Climate change: evidence, attribution and projections

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Outline

- *The climate system and climate change*
- *Attribution of climate change*
- *Impacts of and response to climate change*

Climate system and climate change

A definition of climate

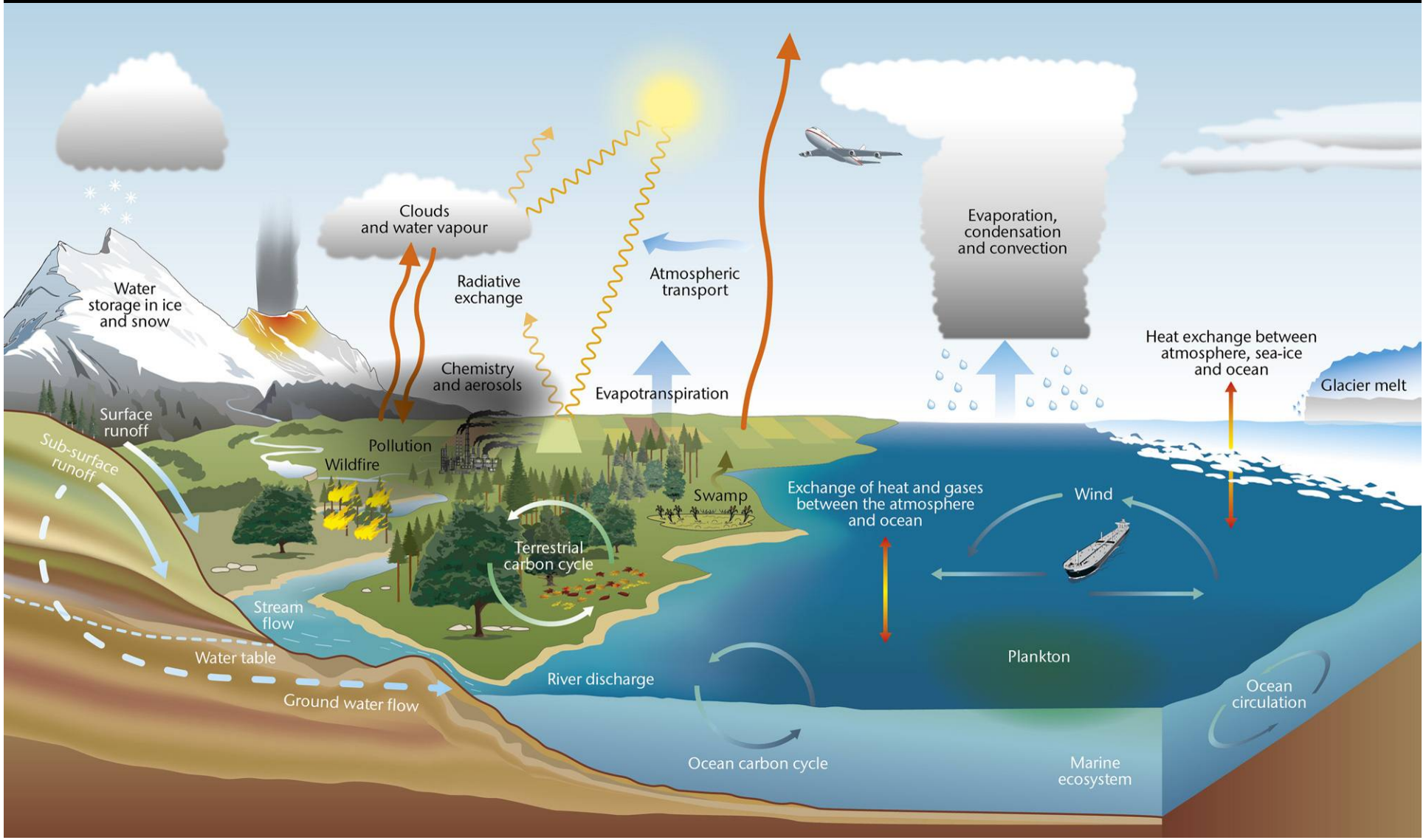
Long term statistics of atmospheric and oceanic phenomena (i.e. mean and higher moments)

Both atmosphere and ocean behave in a non-linear way over many time-scales

At least thirty years samples to estimate meaningful statistics

Many components affect the climate system

Earth system processes

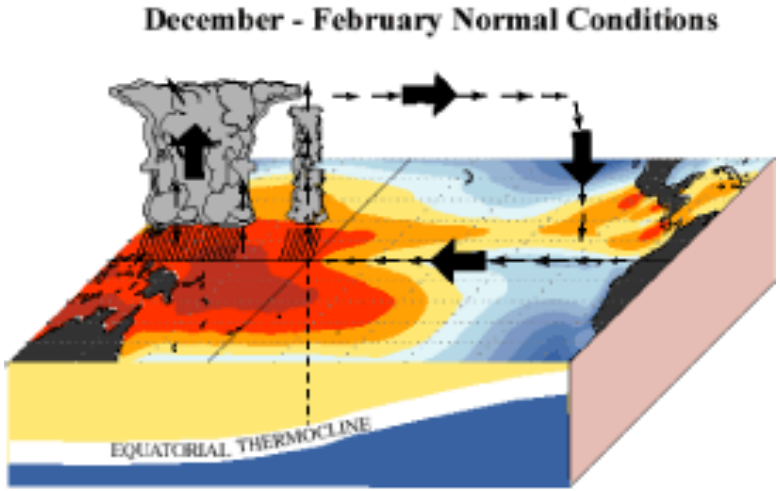


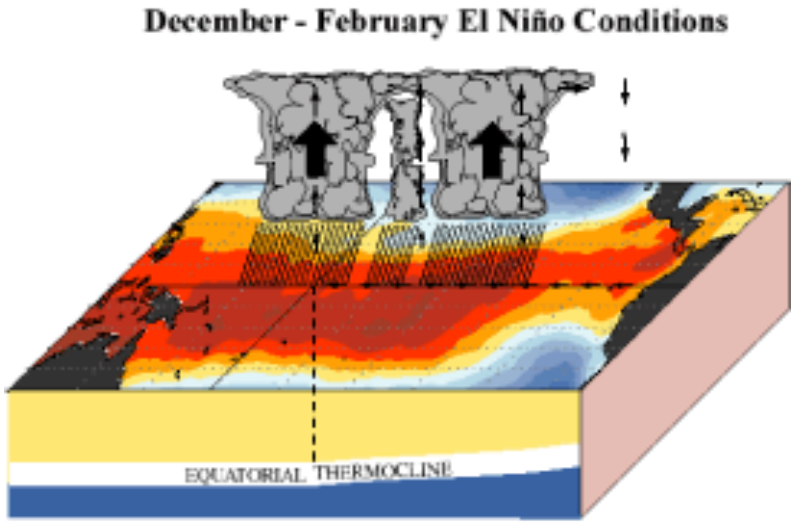
The Climate System

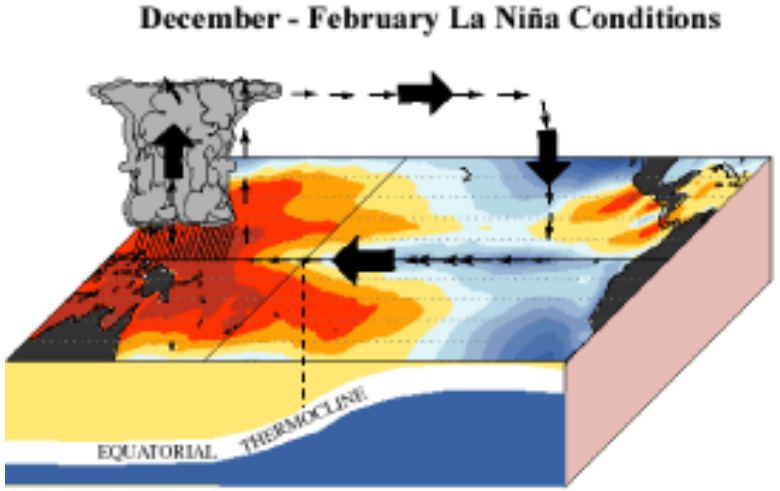
- **Atmosphere**: most unstable and rapidly changing part of the system
- **Oceans**: Transport and store large amounts of energy and CO_2. Source of variability of longer time scales
- **Cryosphere**: High albedo, large thermal inertial, stores large amount of water
- **Land surface**: Vegetation and soils control how solar radiation is returned to the atmosphere. Topography and vegetation influence dynamics of the atmosphere
- **Biosphere**: Impacts the atmosphere's composition

All these components and their interactions are non-linear

El Nino-Soutern Oscillation

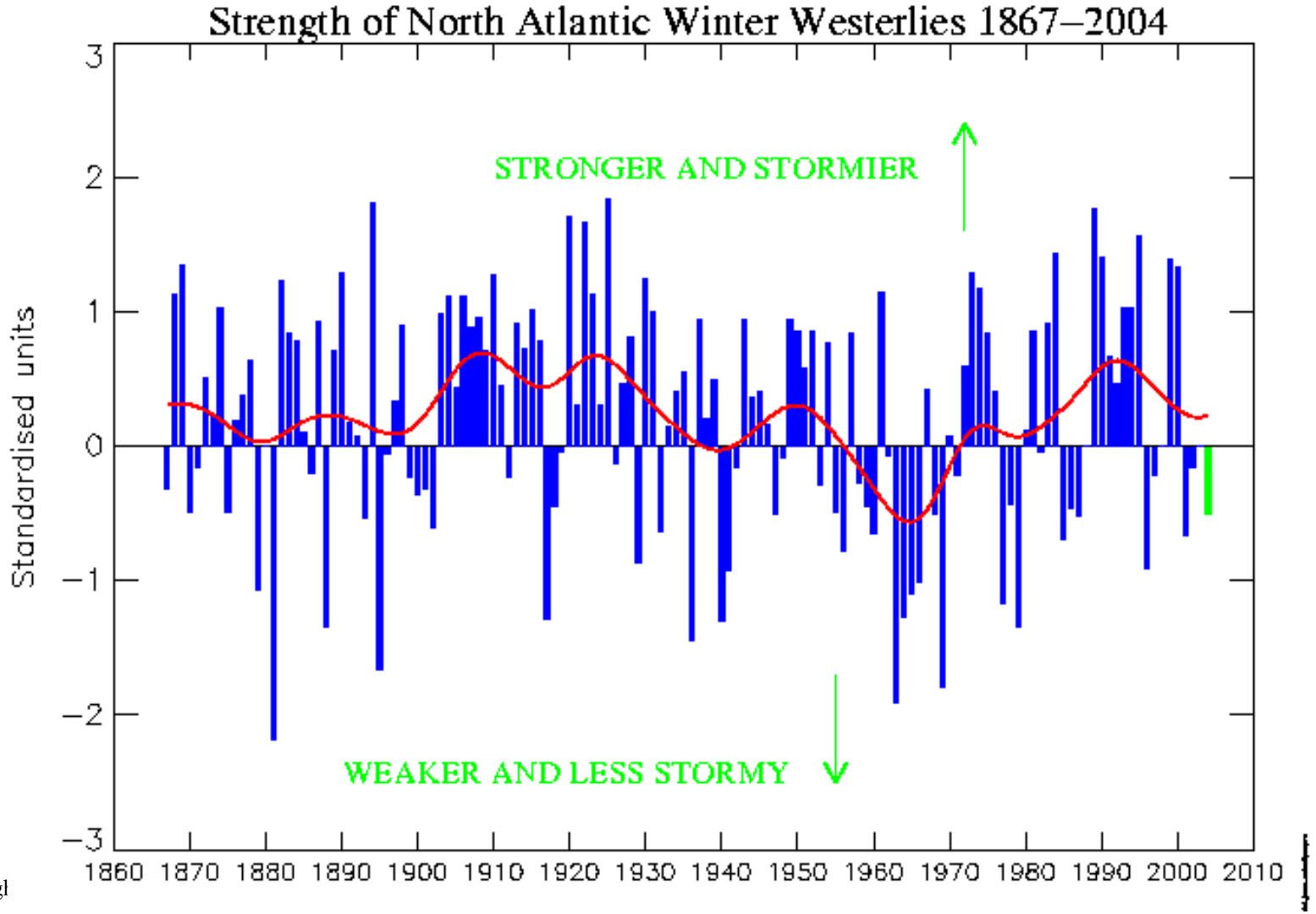




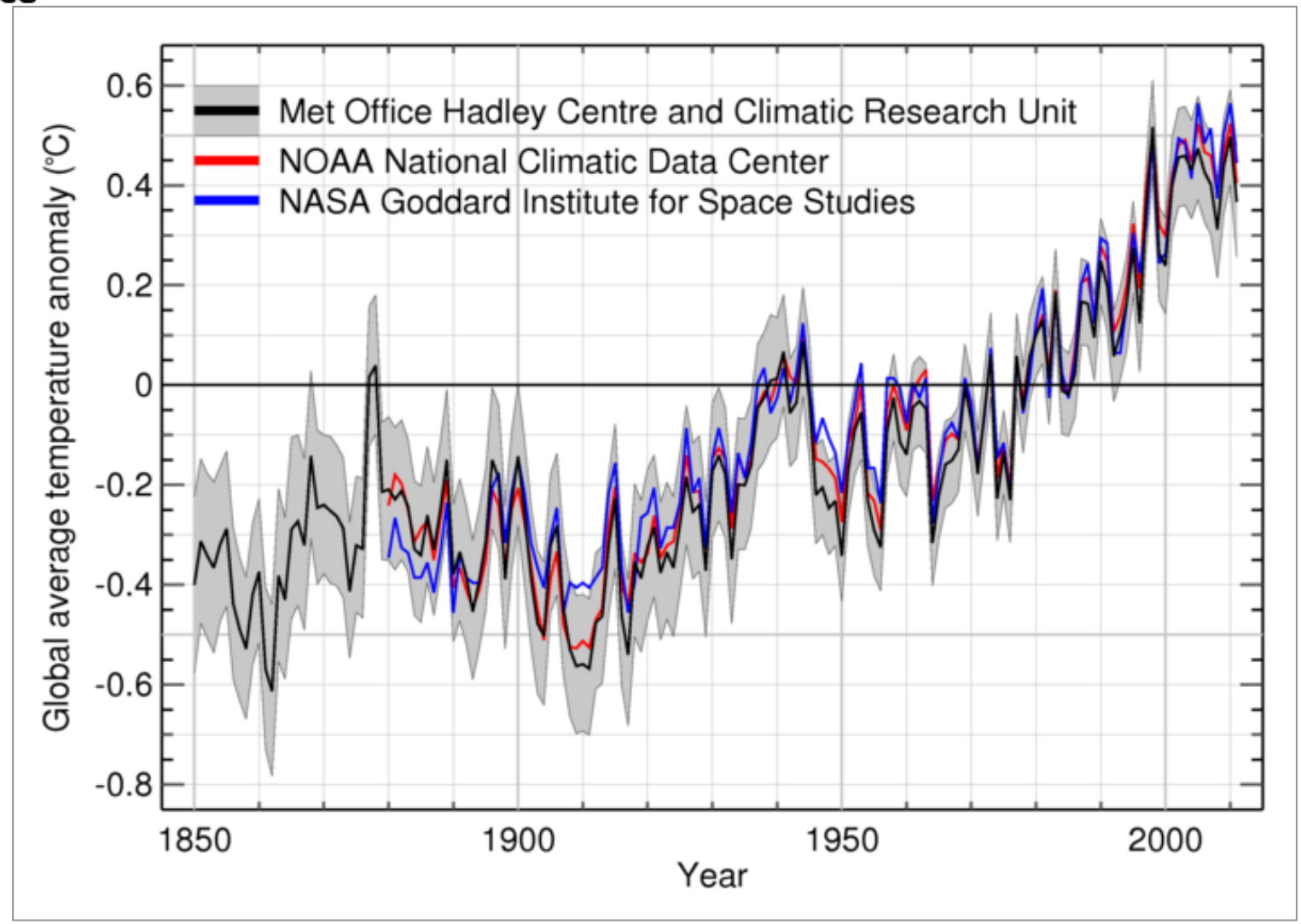


El Nino Southern Oscillation represents the principal mode of variability of the global climate system

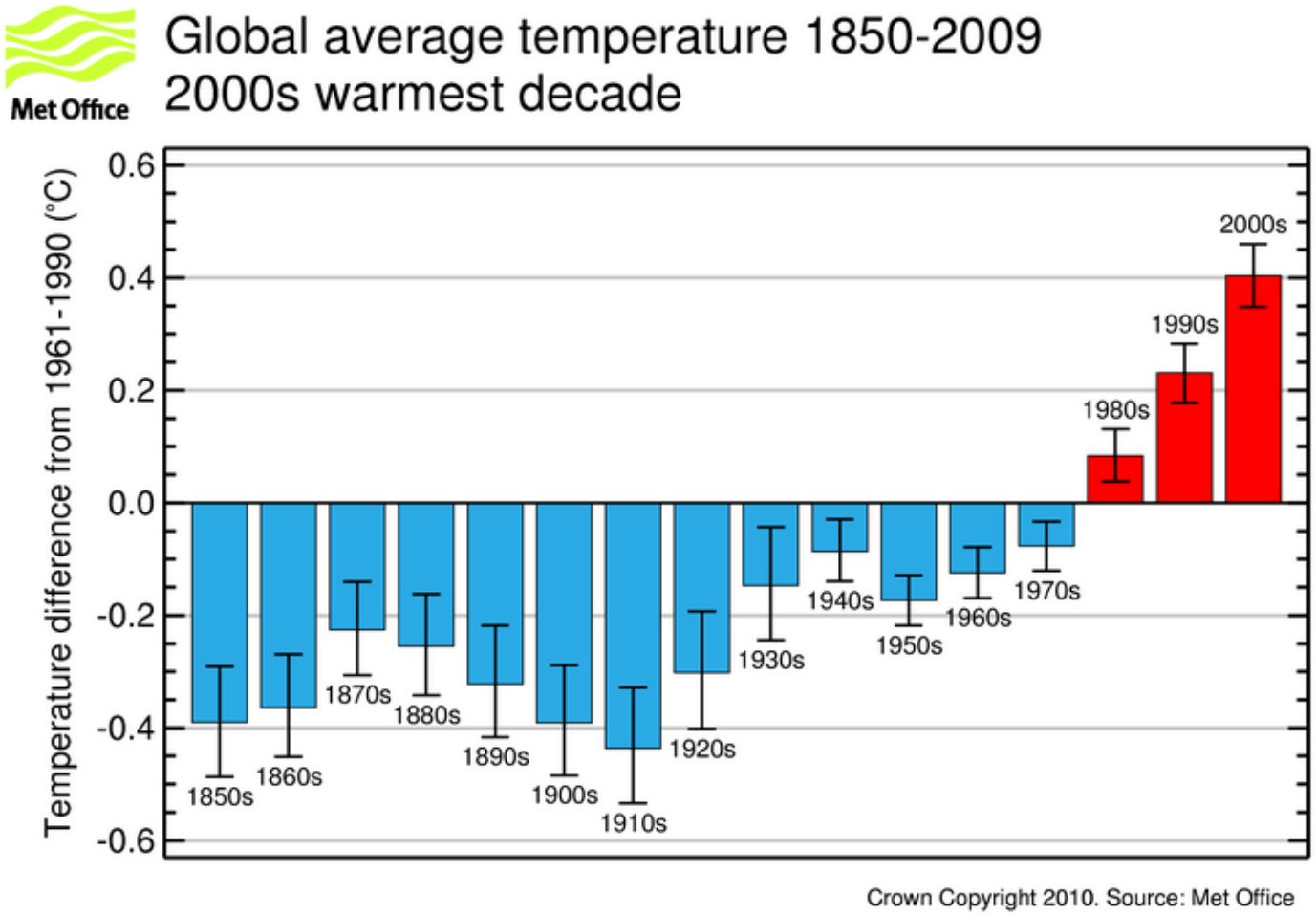
Winter NAO index



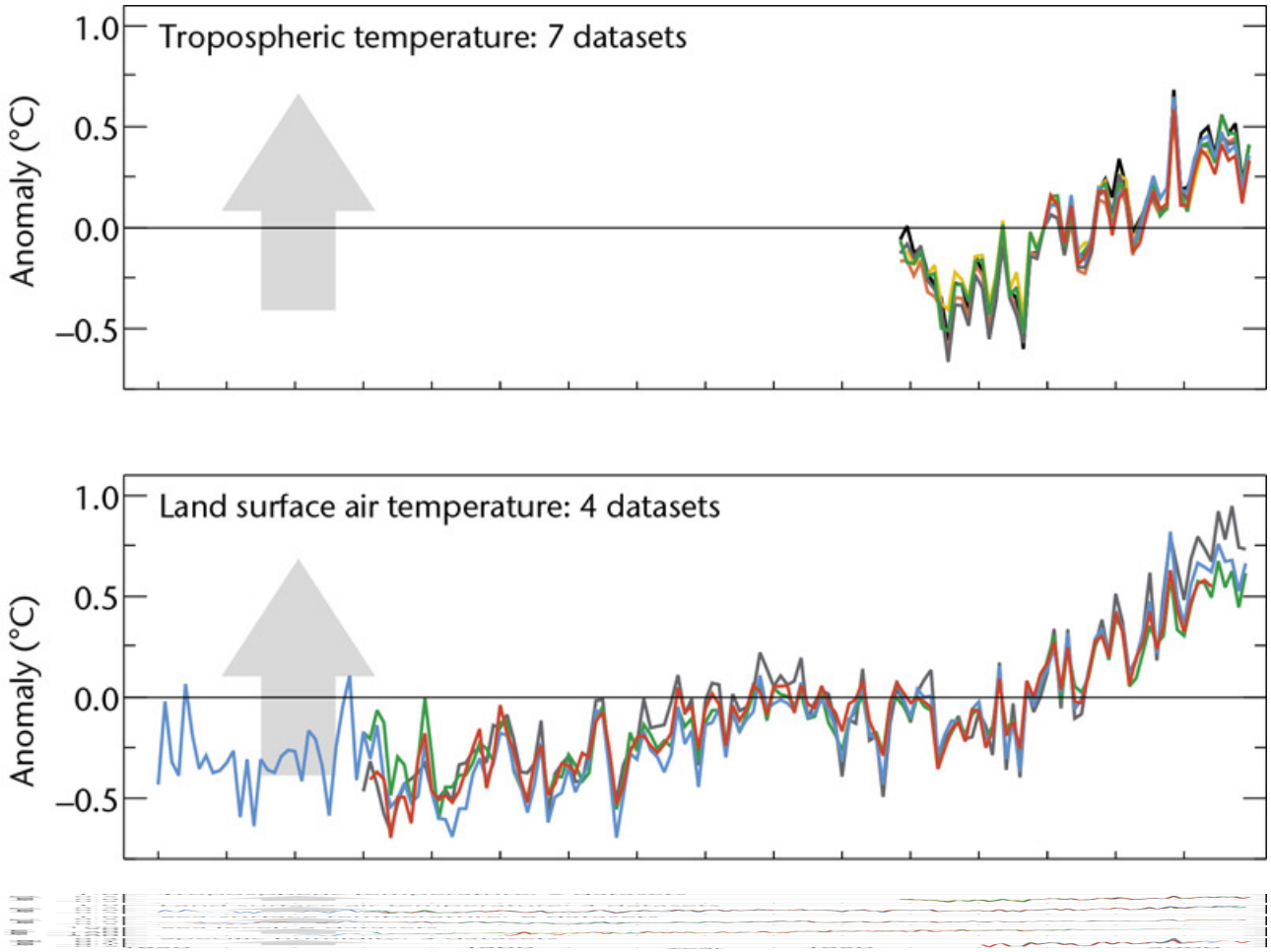
Global temperature analyses



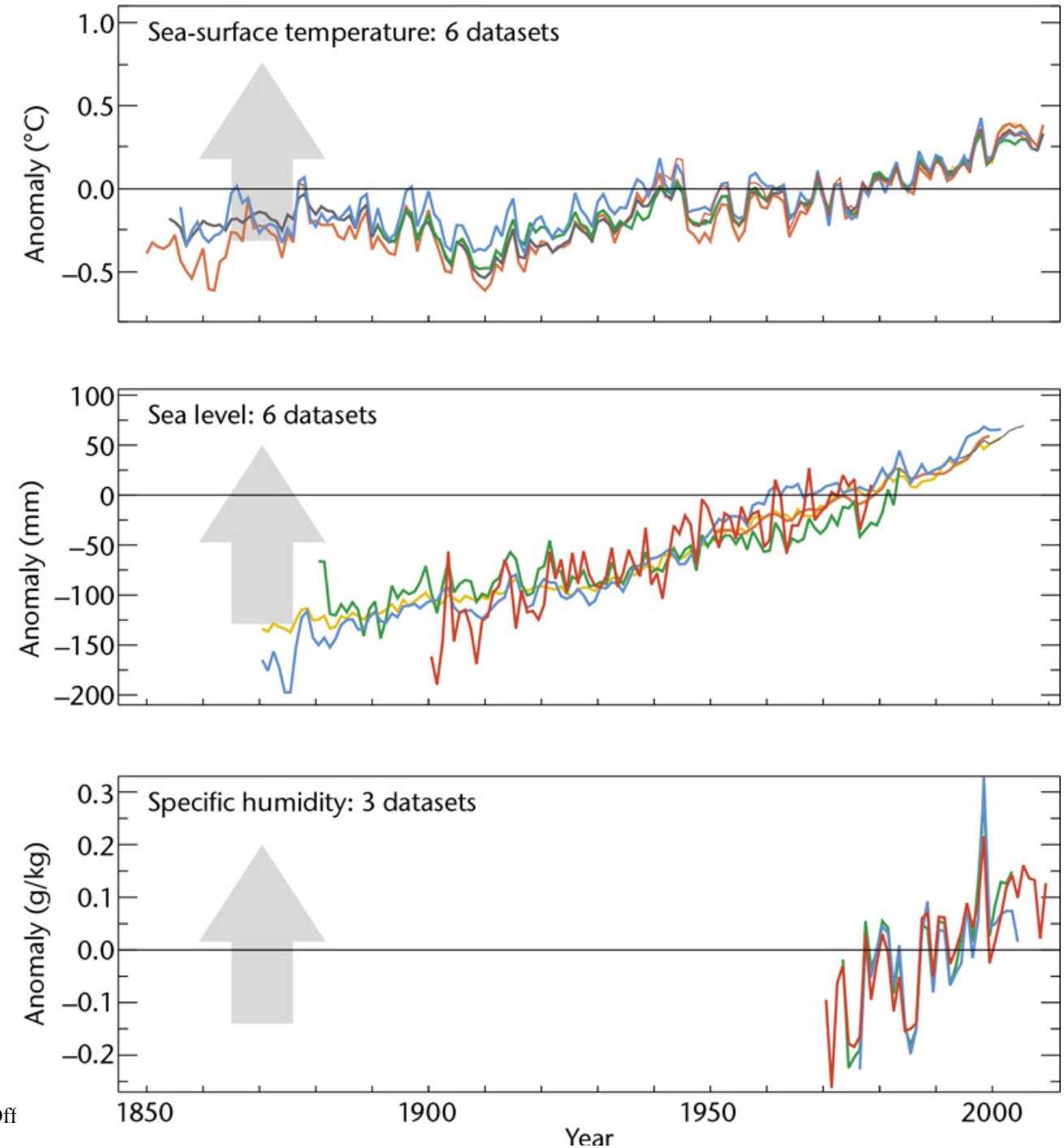
2000-2009 warmest decade on record



9 indicators of a changing climate



Met Office
Hadley Centre



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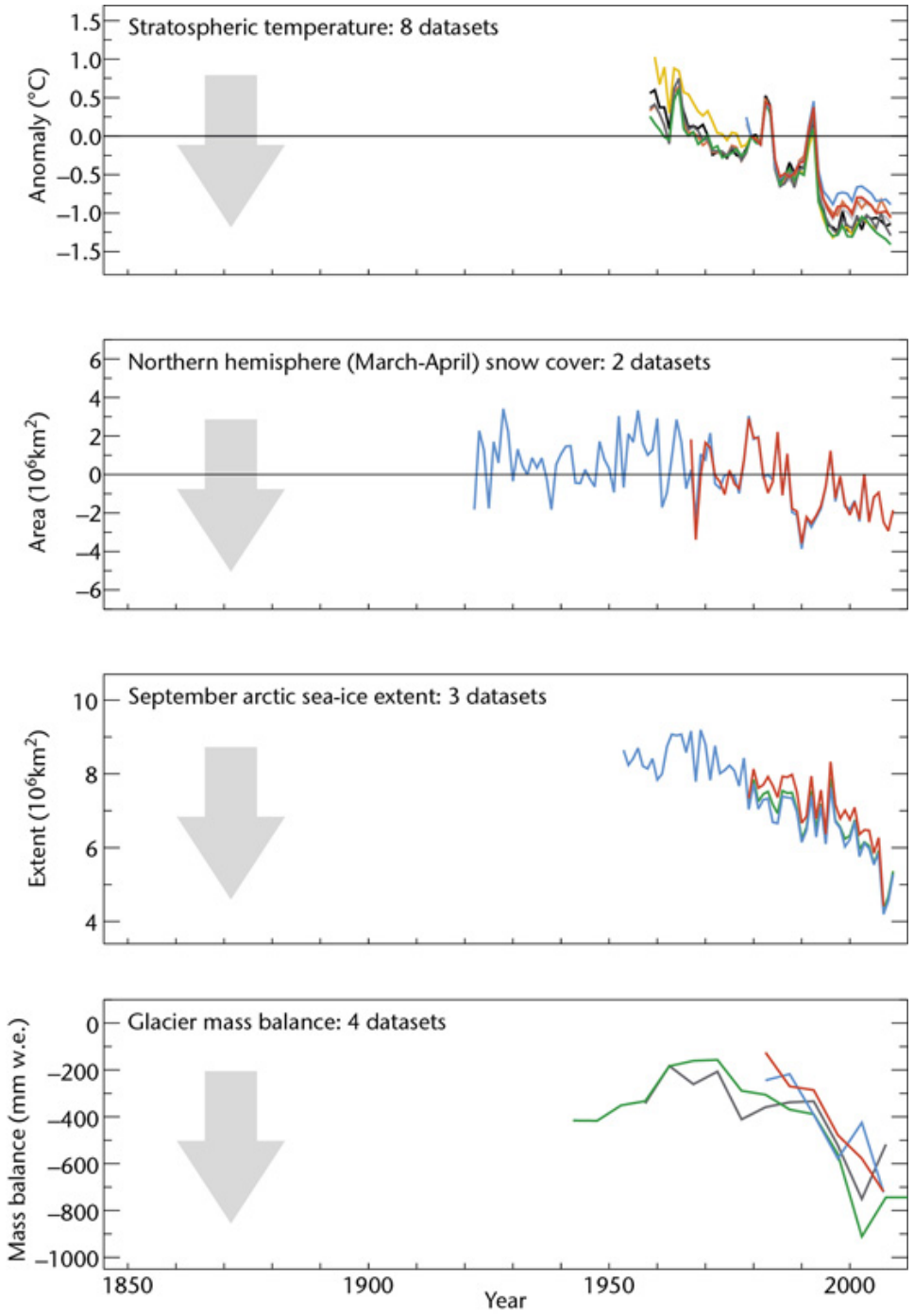
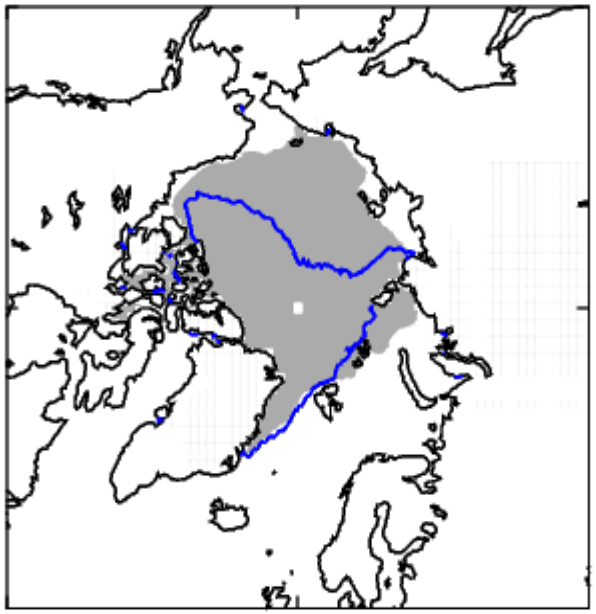
Hadley Centre



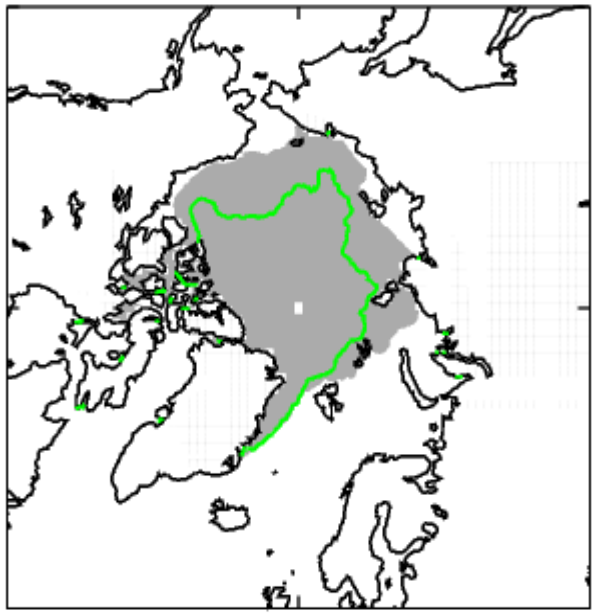
Sea ice decline and variability

Average summer ice extent – grey shading

Summer 2007

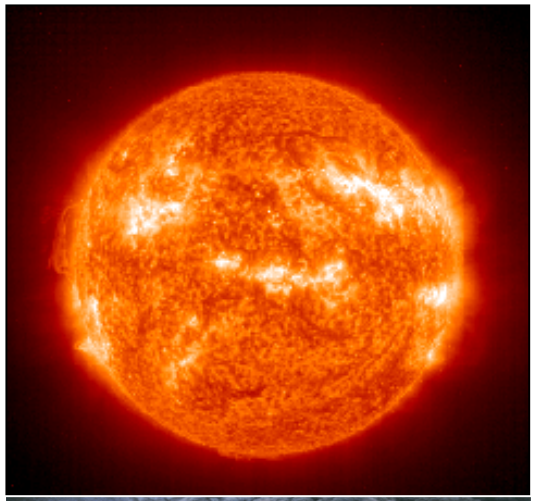


Summer 2011



Attribution of climate change

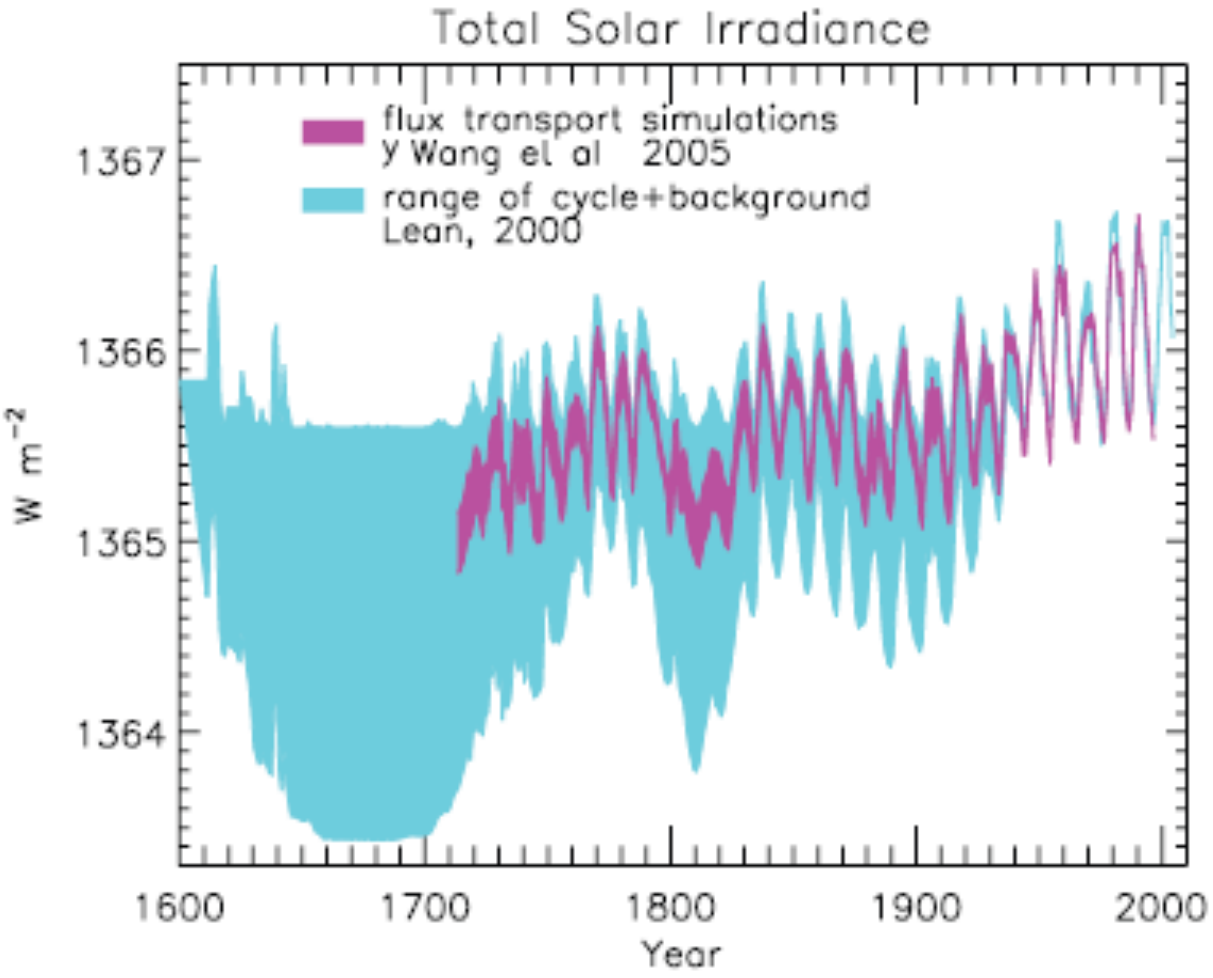
“External” drivers of the climate systems



- Long-term changes in Earth’s orbit
- Variation in solar output
- Volcanic aerosol

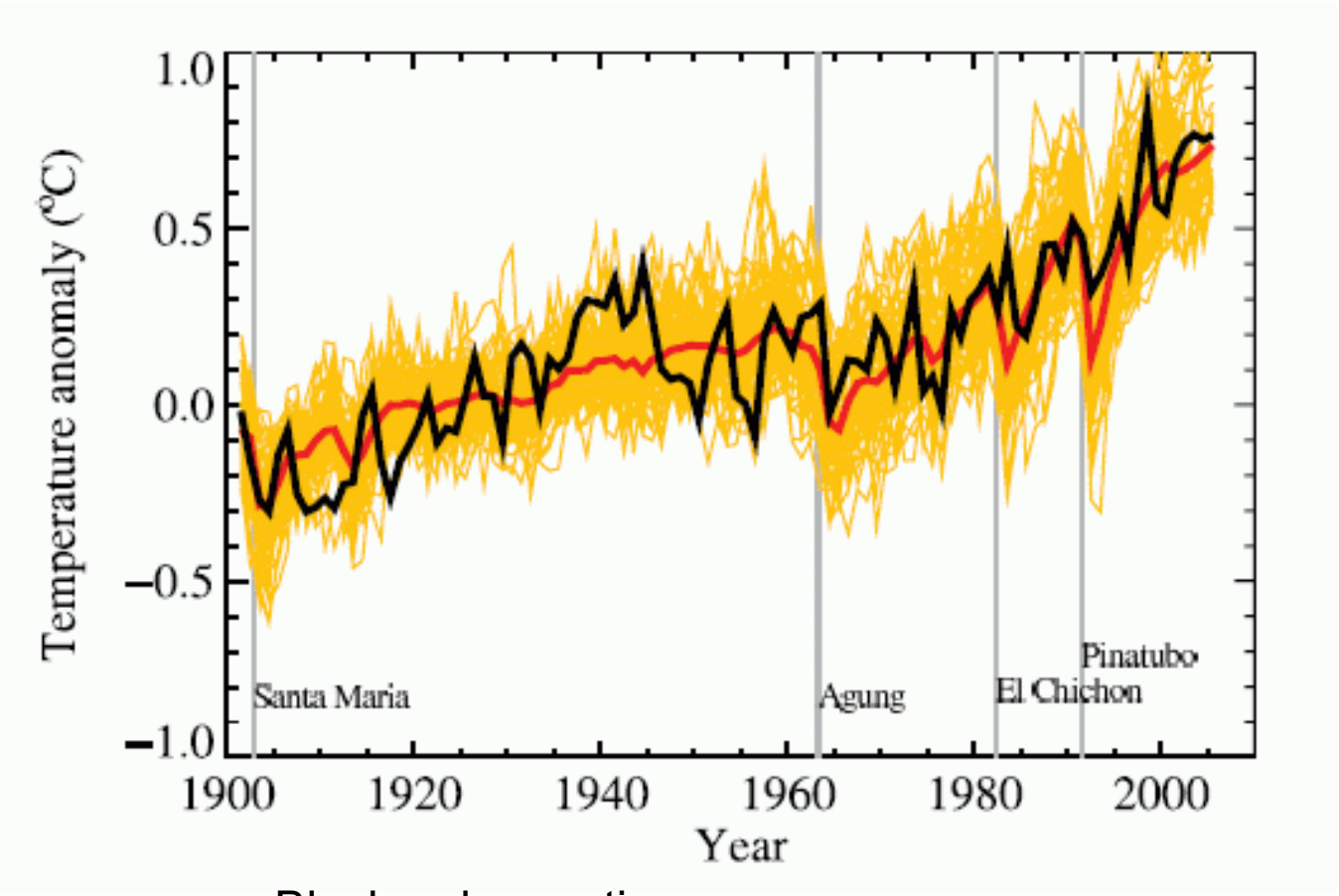
Contribution of the sun to climate change

•Blue – range of solar irradiance arising from 11-year solar activity cycle



Volcanoes

- Affects global temperatures
- Causes cooling of the climate in time-scales of few months – a year or two.



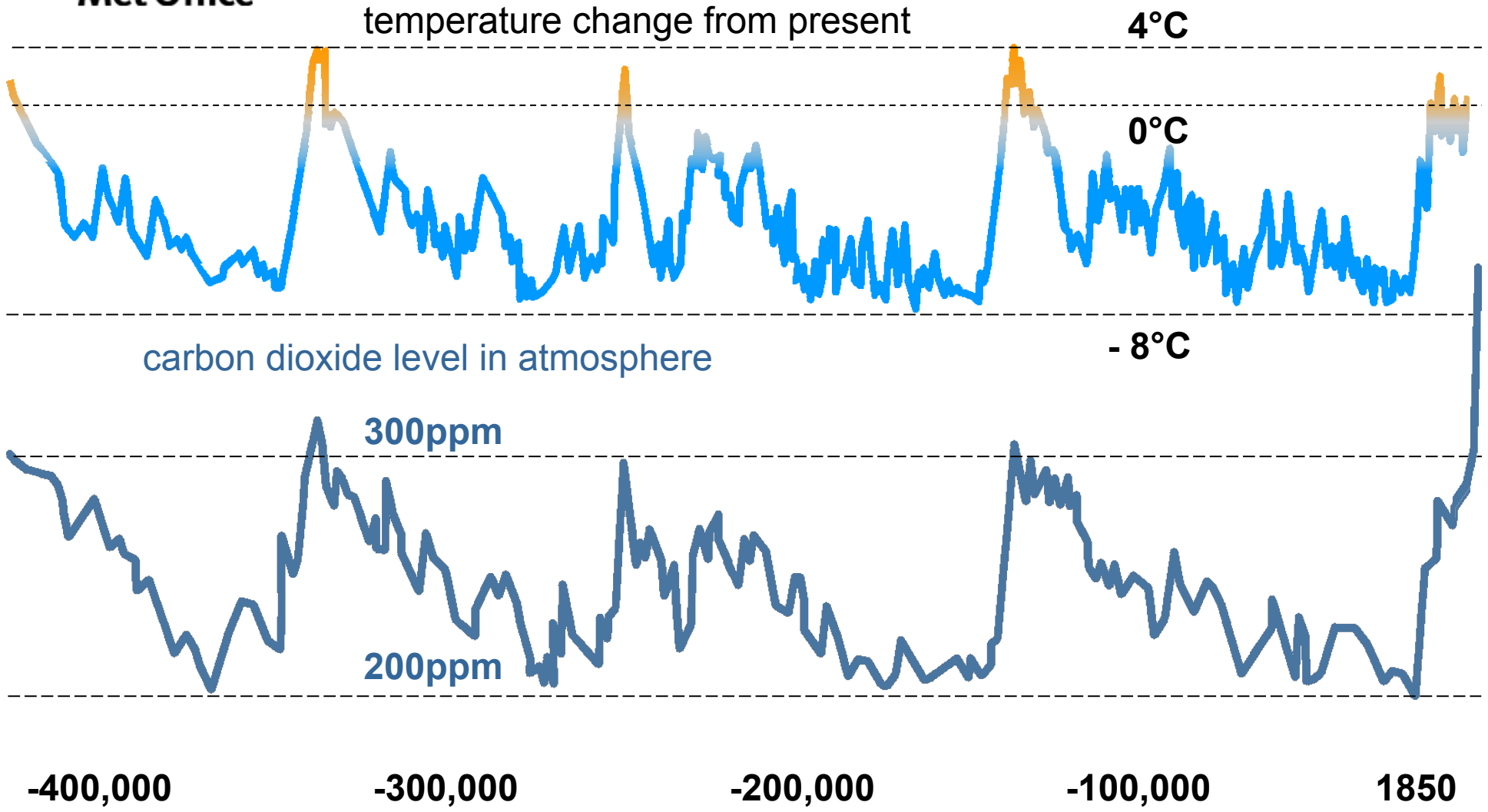
- Black - observations

Anthropogenic contribution

- Greenhouse gases – warming
- Sulphate aerosols – cooling

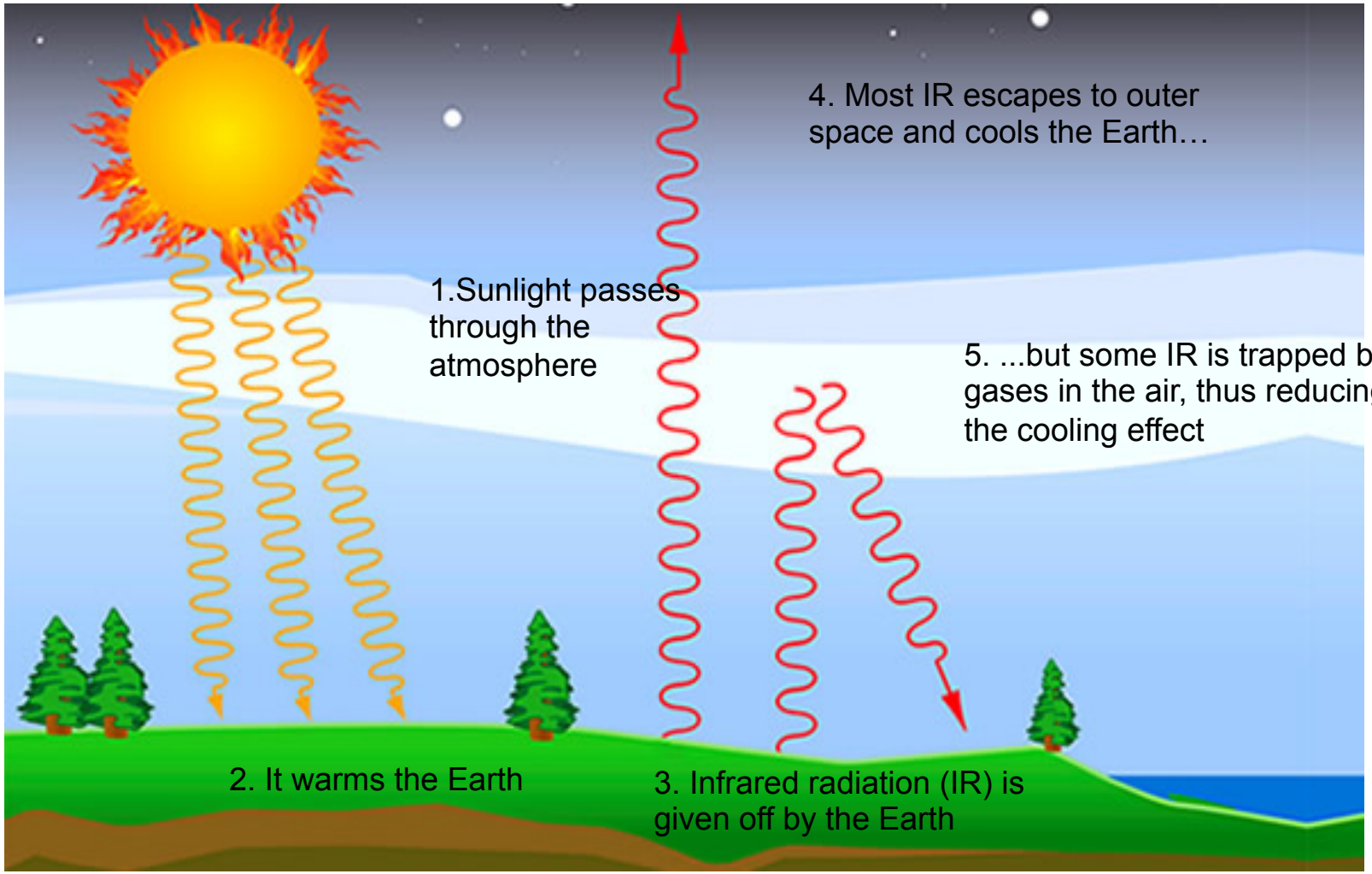
CO_2 in atmosphere is highest in 800,000 years

Vostok ice cores

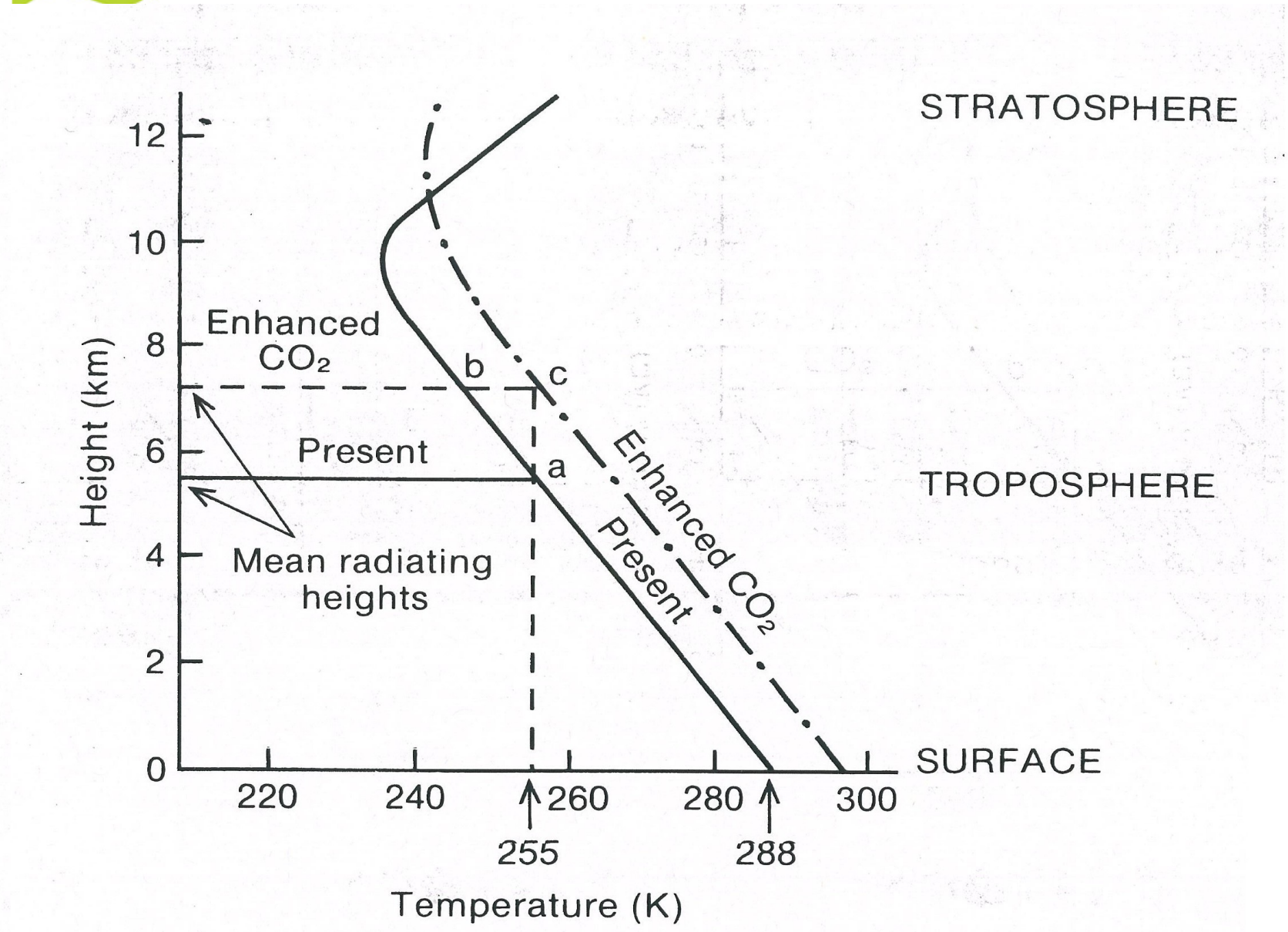


slide courtesy of carbonsense

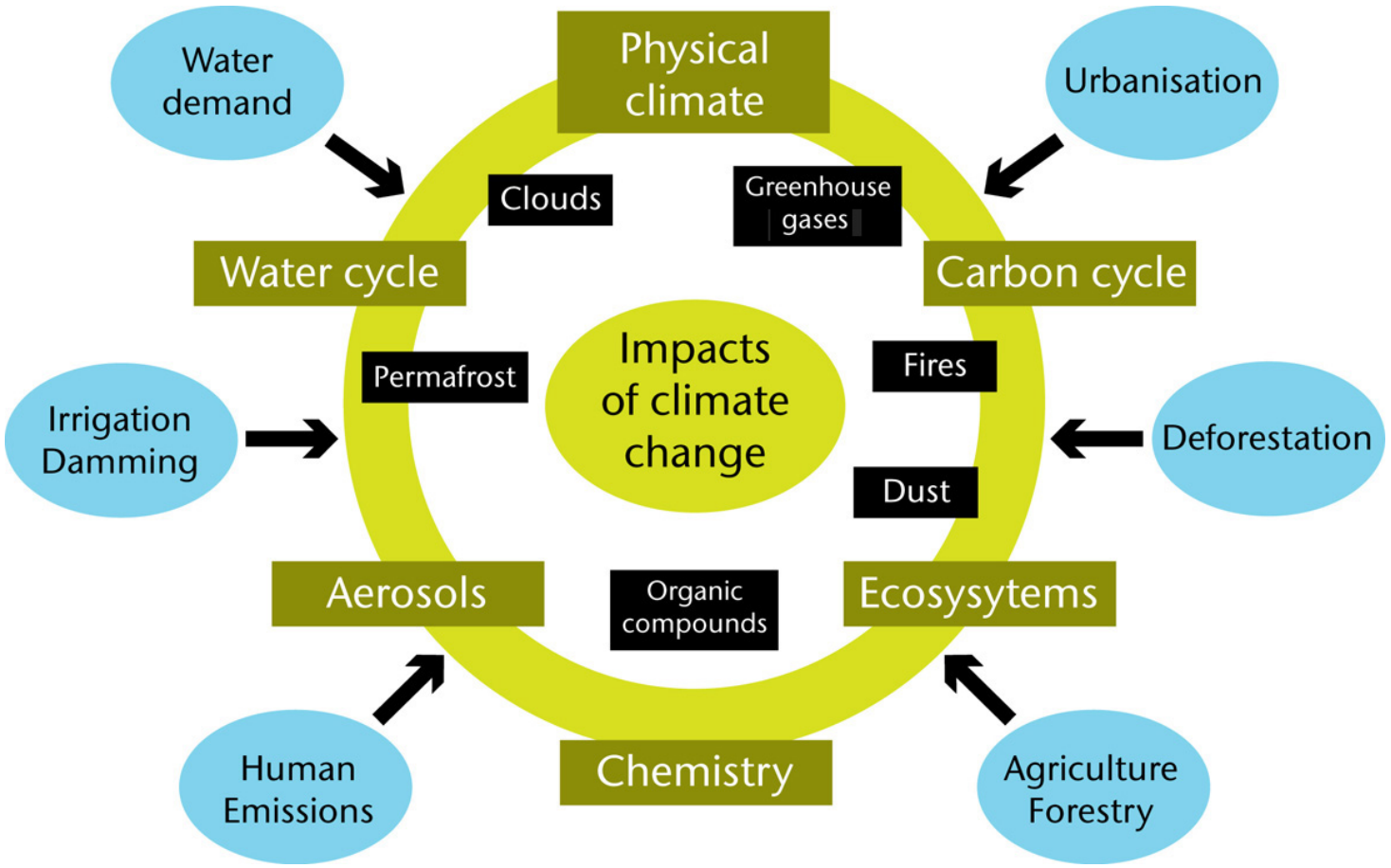
The greenhouse effect



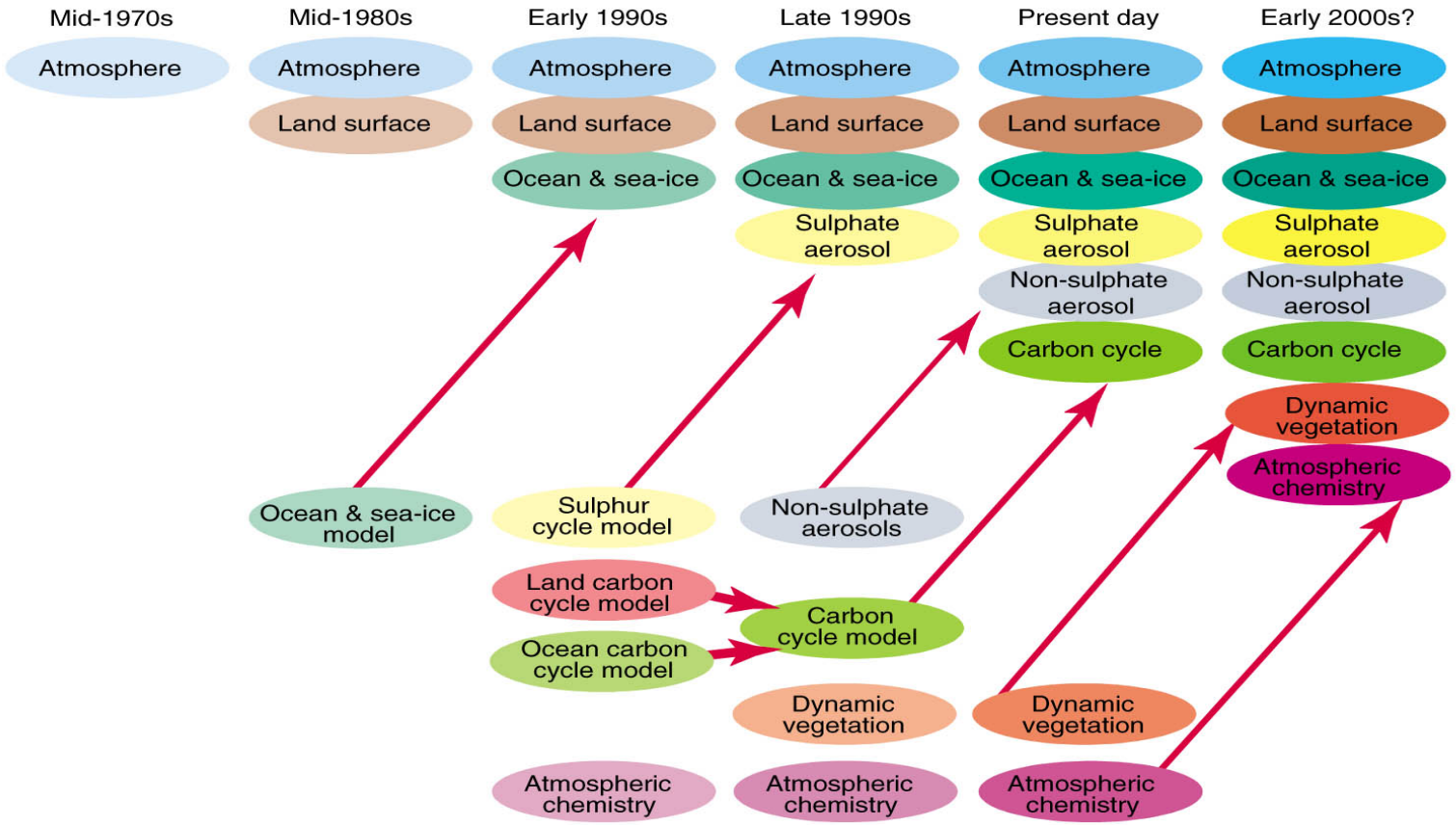
Greenhouse effect



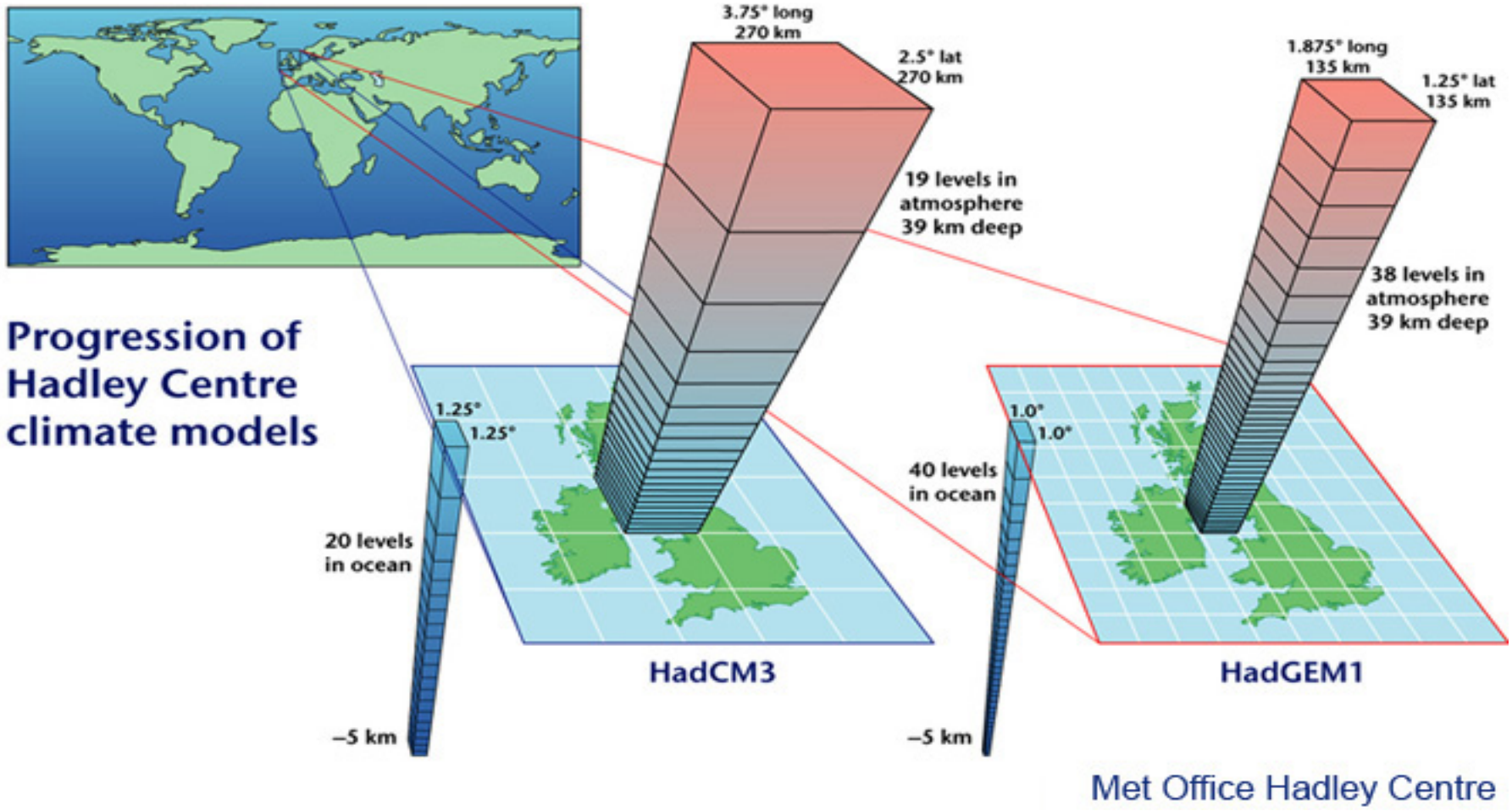
Climate Models



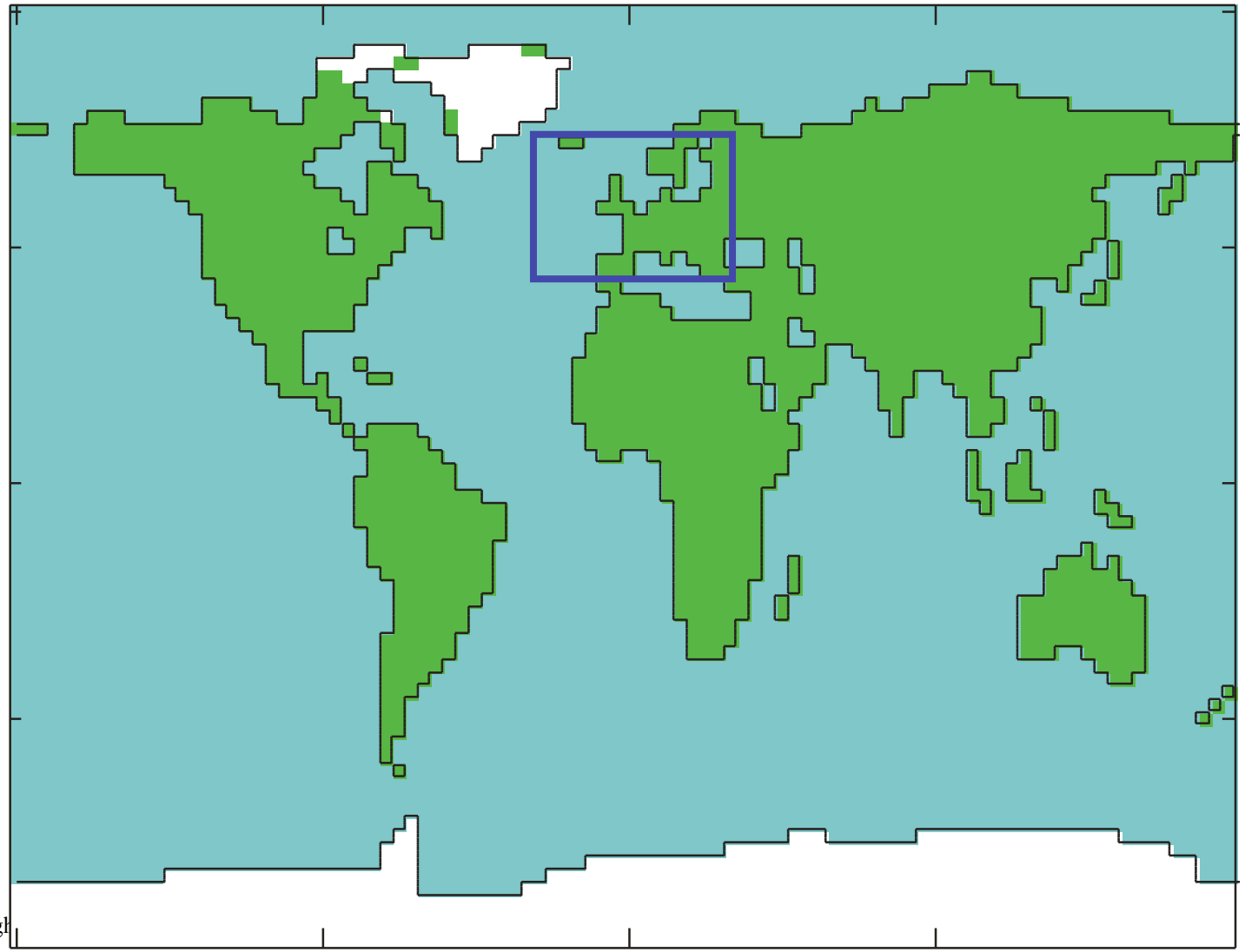
Development of Climate Models



Hadley Centre Climate Models



Land mask in HadCM3 (~300km)



Model Uncertainty

Important processes occur in the atmosphere on scales smaller than those which can be resolved on the grid of the dynamical part of the model. Examples include convection, turbulence, radiative processes..

The effects of these unresolved (sub-gridscale) processes are derived from the large scale state variables by the model (wind, pressure, temperature, moisture). This procedure is called parametrisation.

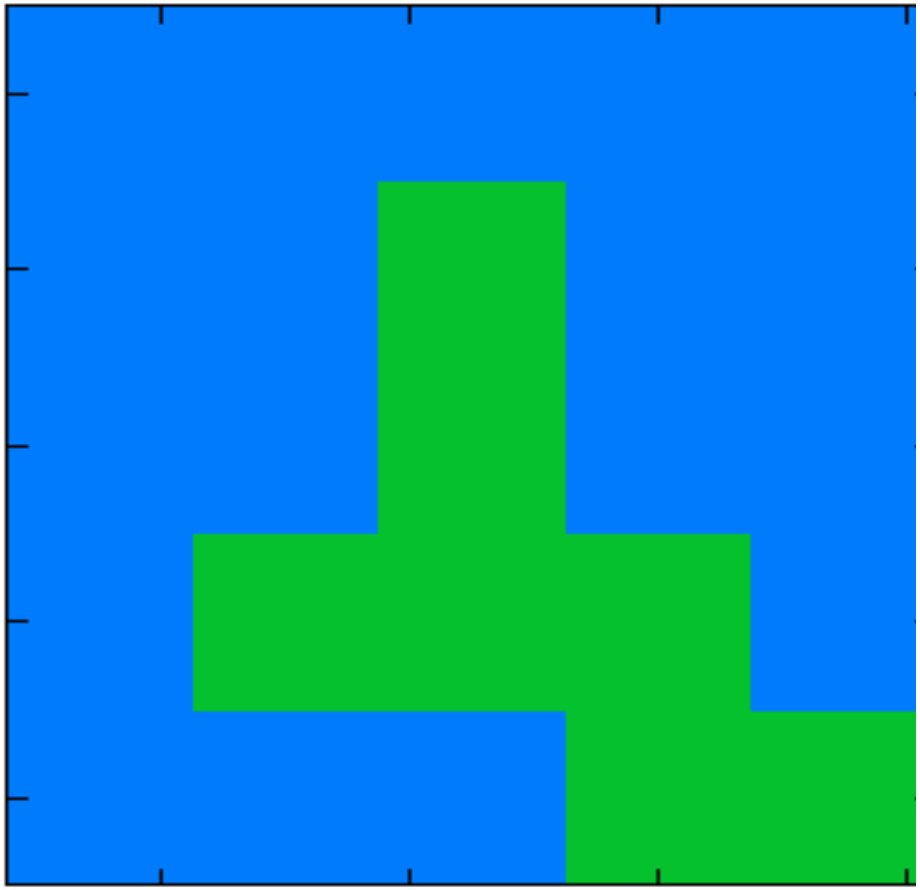
Difference choices are possible both for the parametrisation scheme and for the parameters used by these schemes. This is one of the main source of model uncertainty.

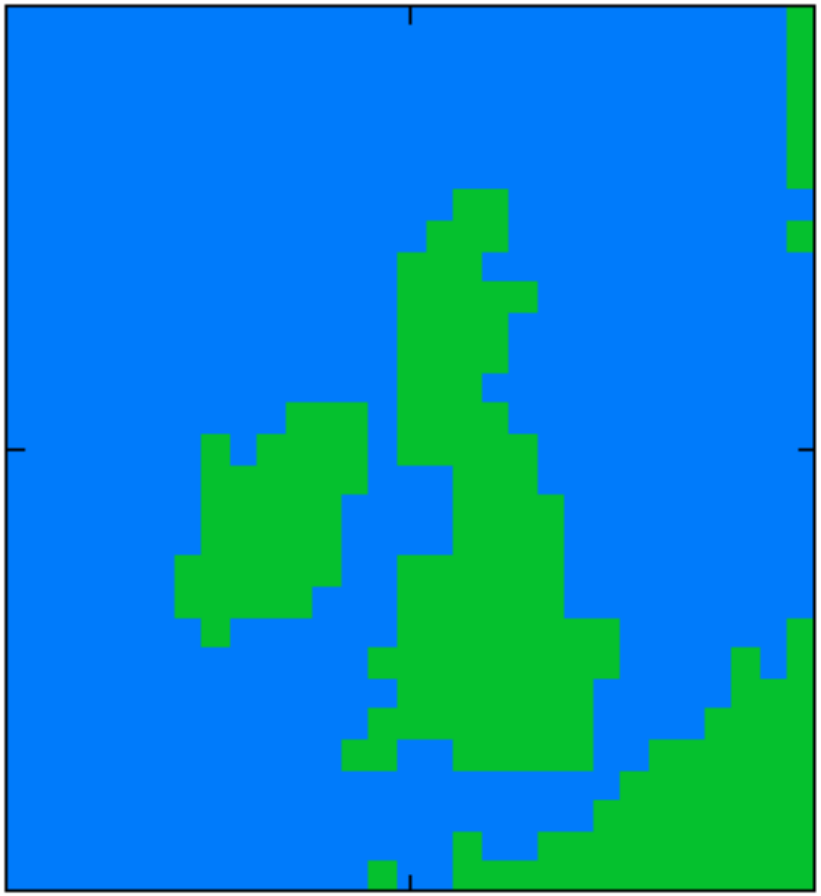
Model intercomparison projects such as CMIP3 and CMPI5 have been set up to allow research in model uncertainty

Downscaling

GLOBAL MODEL

REGIONAL MODEL

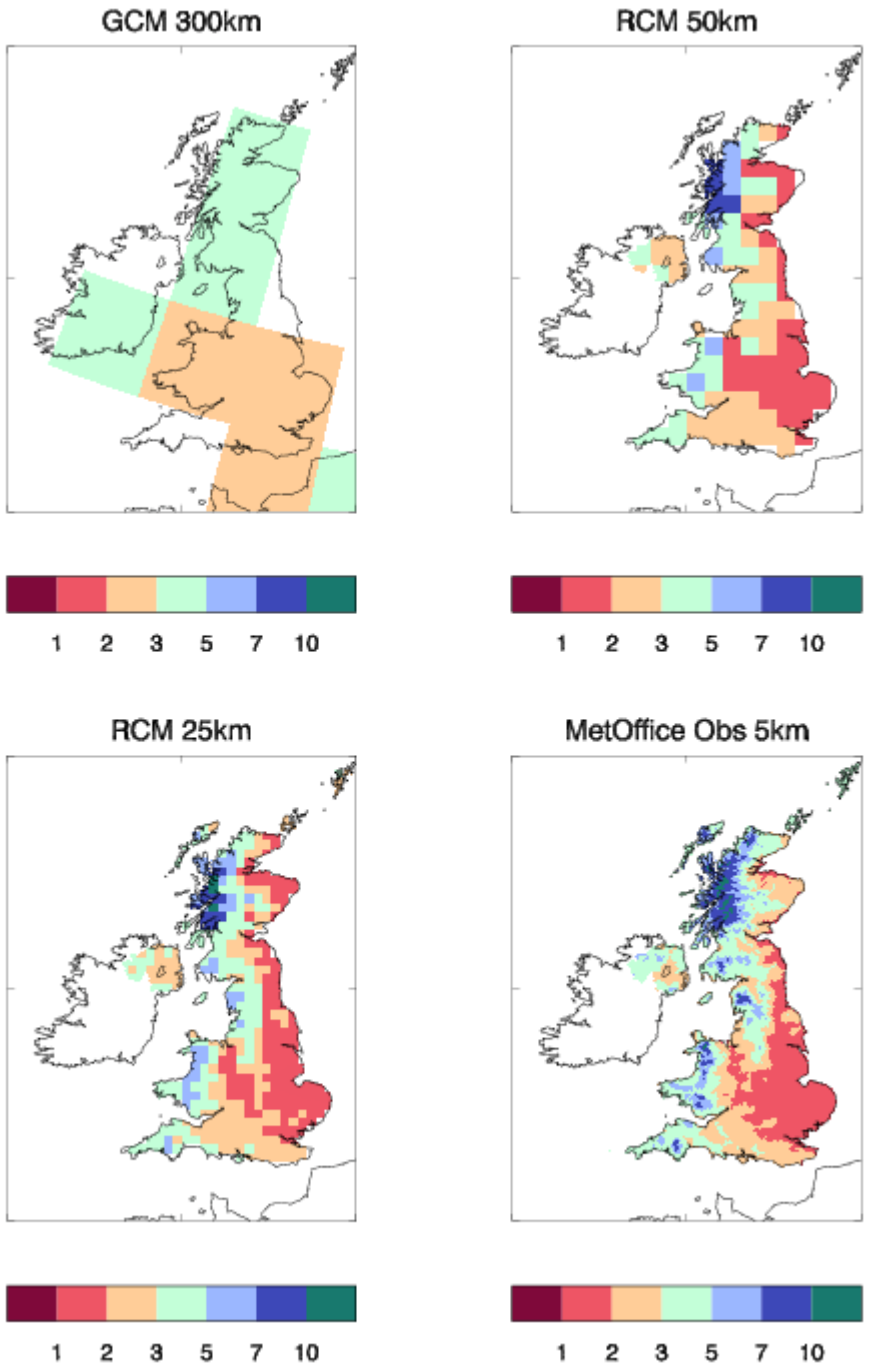




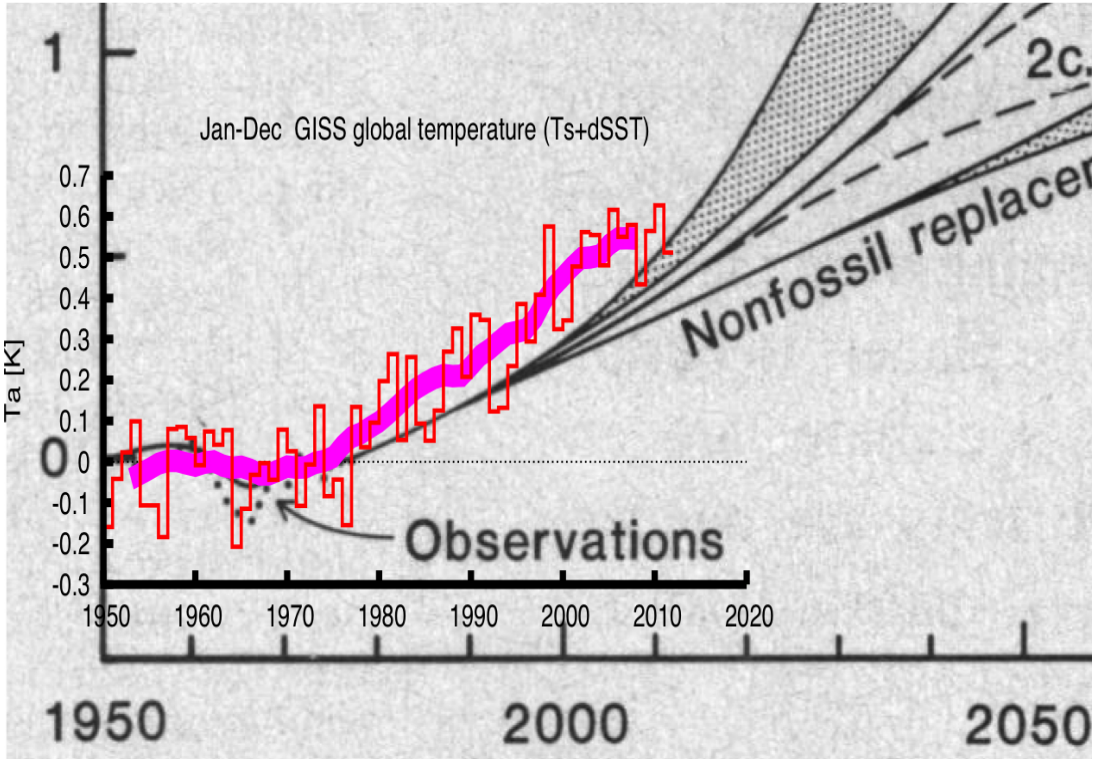
Met Office
Hadley Centre

RCMs simulate current climate more realistically

Patterns of present-day winter precipitation over Great Britain (1960-1990)

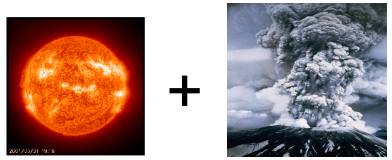


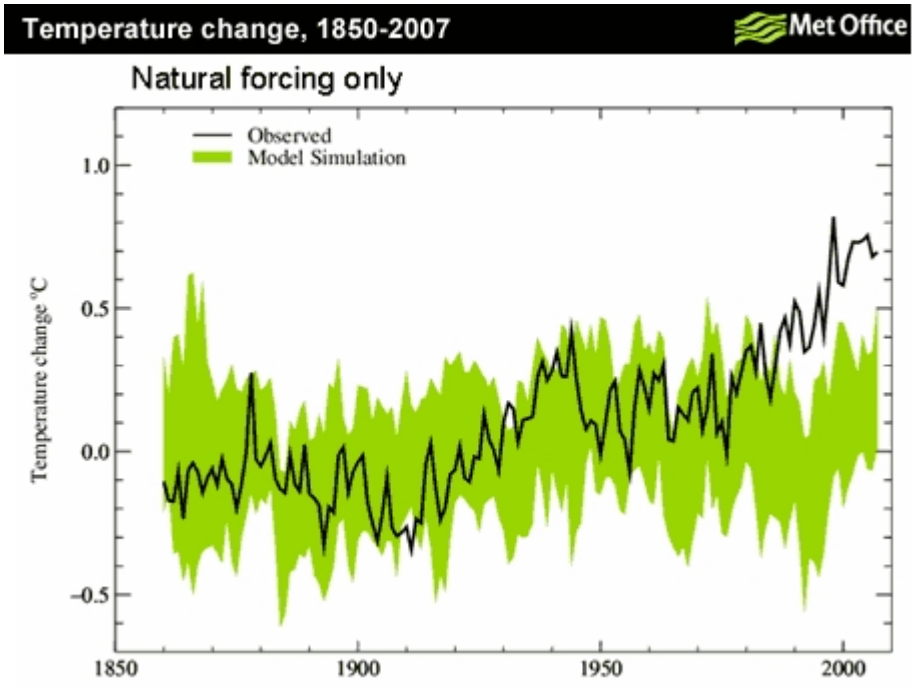
Model predictions from 1980s
(Hansen 1986)

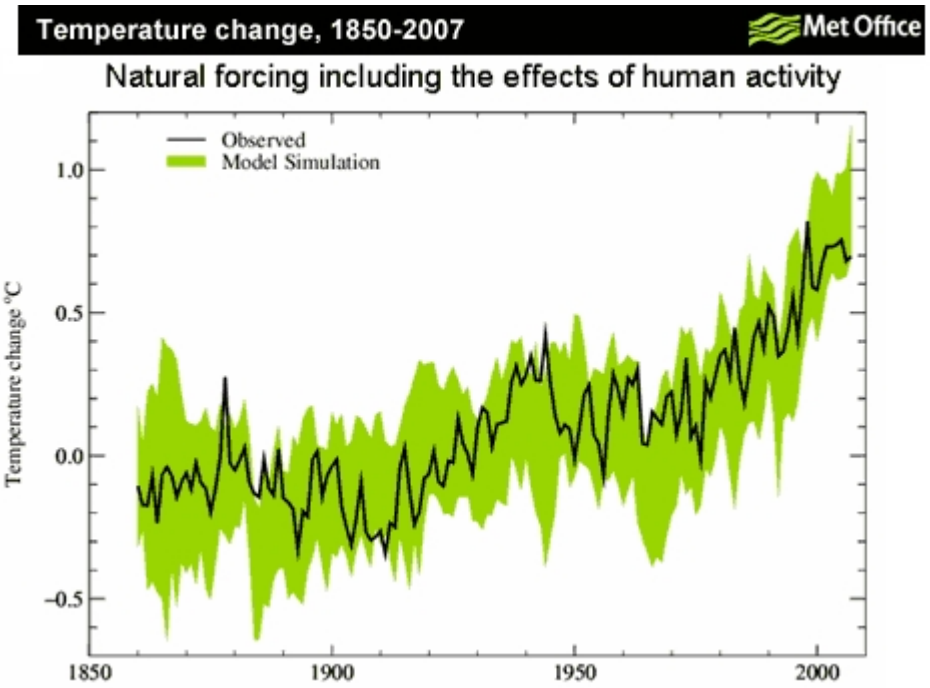


but also Sawyer (Met Office), Nature, 1972, 0.6K warming by 2000

What is causing climate change ?

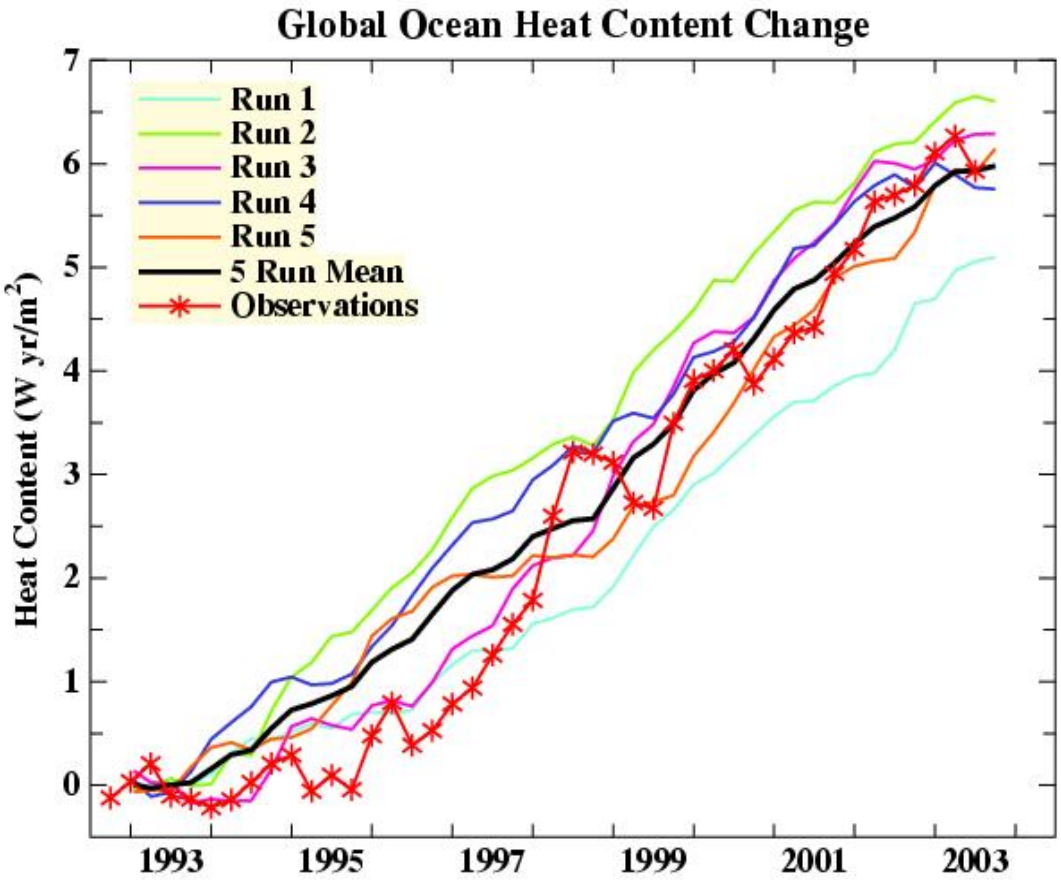






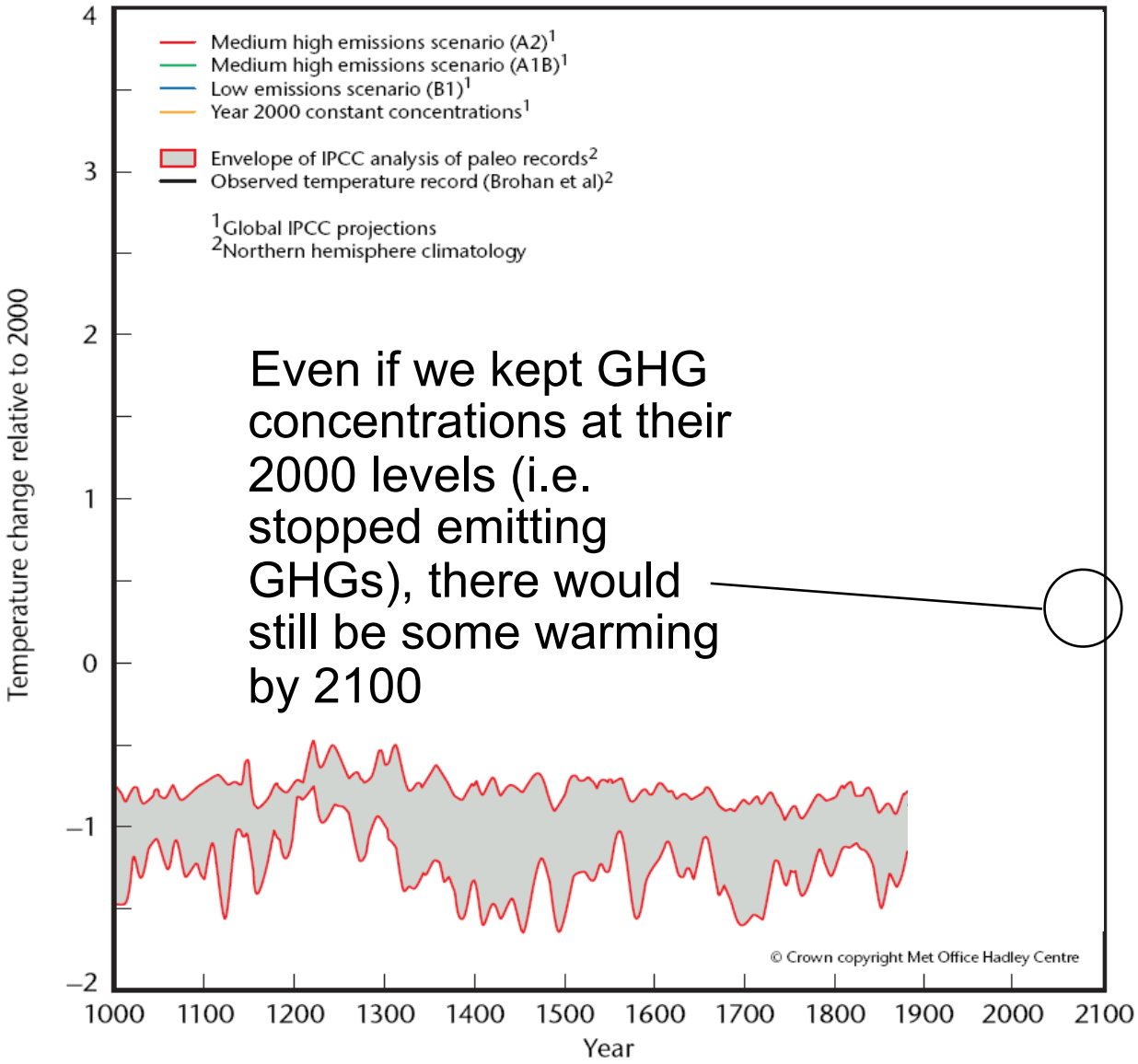
Closing the balance: ocean heat uptake

GISS model (Hansen et al, 2005)
Measurements for upper 750m ((Willis et al, 2004)

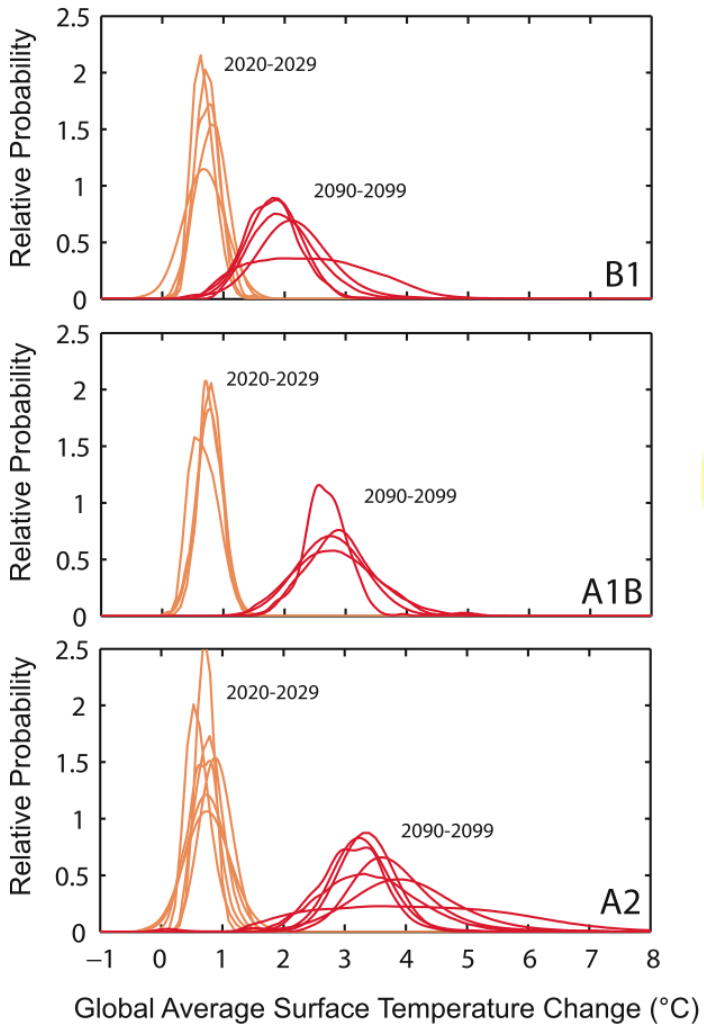


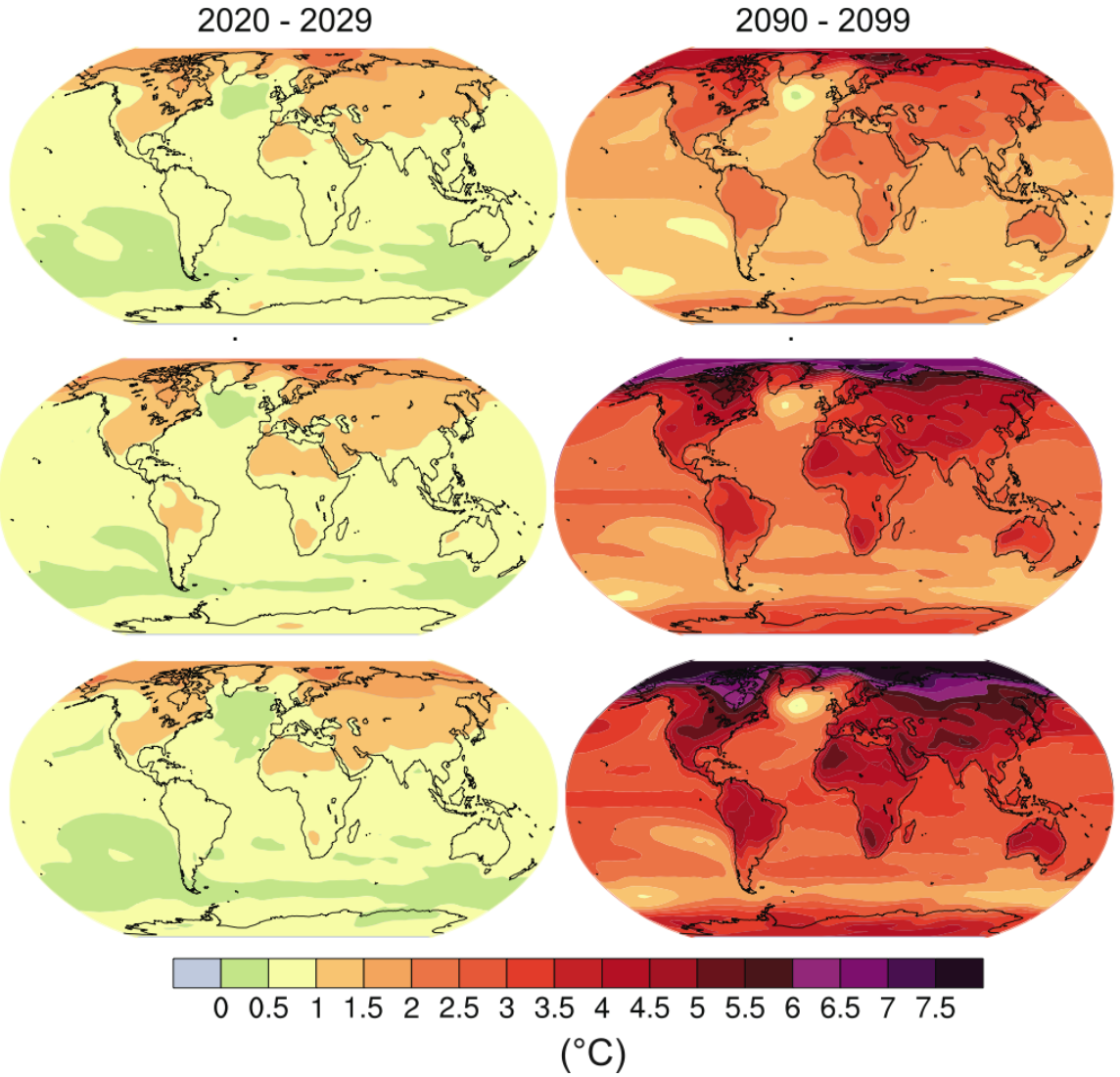
Climate change projections

Projections of temperatures (IPCC-AR4)



Uncertainty for different emission scenarios

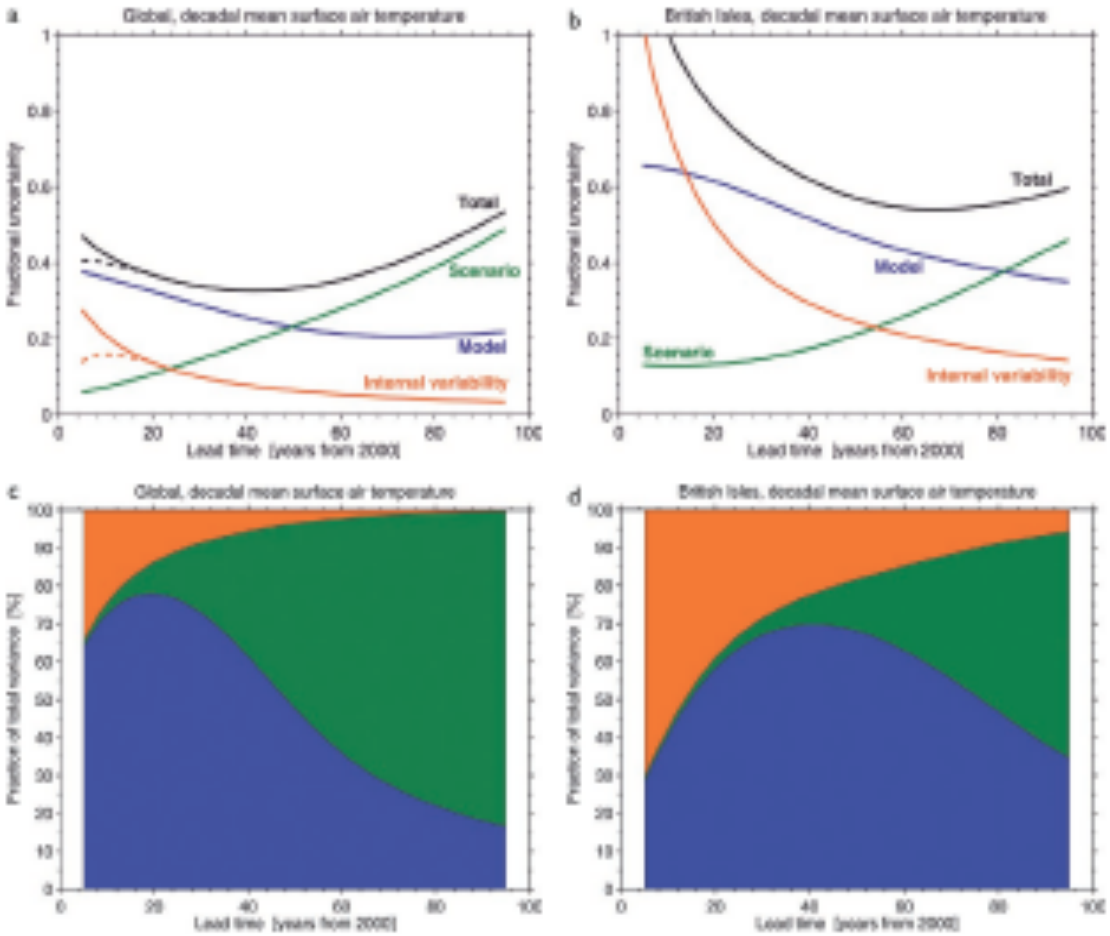




Sources on uncertainty

Global Temperature

British Isles Temperature



Fractional uncertainty (90% confidence interval/mean projection) for 10y temperature as a function of lead time. From the CMIP3 dataset (Hawkings and Sutton, 2009). Orange, internal variability; Green, emission scenario; Blue, model.

Model Uncertainy: Climate Sensitivity

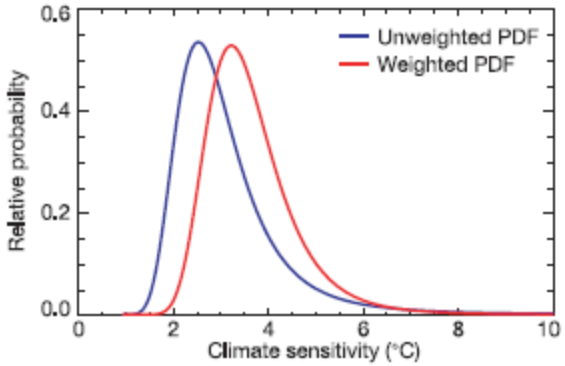
Climate sensitivity: climate response when doubling [CO_2] with respect to pre-industrial revolution concentrations

One parameter “summary” of climate models

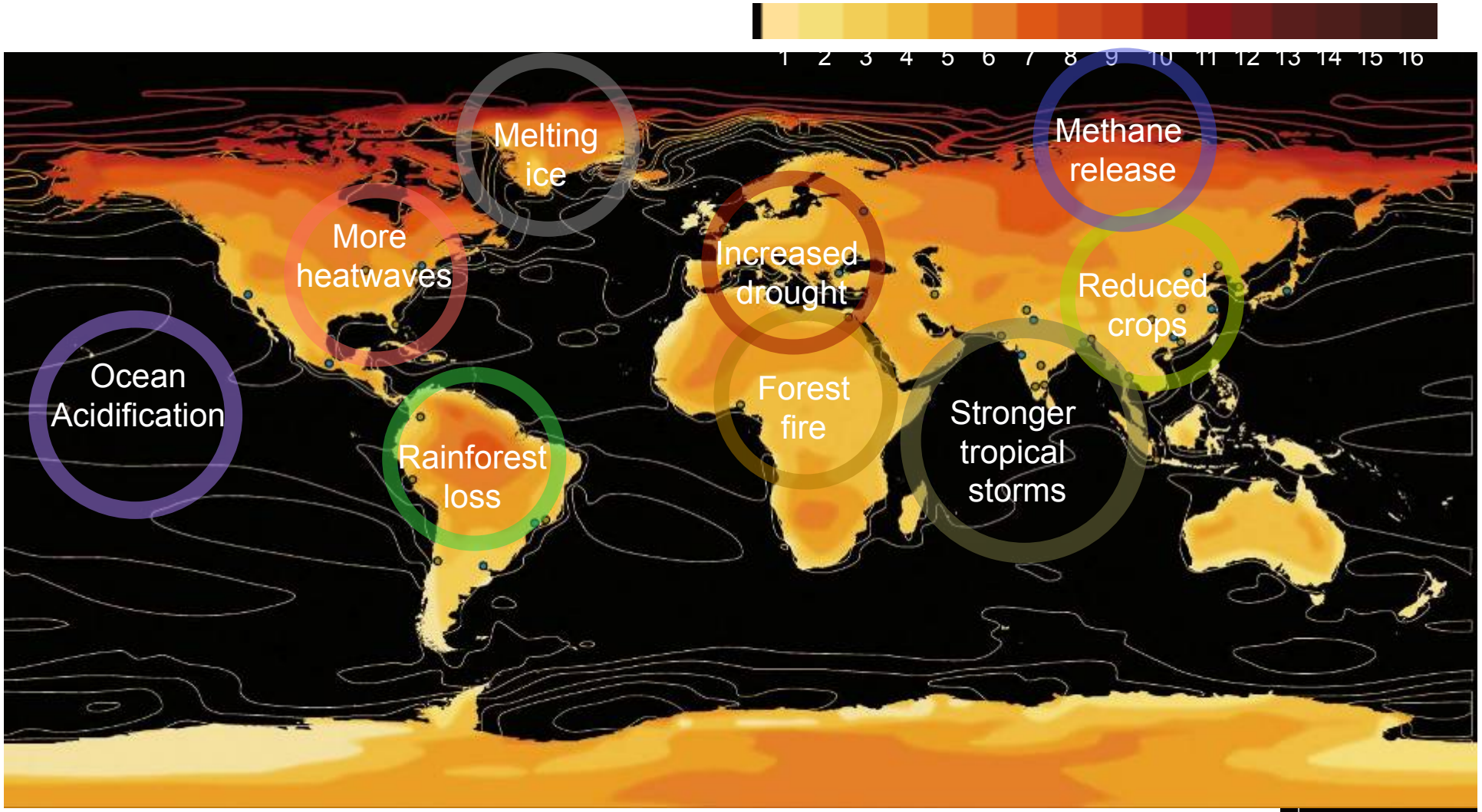
Climate change has no precedents in the available record, ongoing research in estimating a range for climate sensitivity

Parameter perturbation: generating all possible models consistent with a given model structure

Murphy et al, 2004
Bayesian approach to constrain climate sensitivity with observed data



The impact of a global temperature rise of 4 ºC

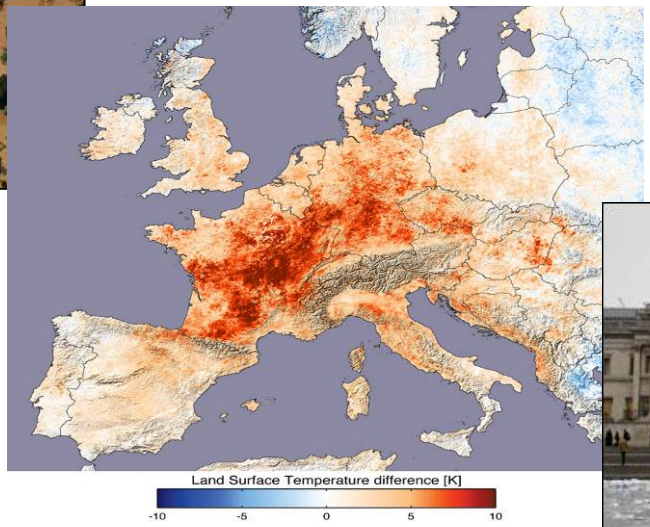


• 3-10 million • 10-20 million

HM Government

Natural variations compounded by global warming may give unprecedented extremes

Tewkesbury flooding
July 2007



Summer heatwave 2003

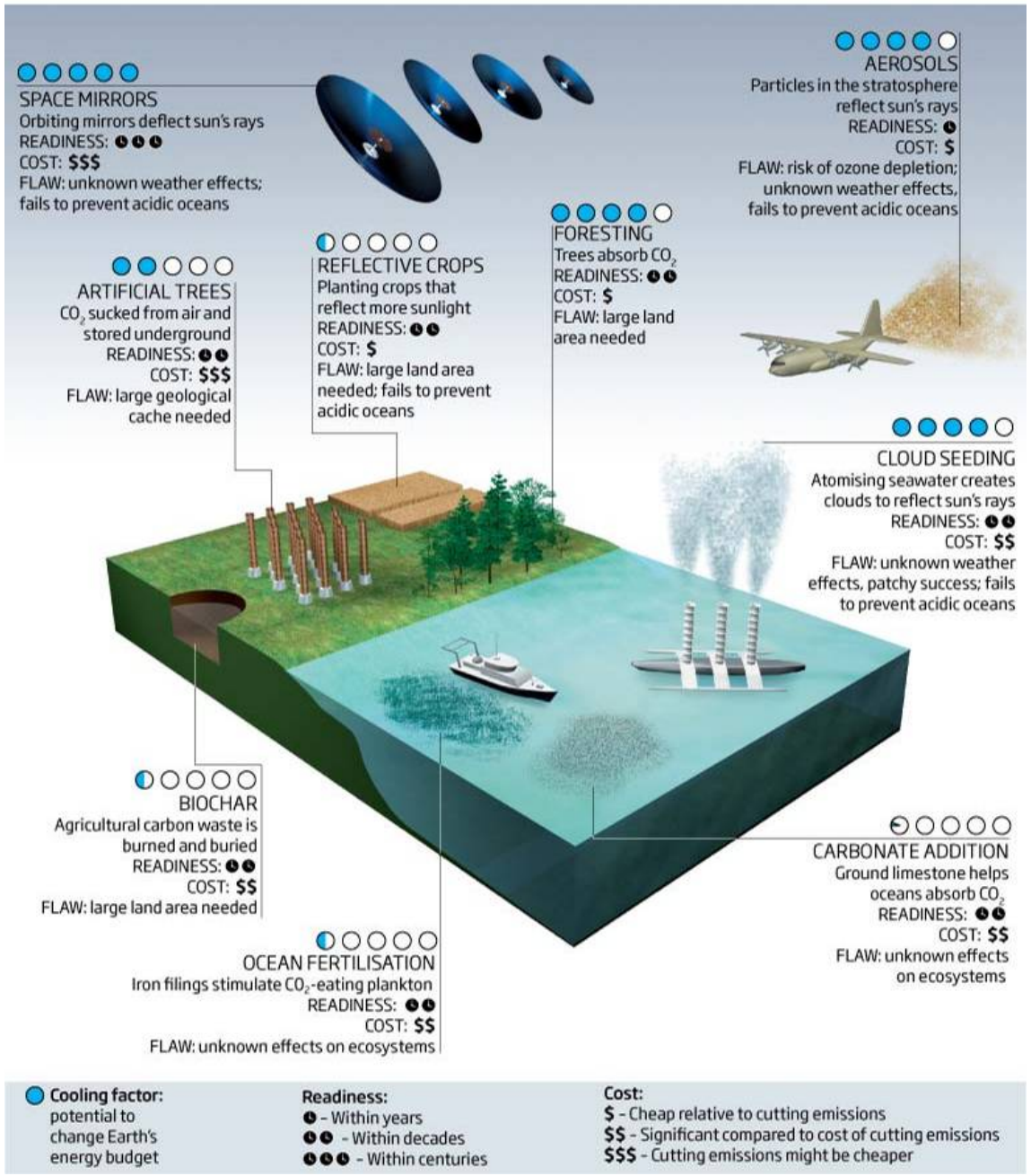
Protecting society against extreme weather events in the future requires modelling the weather at regional and local scales

Cold winters, UK, 2009, 2010

Is Geo-engineering an option?

- The most effective options involve interference with the climate system.

- These will have regional consequences (e.g. rainfall changes) that must be understood.



Questions