Air Quality Modelling under a Future Climate

Rachel McInnes

Met Office Hadley Centre

Quantifying the impact of air pollution on health - Fri 12th Sep 2014

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Air Quality Modelling under a Future Climate

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What do air quality & health mean to the Met Office?

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Climate

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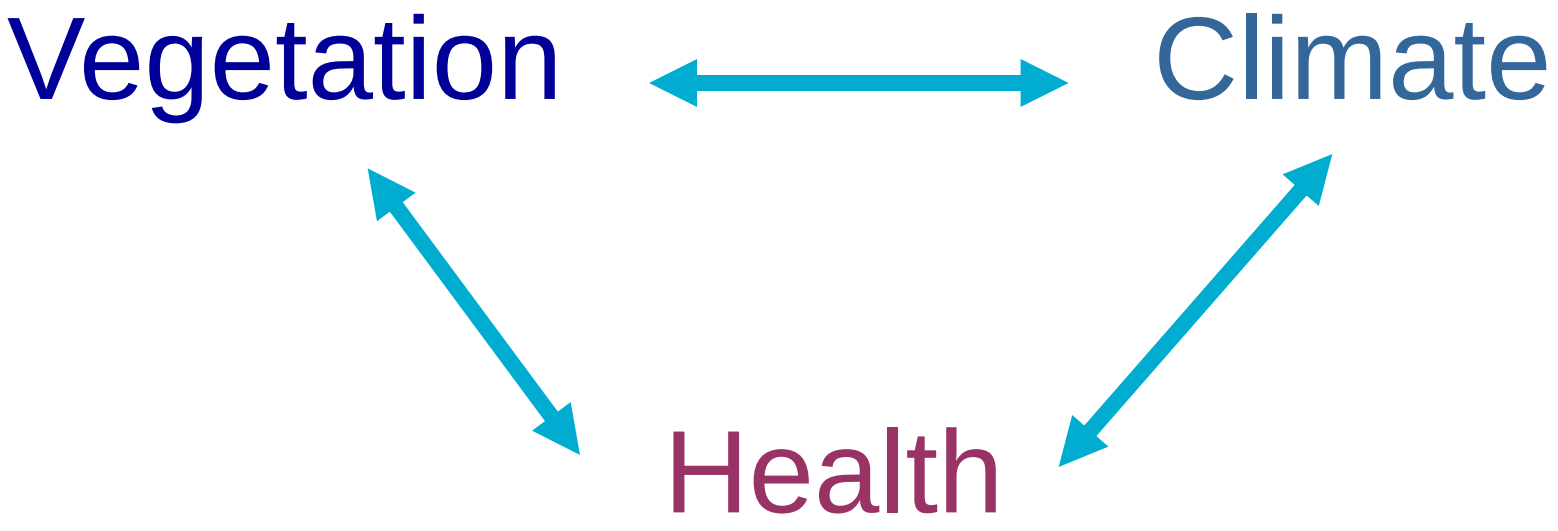
What do air quality & health mean to the Met Office?



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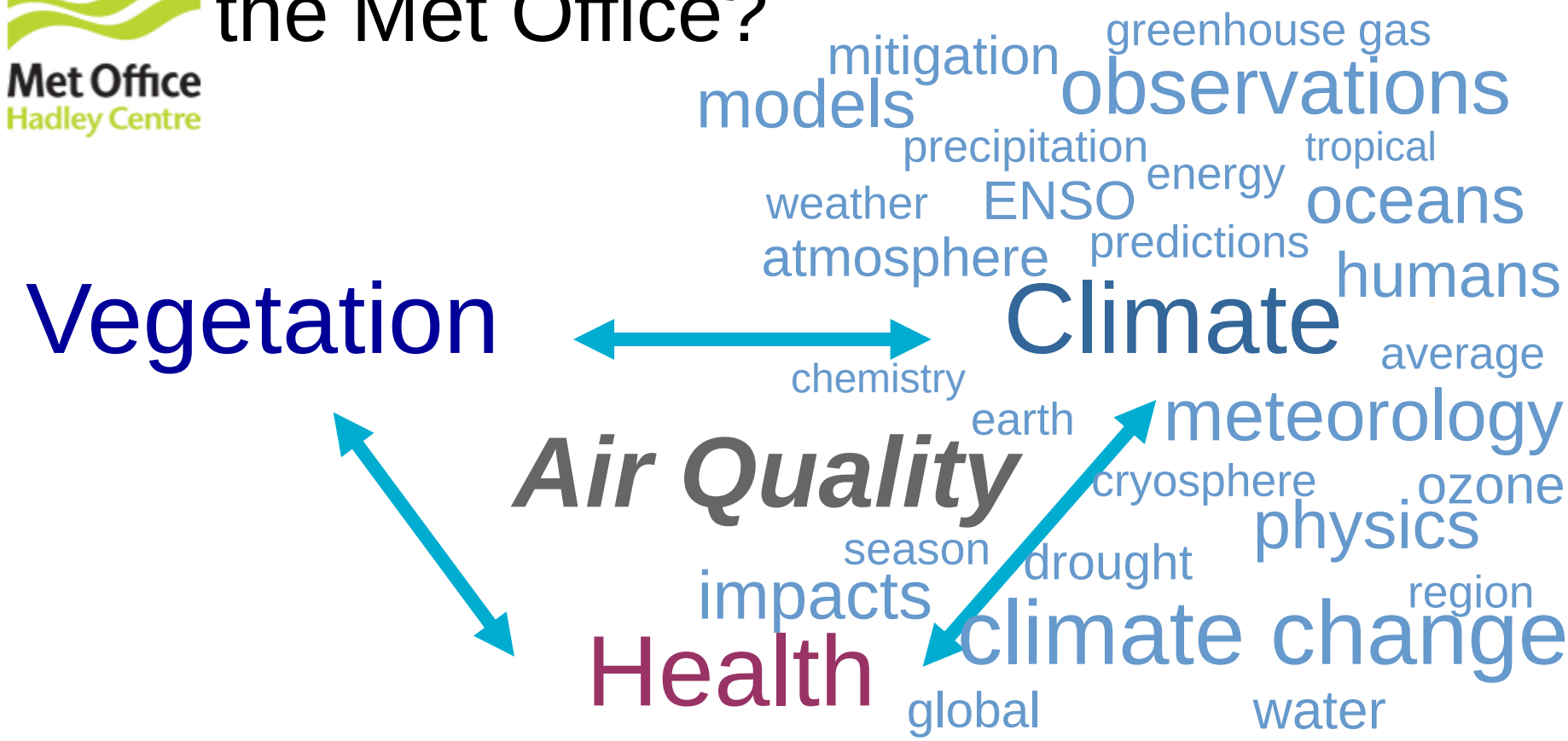

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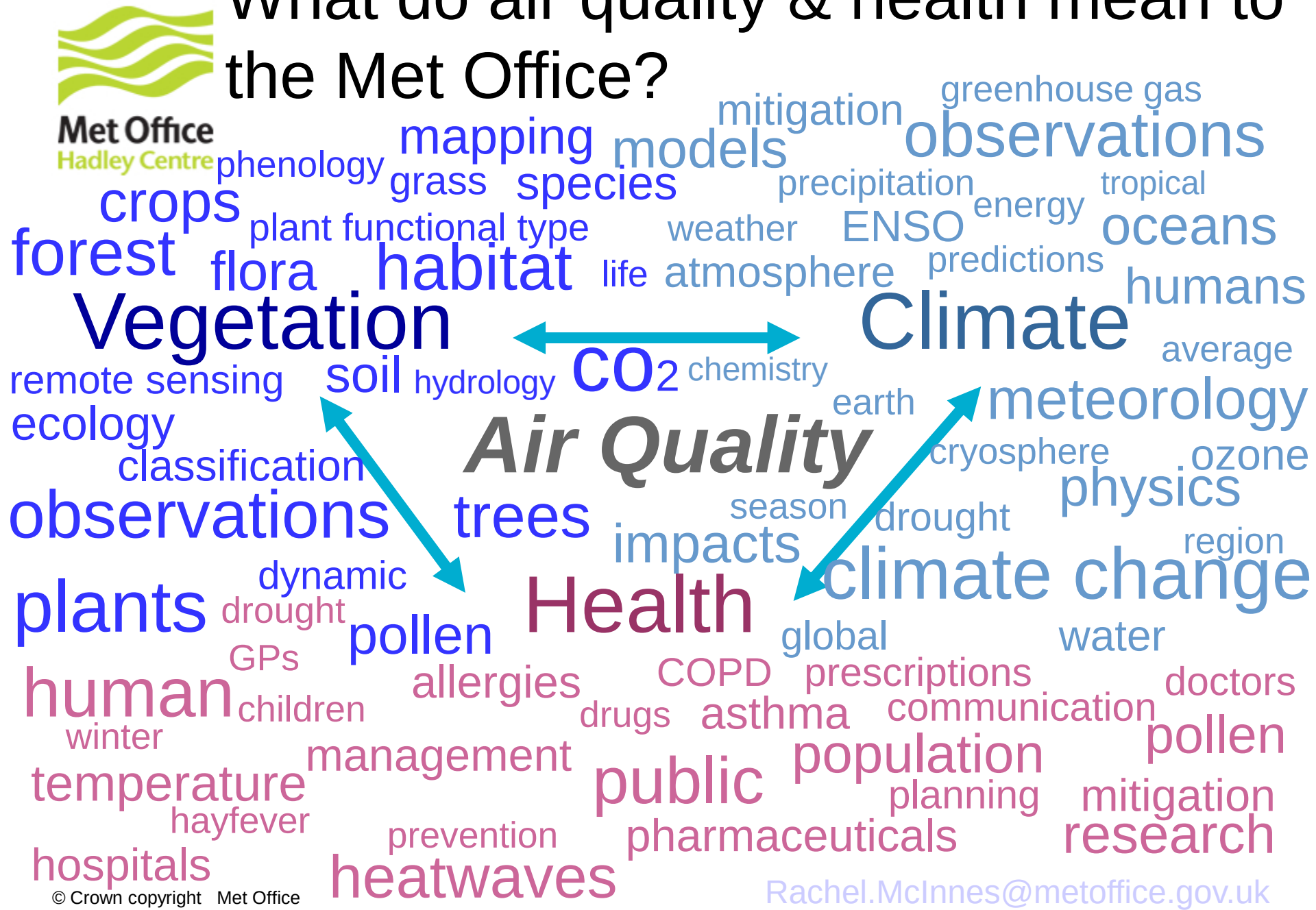

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Air chemistry - climate interactions

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Air quality-climate

NOx, VOCs

- Ozone precursors
- Methane lifetime

Ozone

- Greenhouse Gas
- Crop yields

$PM_{2.5}$ & PM_{10}

- Black carbon – warming
- Organic carbon – cooling
- Pollen

Health impact

- Risk factor: asthma, lung infections, heart disease, COPD, stroke, lung cancer
- 7 million deaths annually (WHO, 2014)
- Rise in respiratory hospital admissions / ED visits

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What do we mean by Air Quality?

- Concentration of pollutants:
  - Nitrogen Oxides (NO_x)
  - Sulphur Dioxide (SO_2)
  - Carbon Monoxide (CO)
  - Ozone (O_3)
  - Particulate Matter ($PM_{2.5}$, PM_{10})
- Concentration at surface
- Monitoring network – DEFRA
- Daily Air Quality Index – Met Office

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Met Office national AQ forecast for Defra

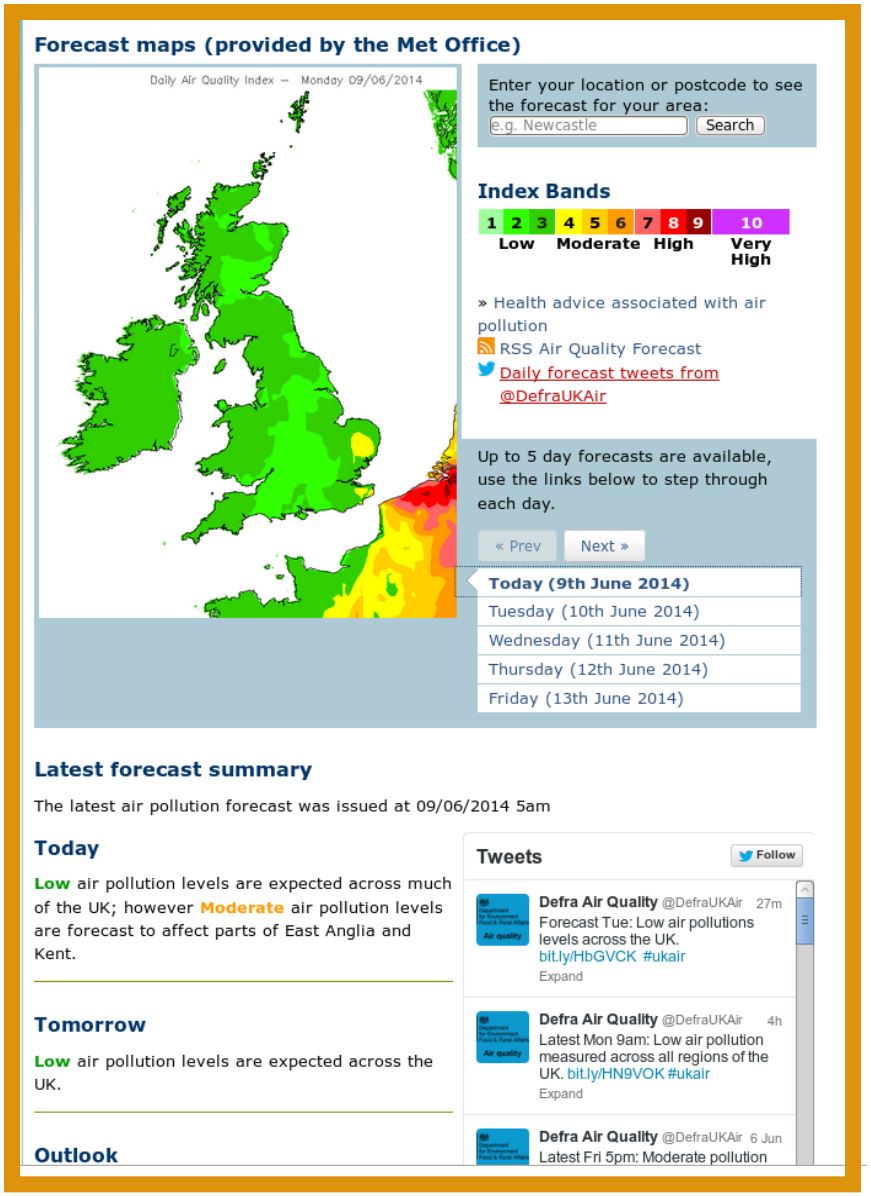
Species:

Ozone, NO_2, SO_2, PM_{10}, $PM_{2.5}$

→ Different time averaging periods for different species

↓ Thresholds

↓ Daily Air Quality Index



Output:

- UK maps
- 5 day AQ forecast

http://uk-air.defra.gov.uk/forecasting/

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Met Office national AQ forecast for Defra

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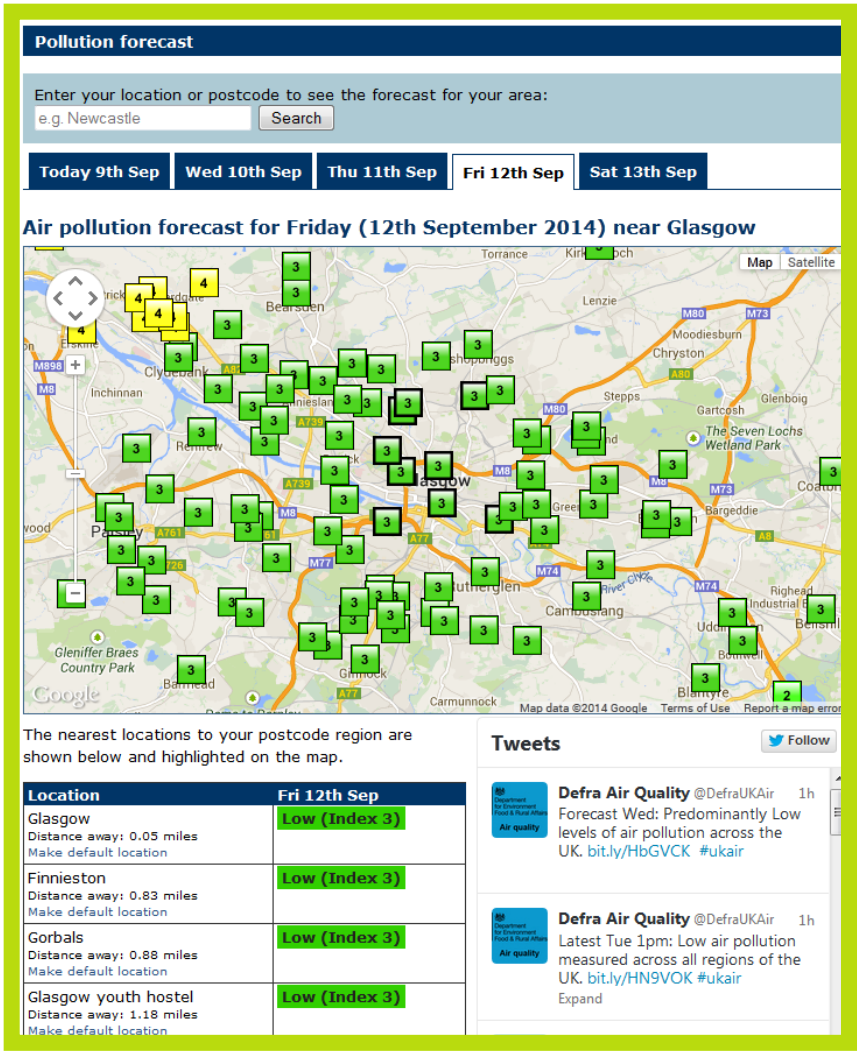

Output:

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http://uk-air.defra.gov.uk/forecasting/

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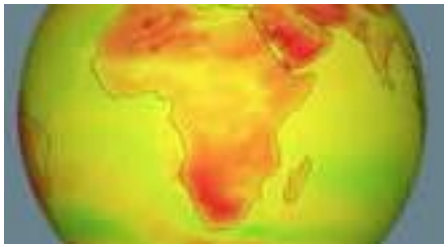
How do we model air quality using Earth-System models?

Definitions – weather vs climate

Weather The day to day changes in temperature, wind and rain.

Climate The **average, variations** and **extremes** of weather in a region over long periods of time



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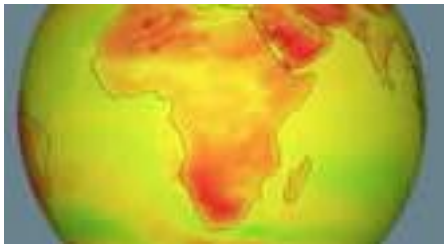

Climate The **average, variations** and **extremes** of weather in a region over long periods of time

- ***Weather*** *decides your outfit for the day…*
- ***Climate*** *determines what is in your wardrobe.*

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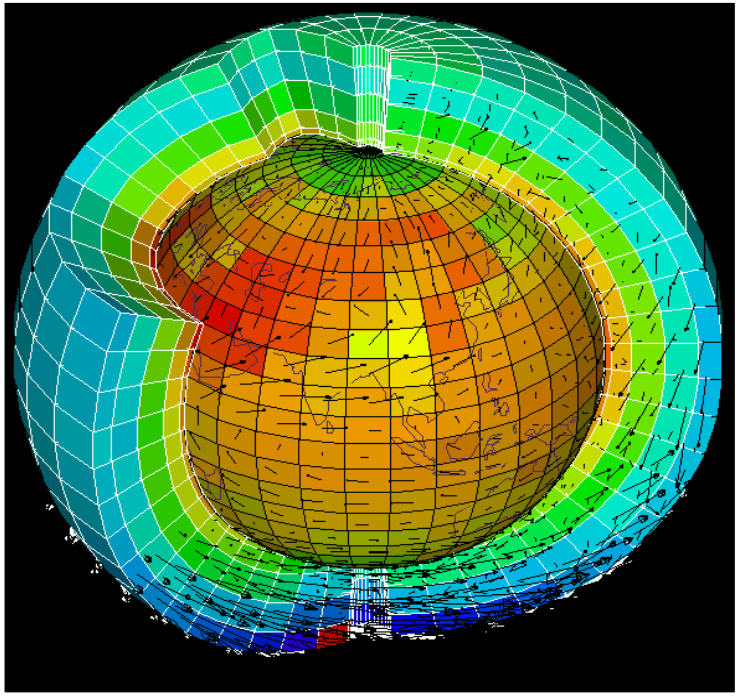
What is a climate model?

Climate system includes atmosphere, oceans, land surface and more.



What is a climate model?

- Laws of physics, chemistry and biology
- Use numerical computer models and supercomputers
- ...and we check how well they model past climate by comparing to observations.

1,000,000 lines of code	**200** output variables
15,000 grid points	**20-40** layers in atmosphere & ocean
30 minute time-step	**250** years simulation = 1-6 months run time

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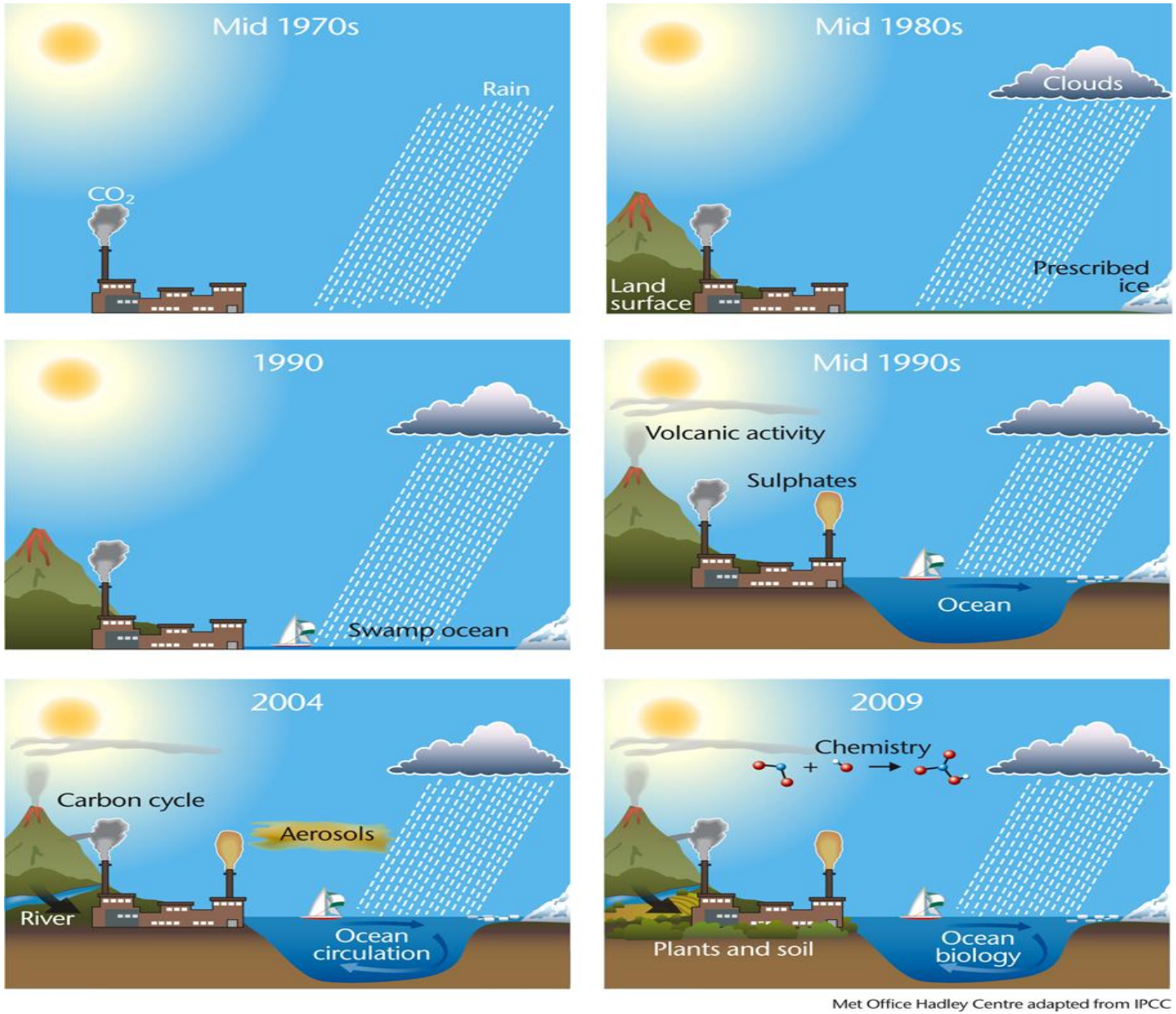
History of climate models



Met Office Hadley Centre adapted from IPCC

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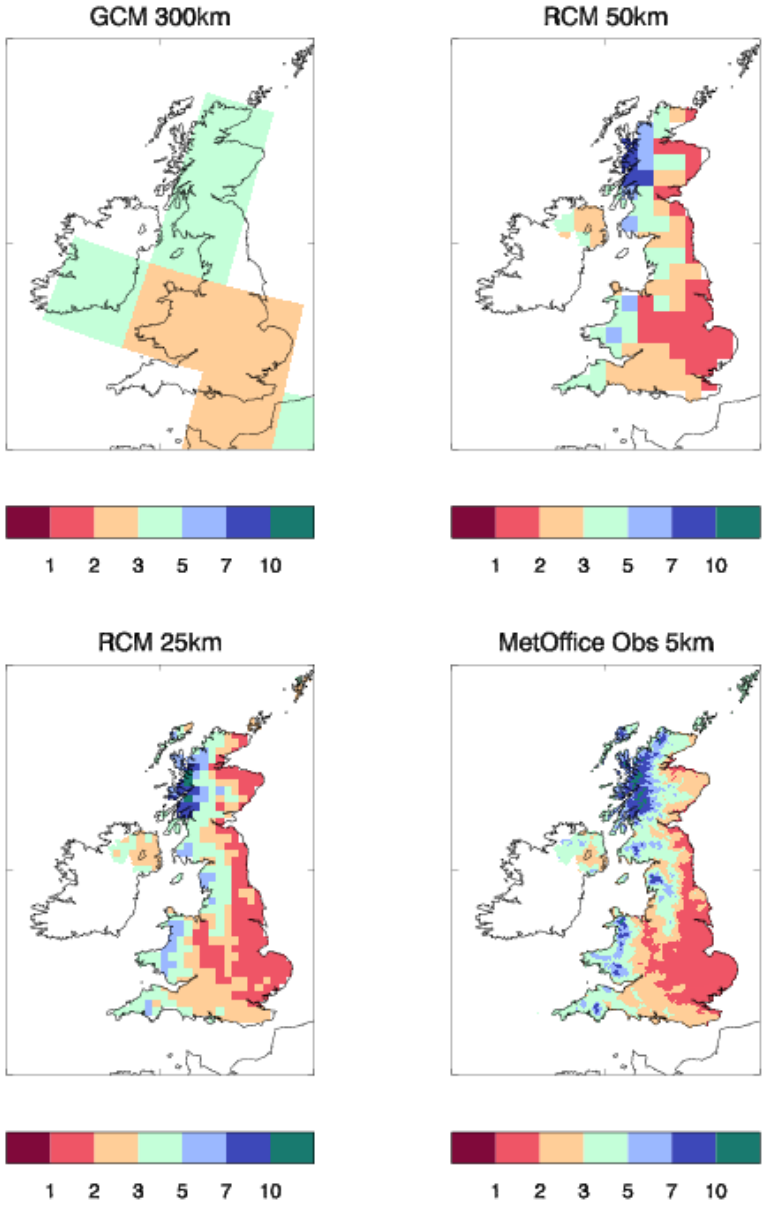
What is a Regional Climate Model?

What is a regional climate model?

- Higher resolution climate model
- Covers limited area of the globe
- More detailed simulation of current climate



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Observing the climate system

2000s: warmest decade on record

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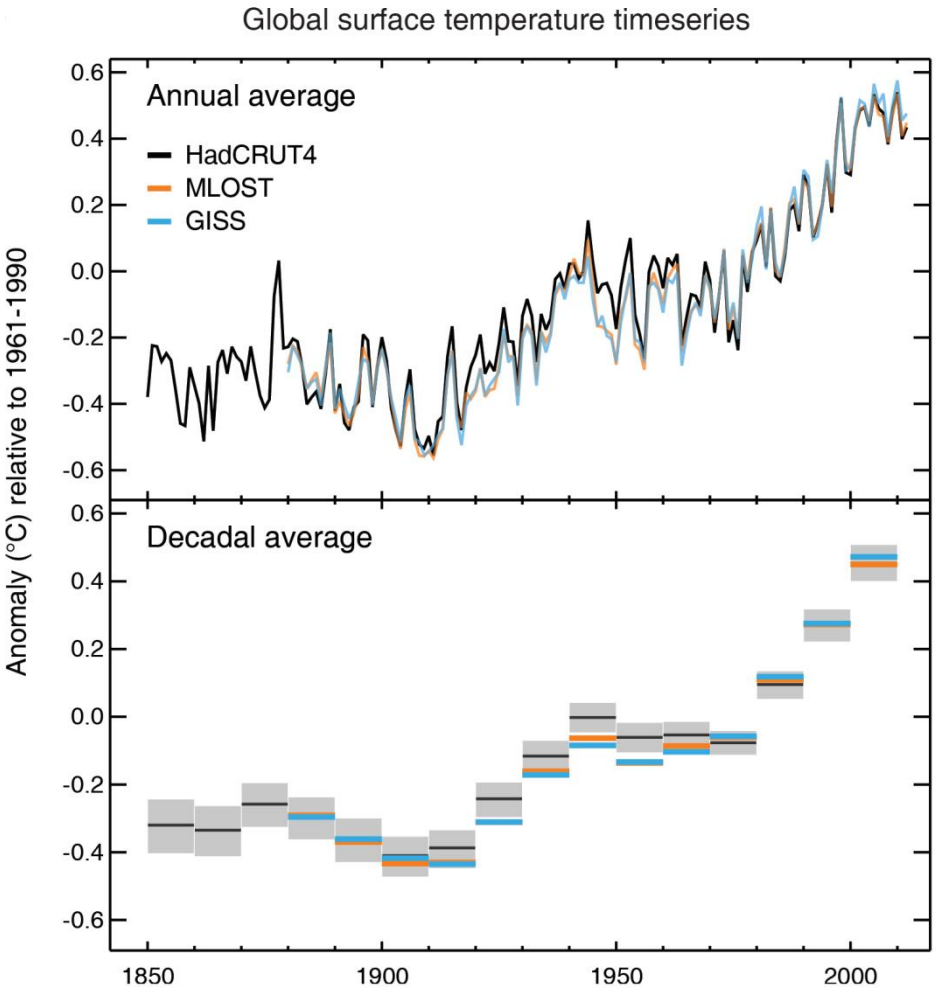

- Last 3 decades warmest in instrumental record.
- From palaeoclimate records, in the NH, last 30 years *likely (66-100%)* the warmest period of past 1400 years.
- *Very likely (90-100%)* that number of warms days has increased and cold nights decreased globally.

WGI, IPCC AR5, Stocker et al. 2013

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Observing the climate system

Almost the whole globe is warming

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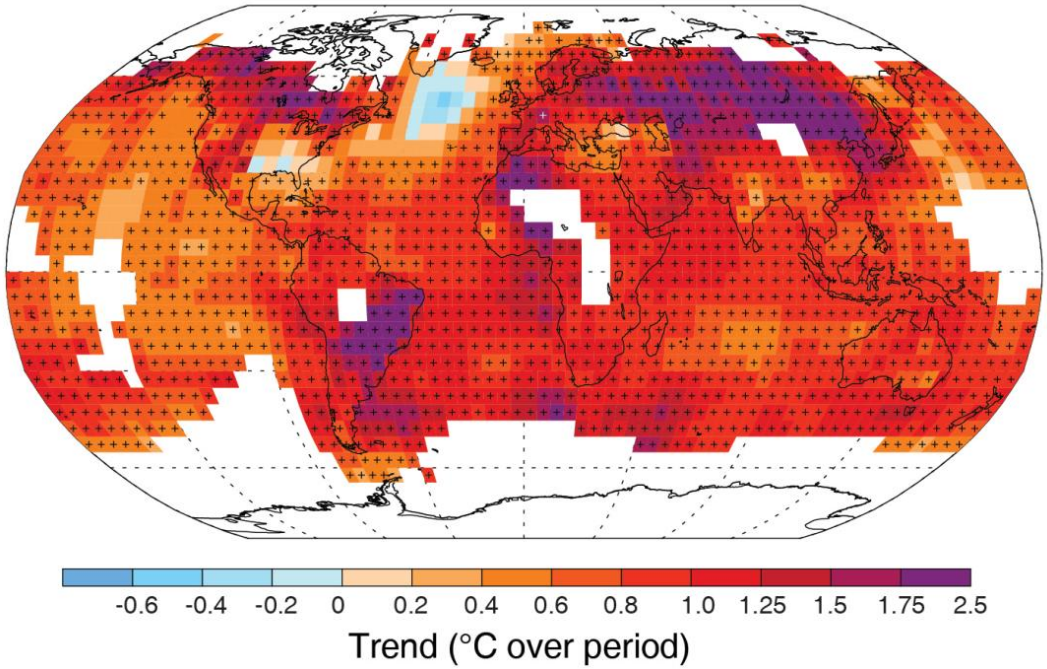
Annual mean temperature (1901-2012)



- Most global land areas have experienced significant warming since 1950
- Robust multi-decadal warming since 1901…
- …with substantial **decadal variability** in the rate of warming with several periods exhibiting almost no linear trend.

WGI, IPCC AR5, Stocker et al. 2013

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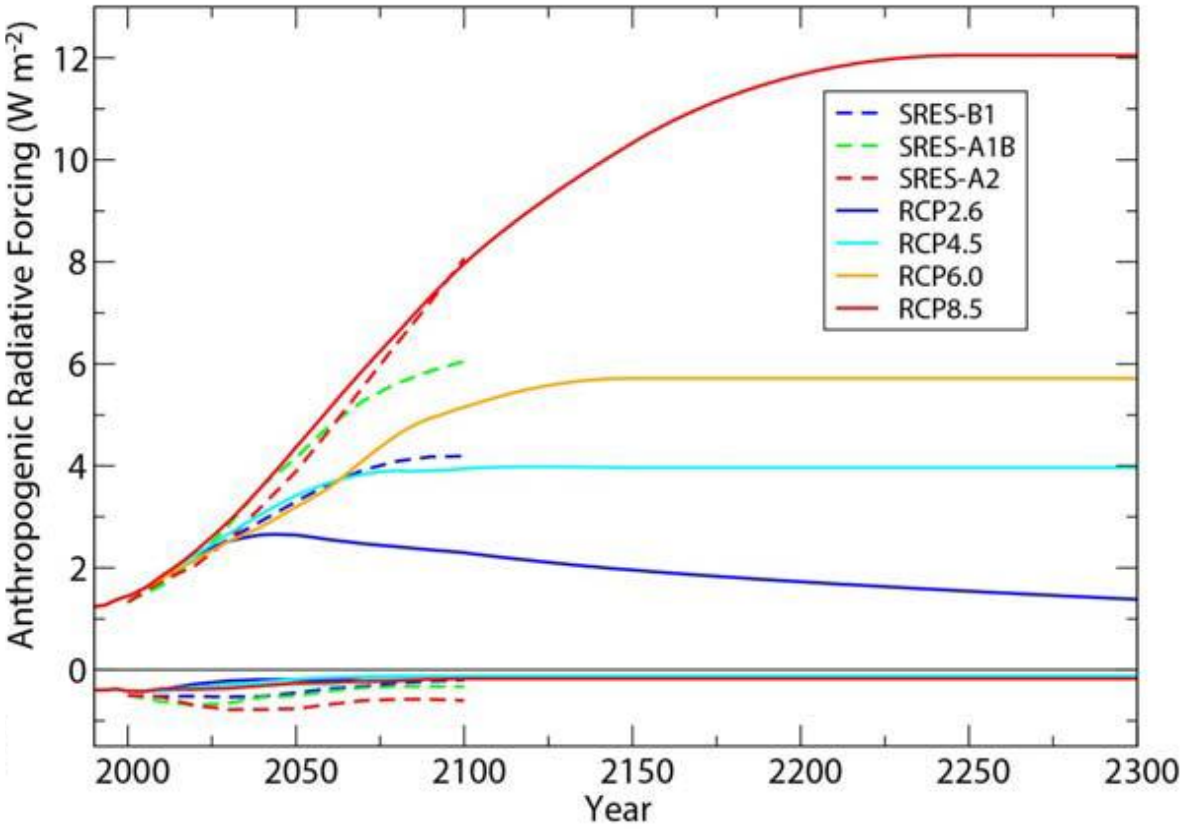
Future Projections of Climate & Air Quality

Future emissions - scenarios

Representative Concentration Pathways (RCPs)

- 4 greenhouse gas concentration trajectories,
- Each describes different future value of radiative forcing in 2100.
- RCPs aim to provide a range of climate model responses



Meinshausen et al., 2011a

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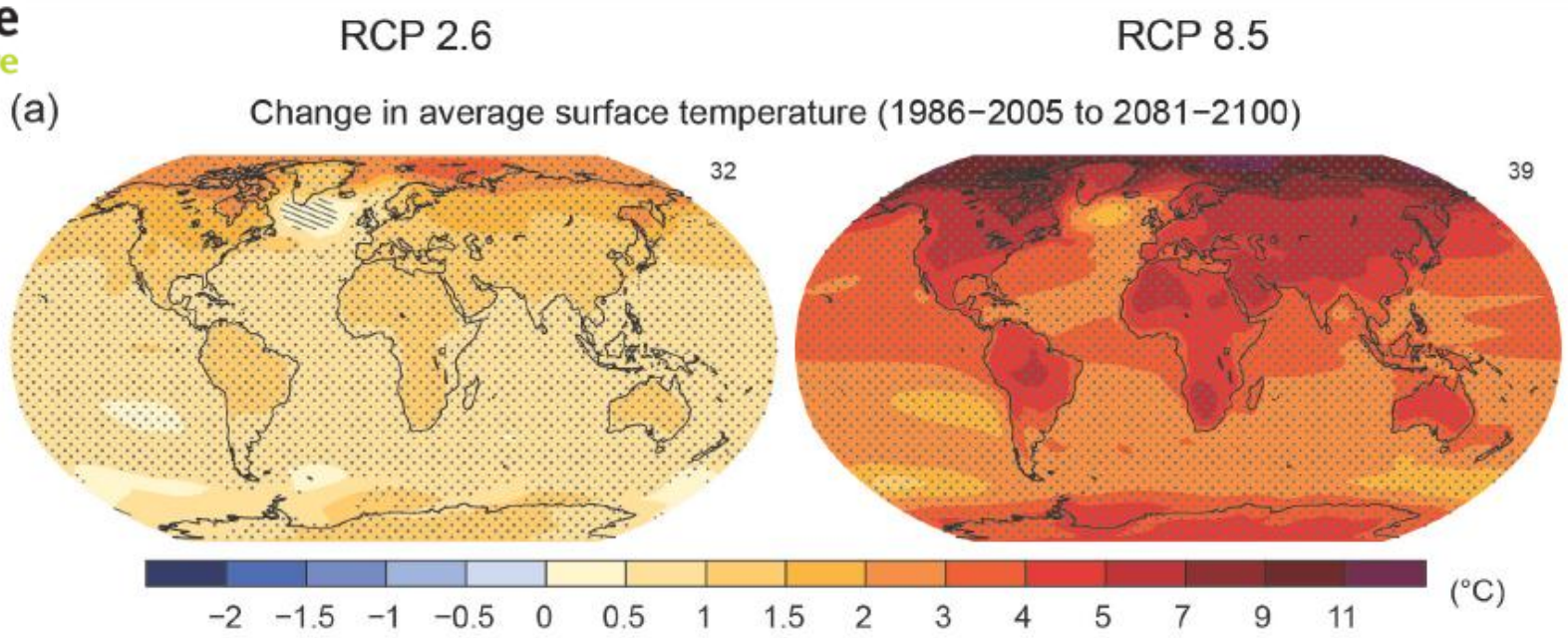
Warming will not be the same everywhere



- *Very high confidence*: long-term warming will be larger over land than over ocean, and the Arctic region will warm most rapidly.
- Ocean warming will continue for centuries, even if greenhouse gas emissions are decreased.

WGI, IPCC AR5, Stocker et al. 2013

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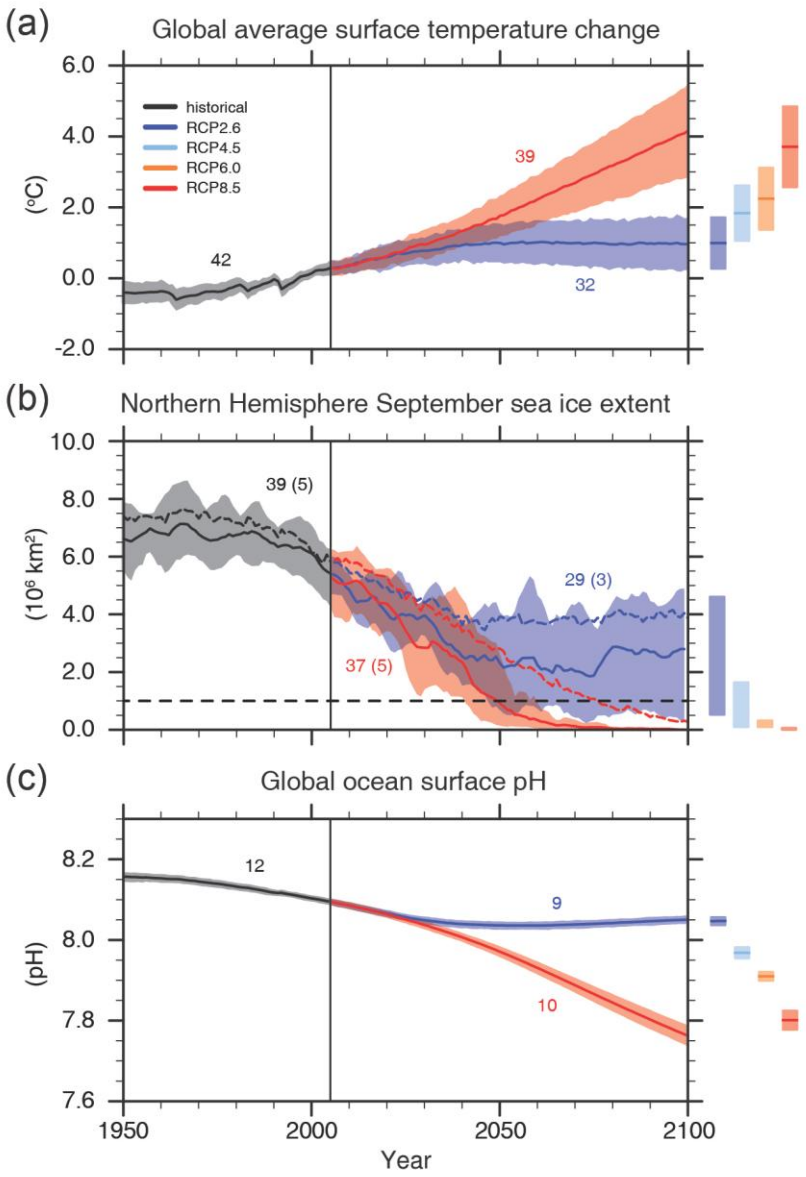
Projections of climate change

- By 2100: increase of global mean surface temperature above 1986-2005 levels is projected to be:

  0.3-1.7˚C for RCP2.6

  2.6-4.8˚C for RCP8.5

- Global warming >2˚C is *likely* (66-100%) for RCP6.0 and RCP8.5
- Global warming >4˚C is *unlikely* (0-33%) except for RCP8.5



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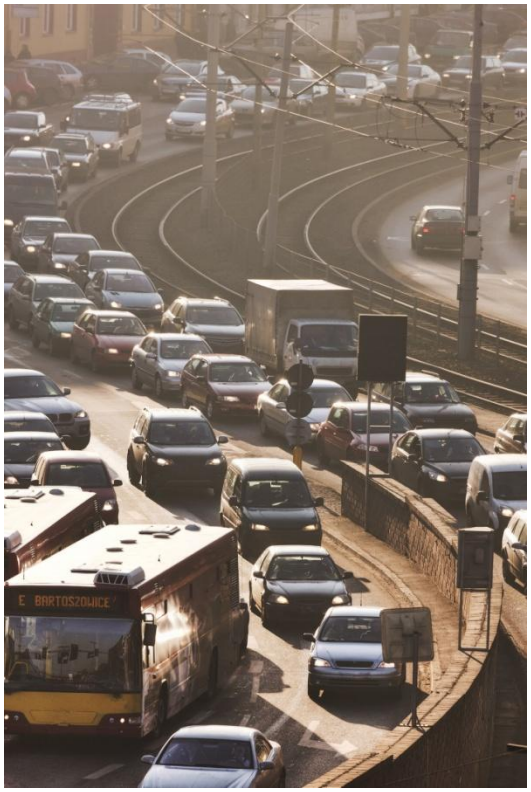
Future projections of Air Quality

- Range in projections of surface O_3 and $PM_{2.5}$ is driven primarily by emissions rather than by climate change.

- Globally, background surface O_3 expected to decrease …

- …but high CH_4 (RCP8.5) can offset this decrease.

- Peak O_3 and $PM_{2.5}$ will increase with climate change.



IPCC AR5, Summary for Policy Makers

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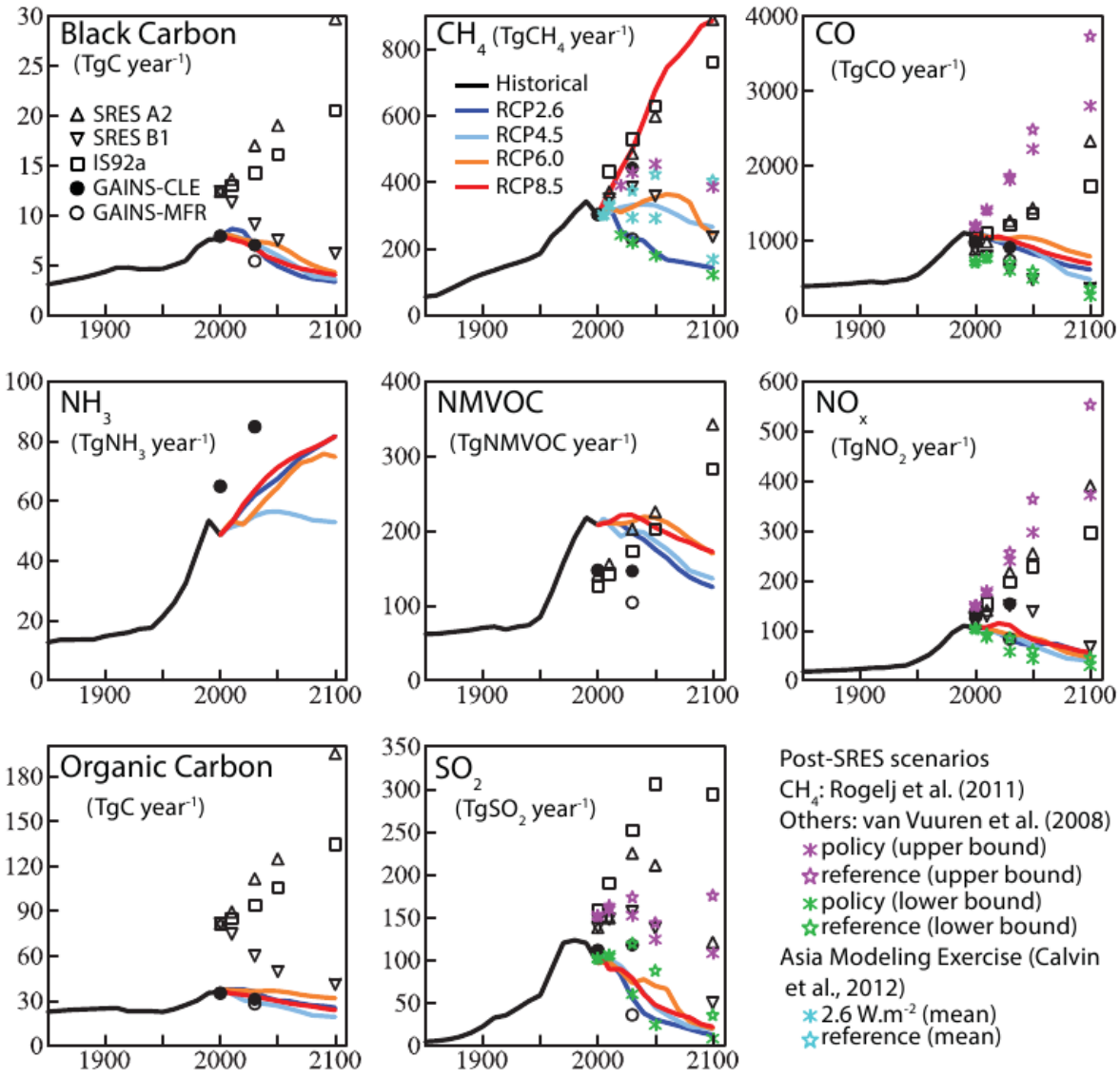
Future Anthropogenic Emissions



IPCC AR5, Figure 8.2, Myhre et al 2013

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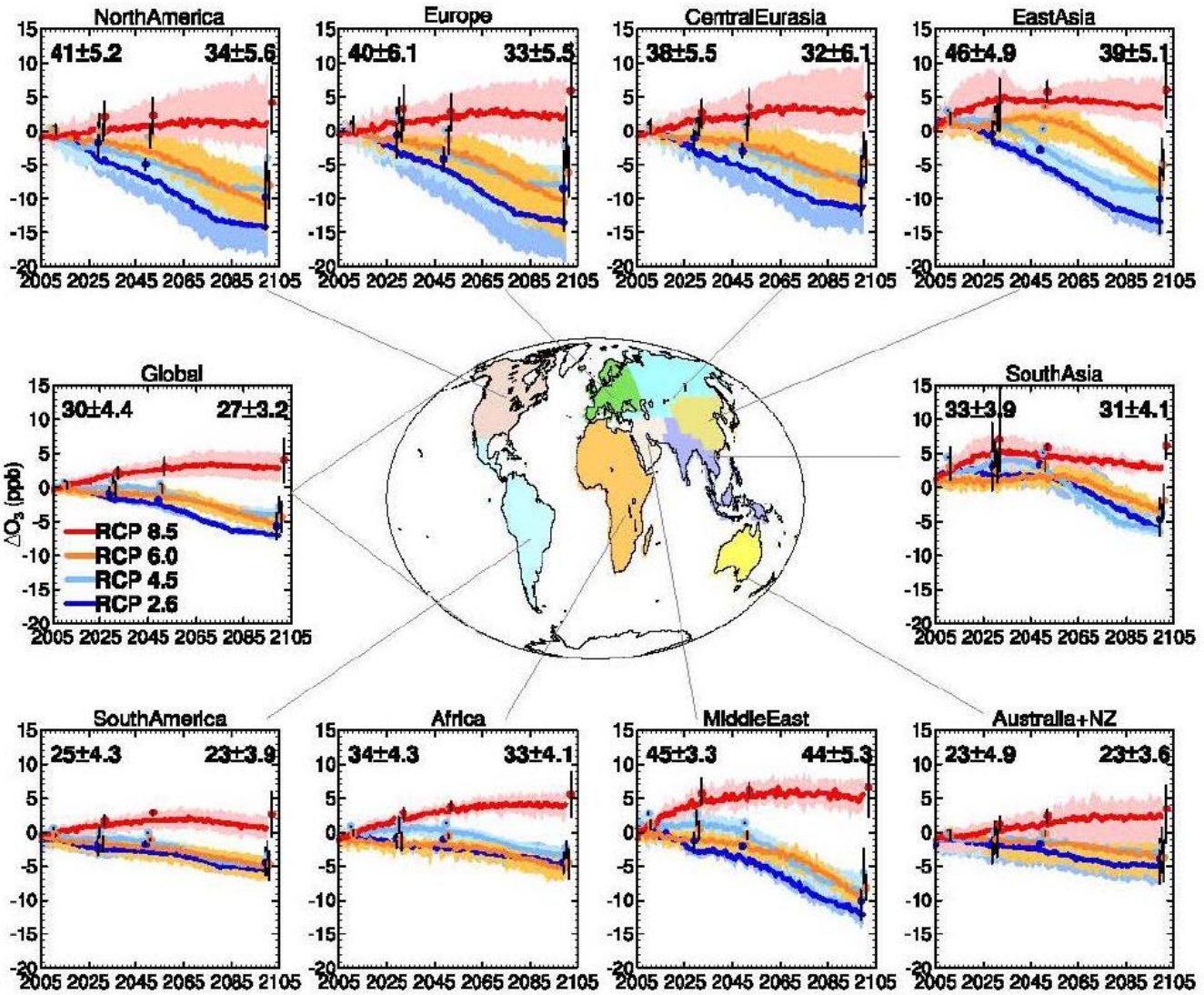
Global and regional changes in surface o3

O_3 time series



IPCC AR5, Figure 11.23a, Kirtman et al. 2013

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Current project: our model for future air quality projections

Funding: EPSRC

University of Glasgow: Alastair Rushworth & Duncan Lee. **University of Southampton**: Sabyasachi Mukhopadhyay & Sujit Sahu.

Met Office: Paul Agnew & Lucy Davies (AQUM), Yolanda Clewlow (Business). Christophe Sarran, Fiona O'Conner, Gerd Folberth, Rachel McInnes, Mohit Dalvi & Debbie Hemming (Hadley Centre).

Project overview

"A rigorous statistical framework for estimating the long-term health effects of air polution"

- Bayesian spatio-temporal modelling of chronic health impacts of air quality in UK
- Present day and future climate modelling
  - hourly UK pollutant fields
  - 12km resolution over UK
  - 5-year (2007-2011) dataset
  - 5-year (2050-2055) future projection dataset

http://www.gla.ac.uk/research/az/airpollution/

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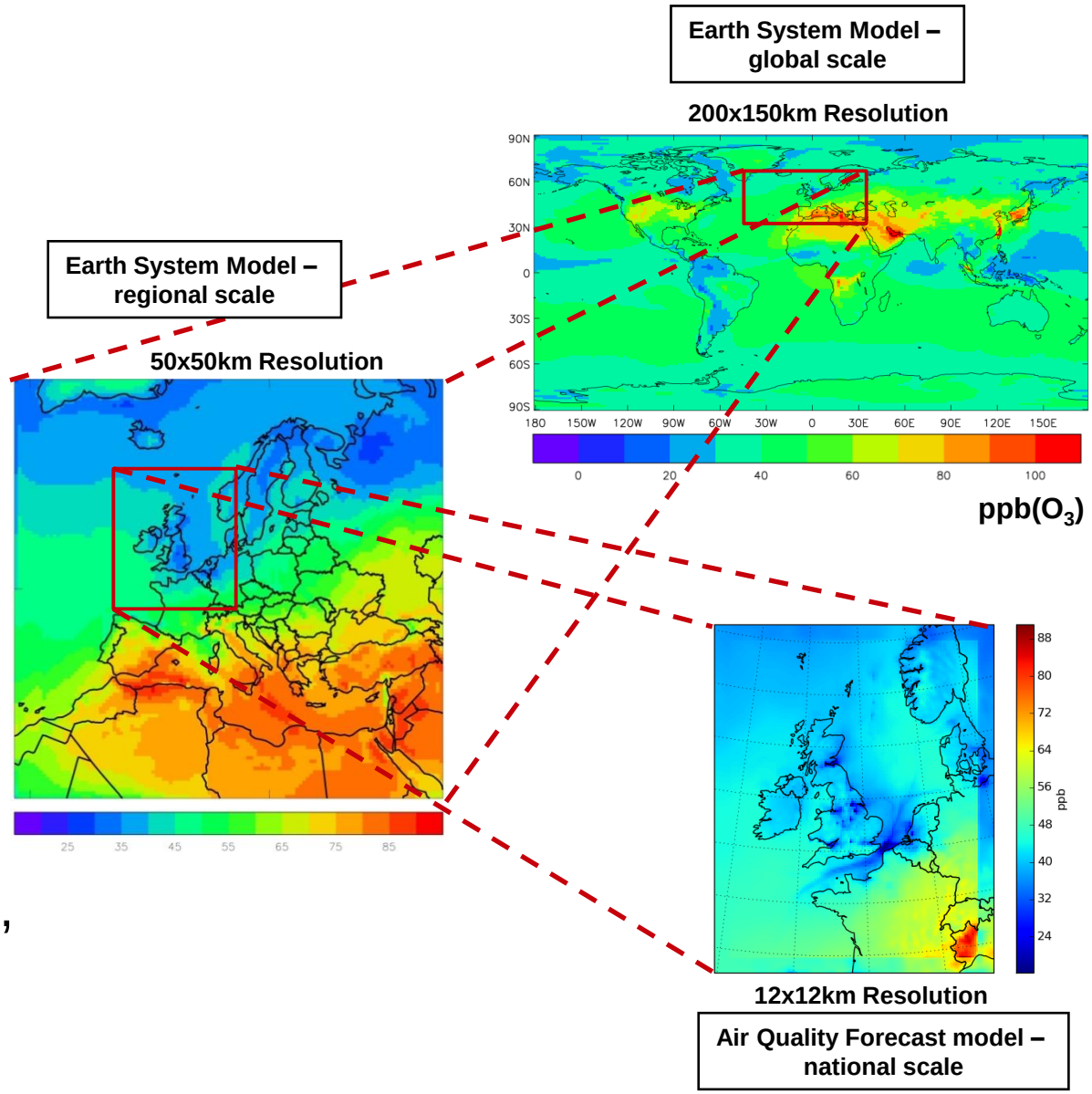
Earth-System model set up

- New configuration of nested models
- Aim – future air quality projections, 2050s.
- Major processes included: transport, emissions, deposition, chemistry.



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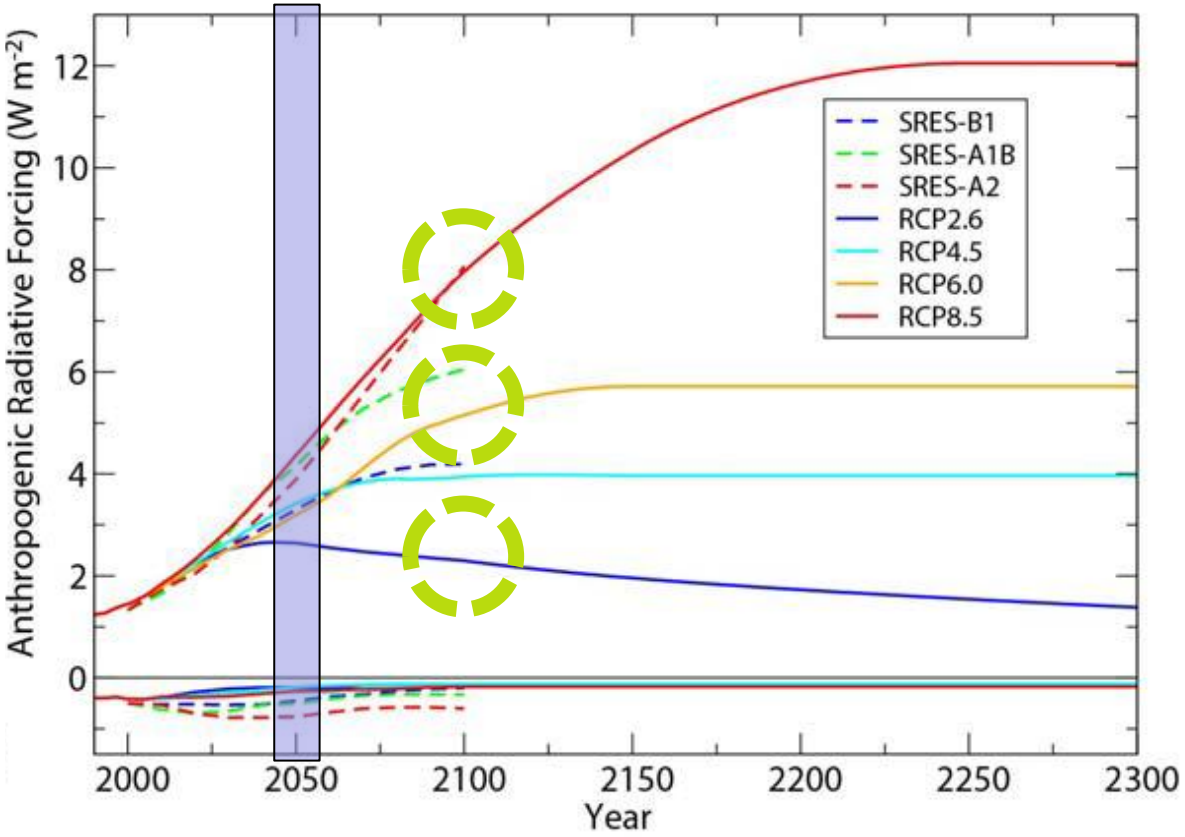

Meinshausen et al., 2011a

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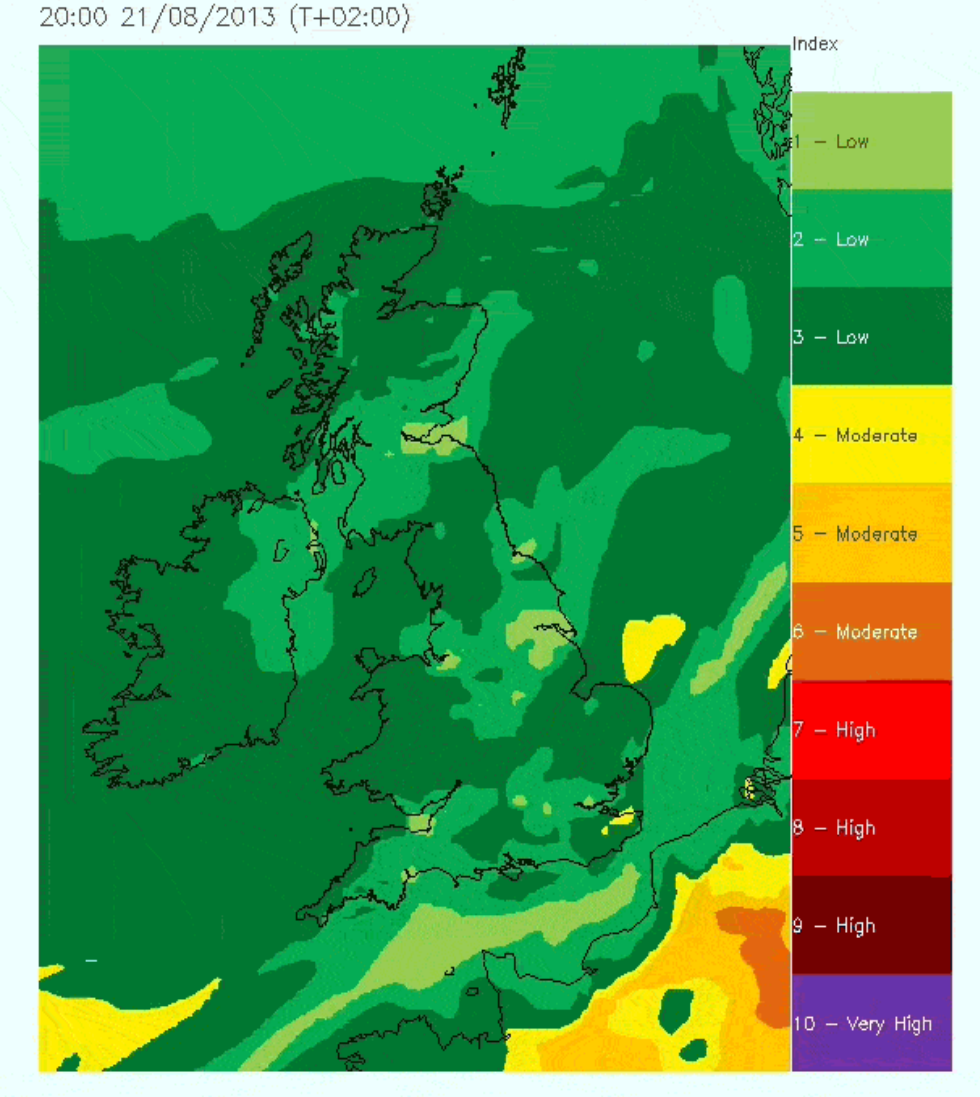
Earth-System model - output

- *In progress...*
- Hourly fields created:
  - Ozone, $PM_{2.5}$, PM_{10}
  - SO_2, NO_x, others upon request
- 12km grid resolution
- Period 2050-2055
- 3 emissions scenarios

Ozone



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Summary

- Cannot separate Air Quality from climate, environment or health – needs holistic approach.

- Not only 1 climate future – need to look at few possible scenarios.

- We have created new nested model for Air Quality and climate – introduces detail on local scale.

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Any Questions?

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