emitted CO_2 dominates climate effect
  - Black carbon from diesel 10-20% of CO_2 warming (Bond and Sun, 2006)
- Pollution abatement is beneficial to health, but generally leads to an increase in global warming
  - Particle filters on diesel cars may give net cooling
- Metrics for comparing climate effects of long and short-lived pollutants are still evolving

Overall Summary

- Climate change will affect air quality
- It is likely to increase pollution in industrialised regions
- We need to take this into account when planning future air quality legislation
- Air quality pollutants can warm or cool climate
- We don’t have a unique way of comparing the effects of short-lived and long-lived pollutants
- Technologies to abate pollution can often lead to a (small) climate warming

- A holistic approach is key when considering the combined issue of climate change and air quality
- AQEG “Air Quality and Climate Change: A UK perspective” 2007