Climate change mitigation and why dealing with CO_2 is so difficult

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Structure

This session will explain

- the role of greenhouse gases in causing climate change
- the projections of, and evidence for, climate change
- why dealing with CO2 is so difficult given the nature of our energy, industrial and transport systems
- where international efforts to prevent climate change have got to and what key emitting countries are doing

Learning outcomes

An understanding of the:

- Contribution of different greenhouses gases to climate change
- Main mitigation strategies, options and technologies for CO_2; and
- Technical and political challenges involved in tackling climate change

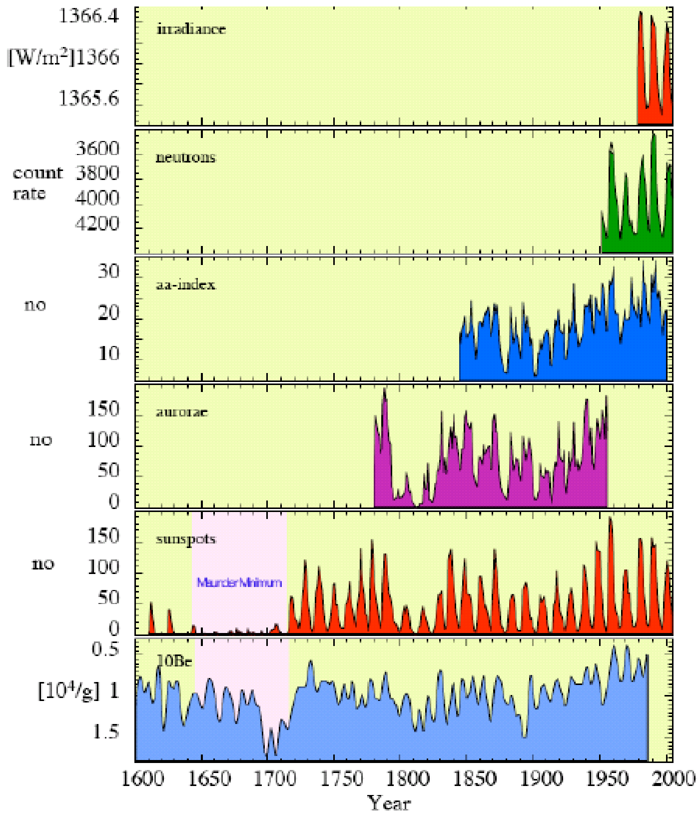
Role of the sun

- Sun provides the energy that drives Earth's climate system.
- Current flux of solar radiation about 1365 Wm^{-2}

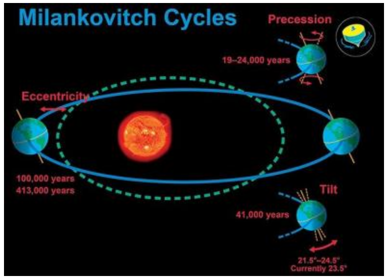
- Variations in the composition and intensity of incident solar radiation may produce changes in global and regional climate which are both different and additional to those from man-made climate change.

Variability due to:

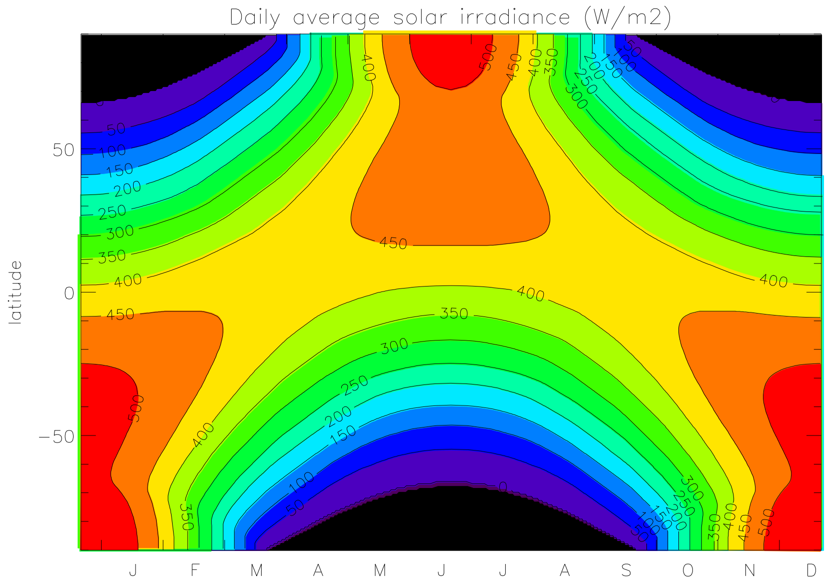
- Internal stellar processes that affect the total radiant energy emitted by the Sun i.e. "solar activity".
- Changes in the Earth's orbit over tens and hundreds of thousands of years directly affect the amount of radiant energy hitting the Earth and its distribution across the globe – Milankovitch cycles..

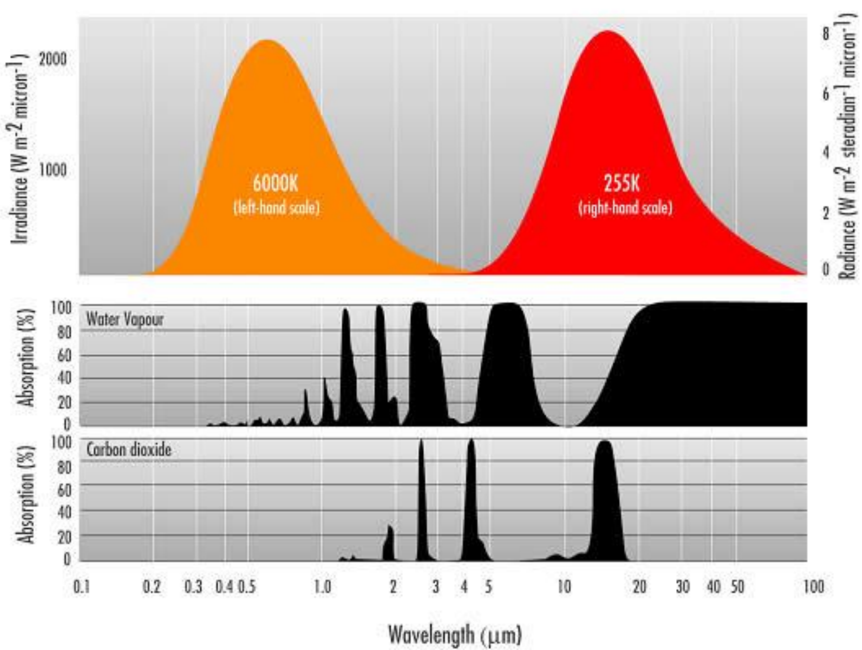


Source: J. Beer, M. Vonmoos and R. Muscheler. Solar variability over the past several millennia. Space Science Reviews 125, 67-79, doi:10.1007/s11214-006-9047-4 (2006)



Solar irradiance and greenhouse effect

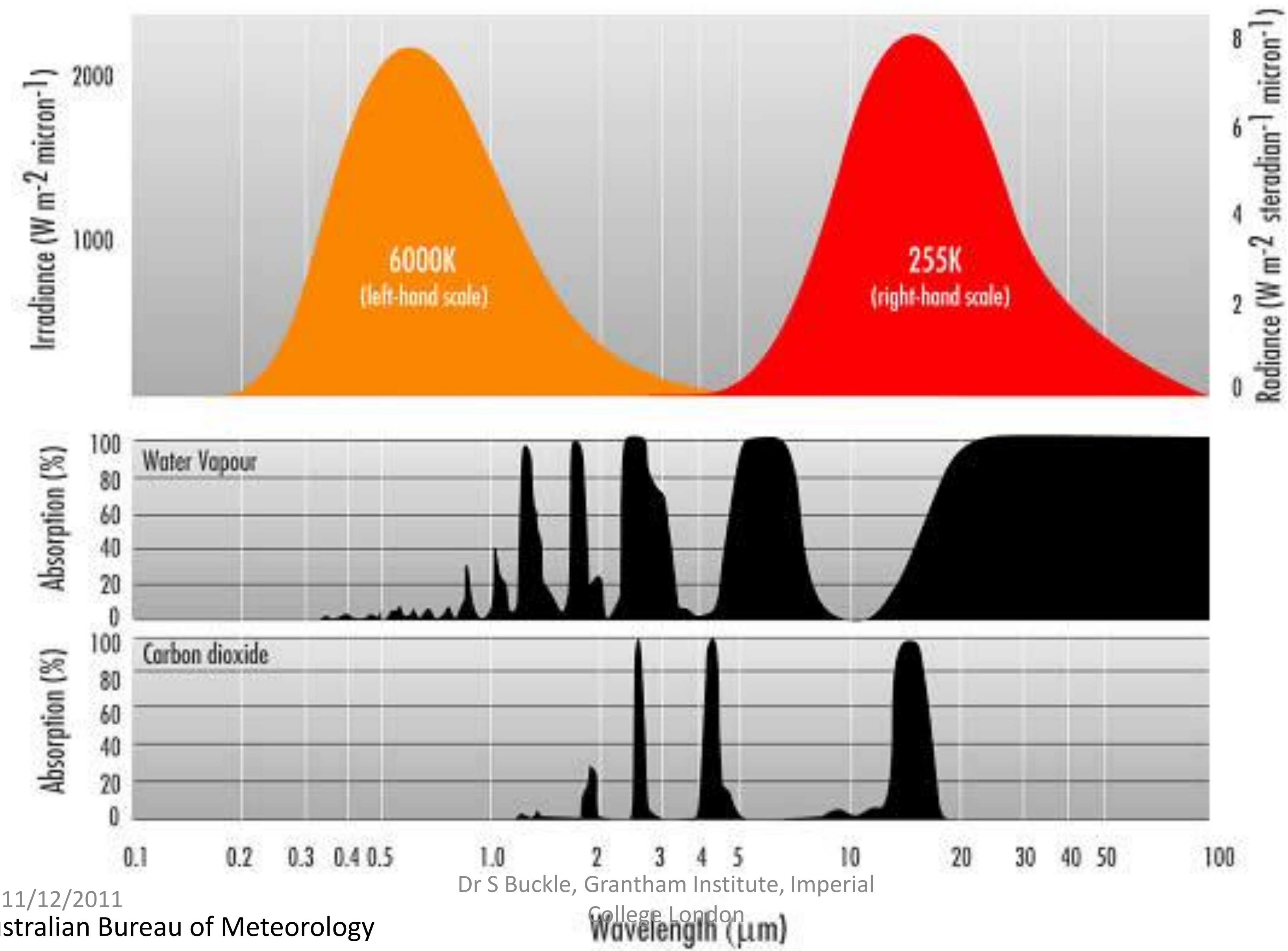




Australian Bureau of Meteorology

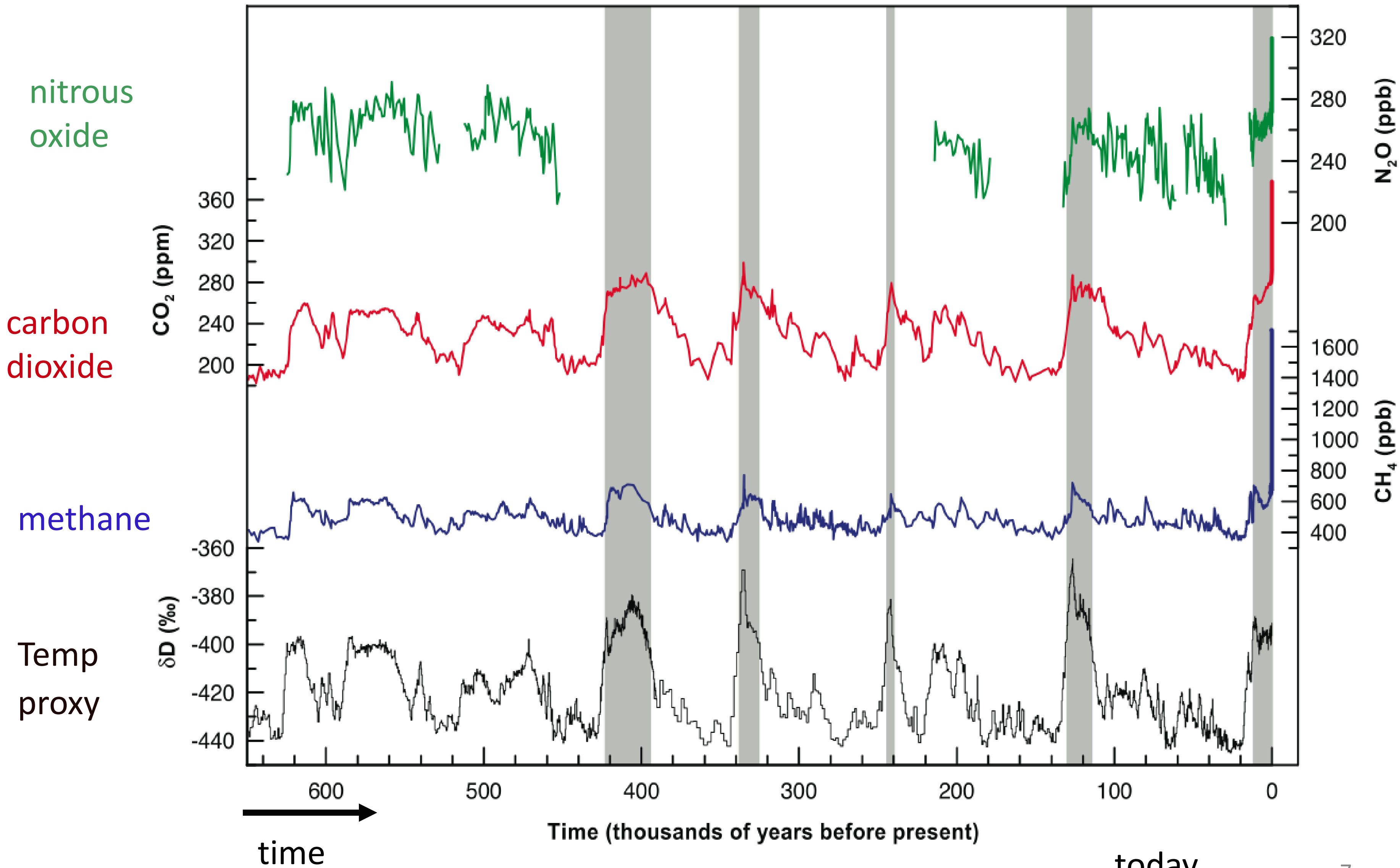
- Of total solar radiation incident on earth, ~30% is reflected back to space by bright surfaces including clouds and ice.
- The remainder is absorbed, warming the surface and the atmosphere.
- Much of the heat radiation emitted by the surface is trapped within the atmosphere by "greenhouse" gases, mainly water vapour but, *in the absence of other changes*, enough heat is emitted to space to balance the incoming solar radiation and establish a climate equilibrium.

The greenhouse effect – absorption of radiation



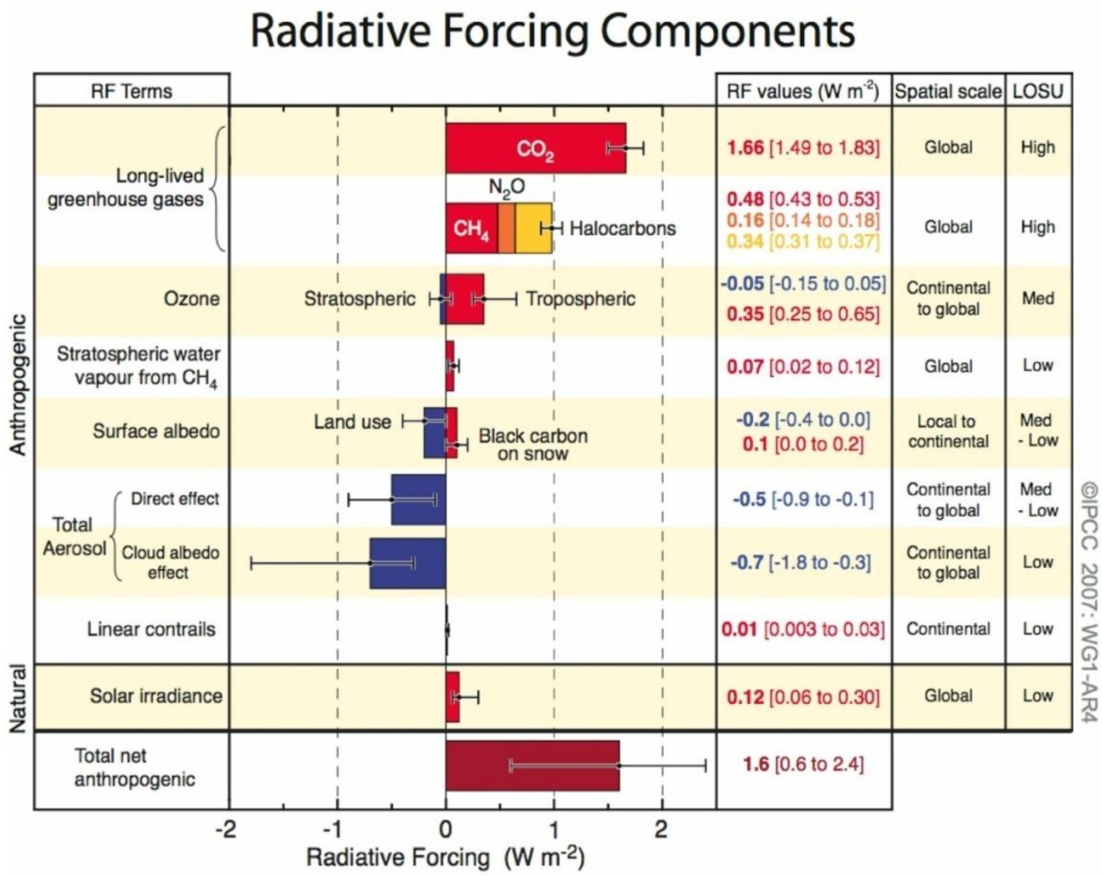
Australian Bureau of Meteorology

Temperature and GHGs in past 650,000 years

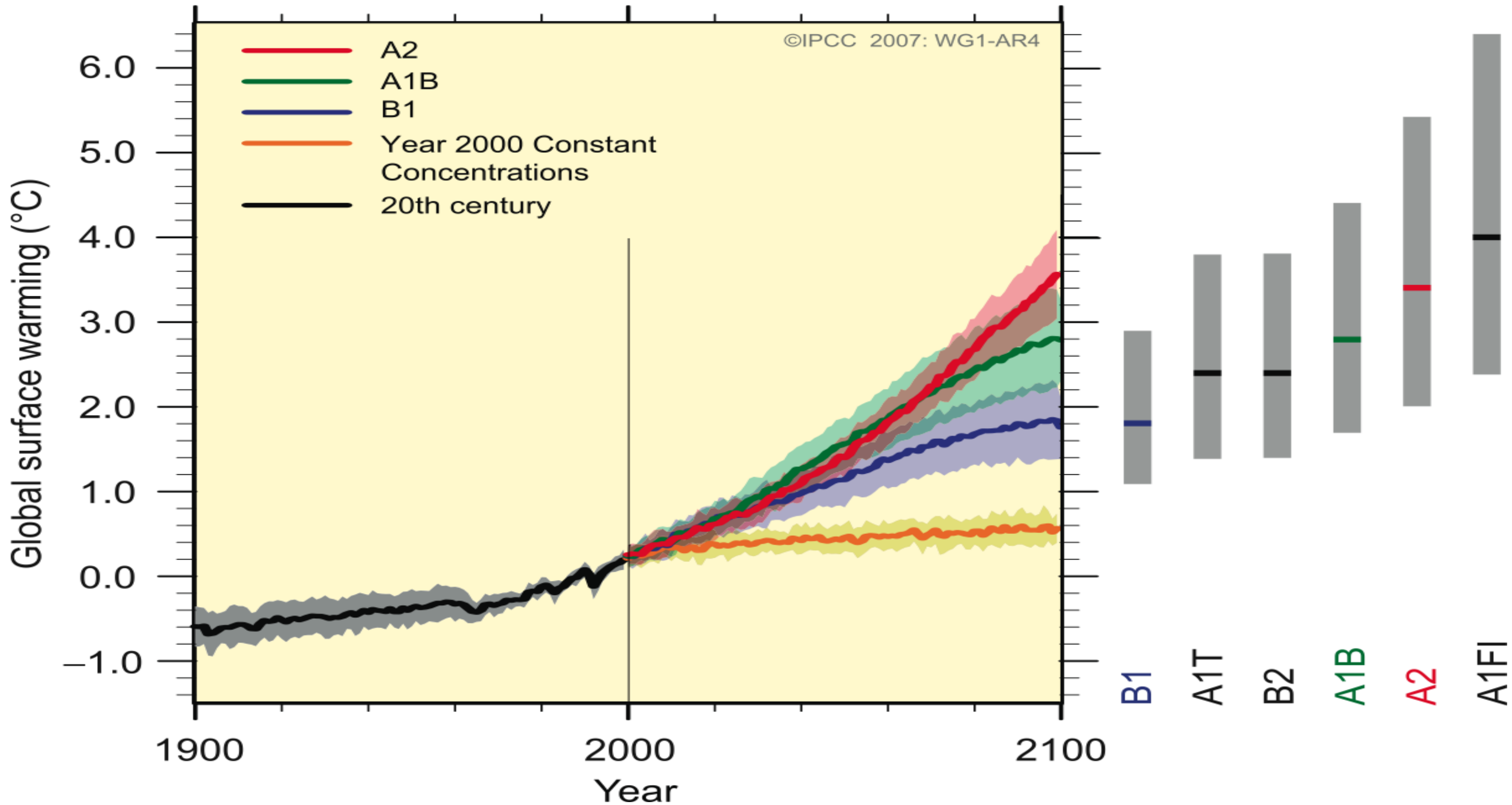


Source: IPCC 2007

GHGs and climate change



Climate change projections – IPCC AR4

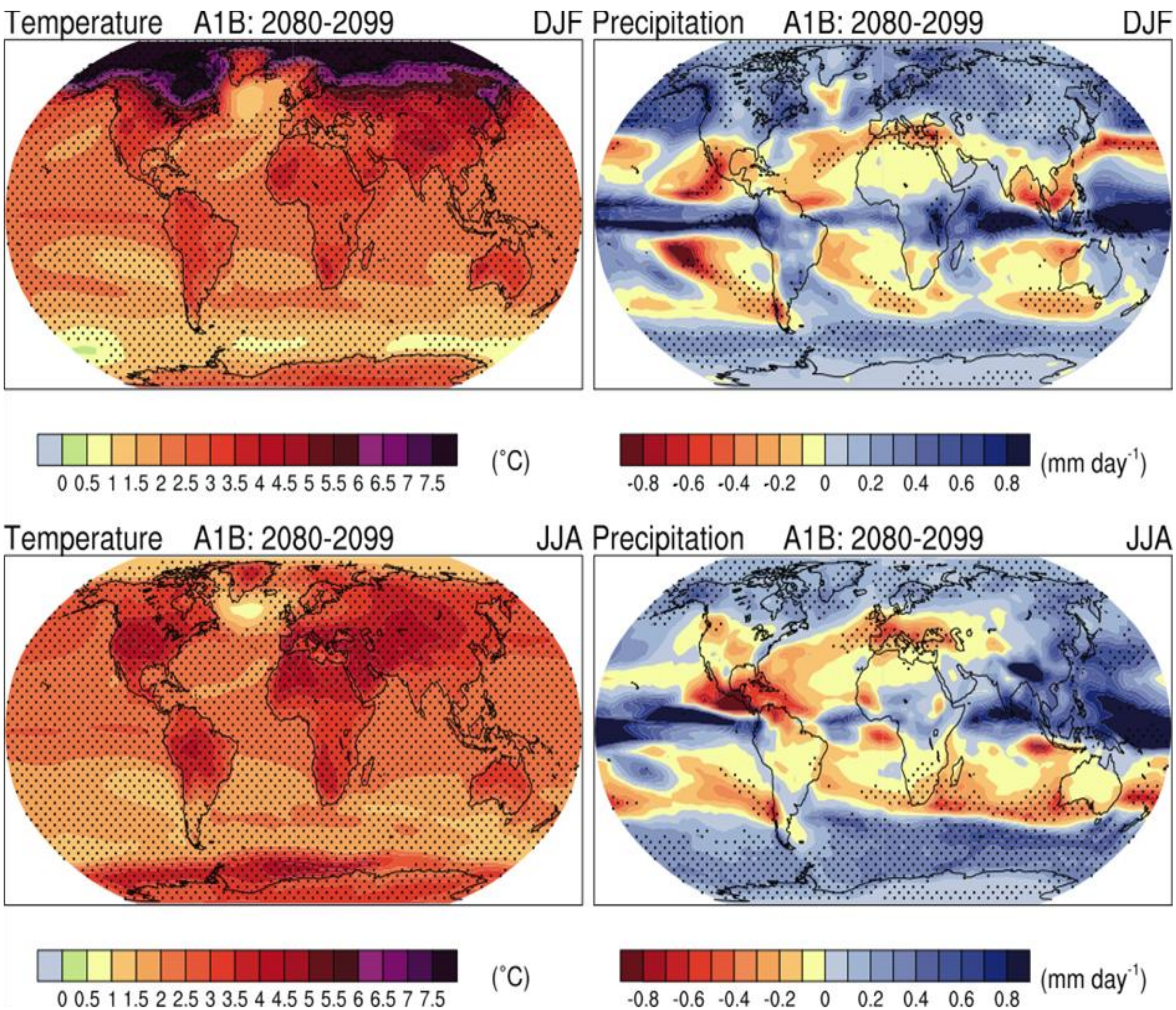


- Warming unequivocal; and
- Most warming since mid- twentieth century very likely due to human activity
- Average temperatures likely to rise by 1.8-4.0°C by 2100 (range 1.1-6.4°C).
- Change already visible e.g. loss of Arctic sea ice; timing of Spring events.

Projected changes for one scenario (A1B)

Northern Hemisphere Winter

Northern Hemisphere Summer



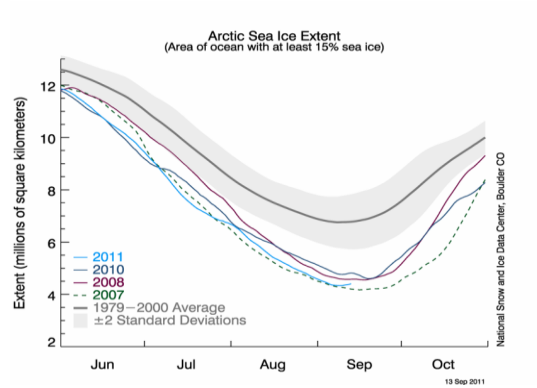
Source: IPCC AR4

Impacts of global warming in different sectors

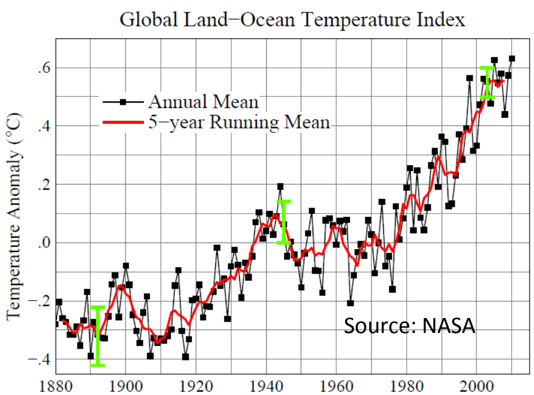
- **Water**:
    - Increases & decreases;
    - More exposed to water shortage
- **Ecosystems**:
    - Species shifts & extinctions
- **Food**:
    - Changes in possible crops;
    - Eventually more reductions than increase in production
- **Coasts**:
    - Increases in coastal erosion & flooding
- **Health**:
    - Increases in malnutrition & changes in infectious diseases e.g. malaria;
    - Increases in deaths from heat, floods & droughts
    - Reduced deaths from cold

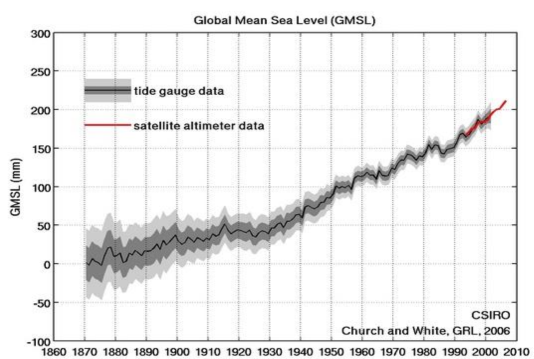
- Increasing atmospheric CO2 also inevitably leads to increasing acidification of the ocean

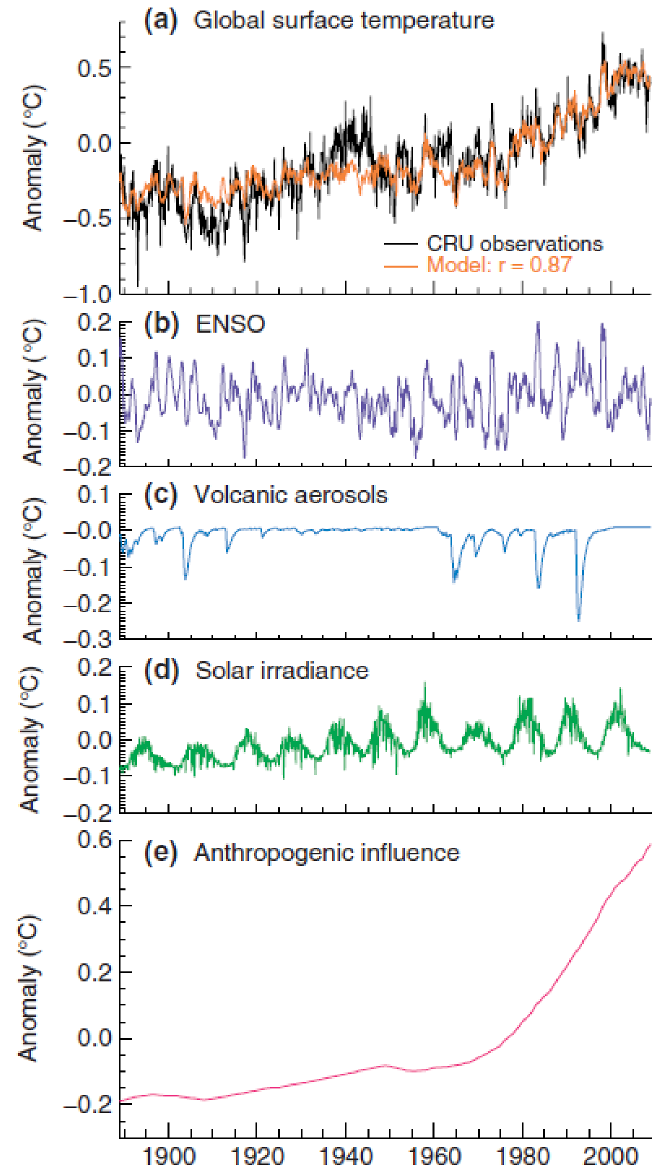
Evidence



Source: National Snow and Ice Data Centre, US



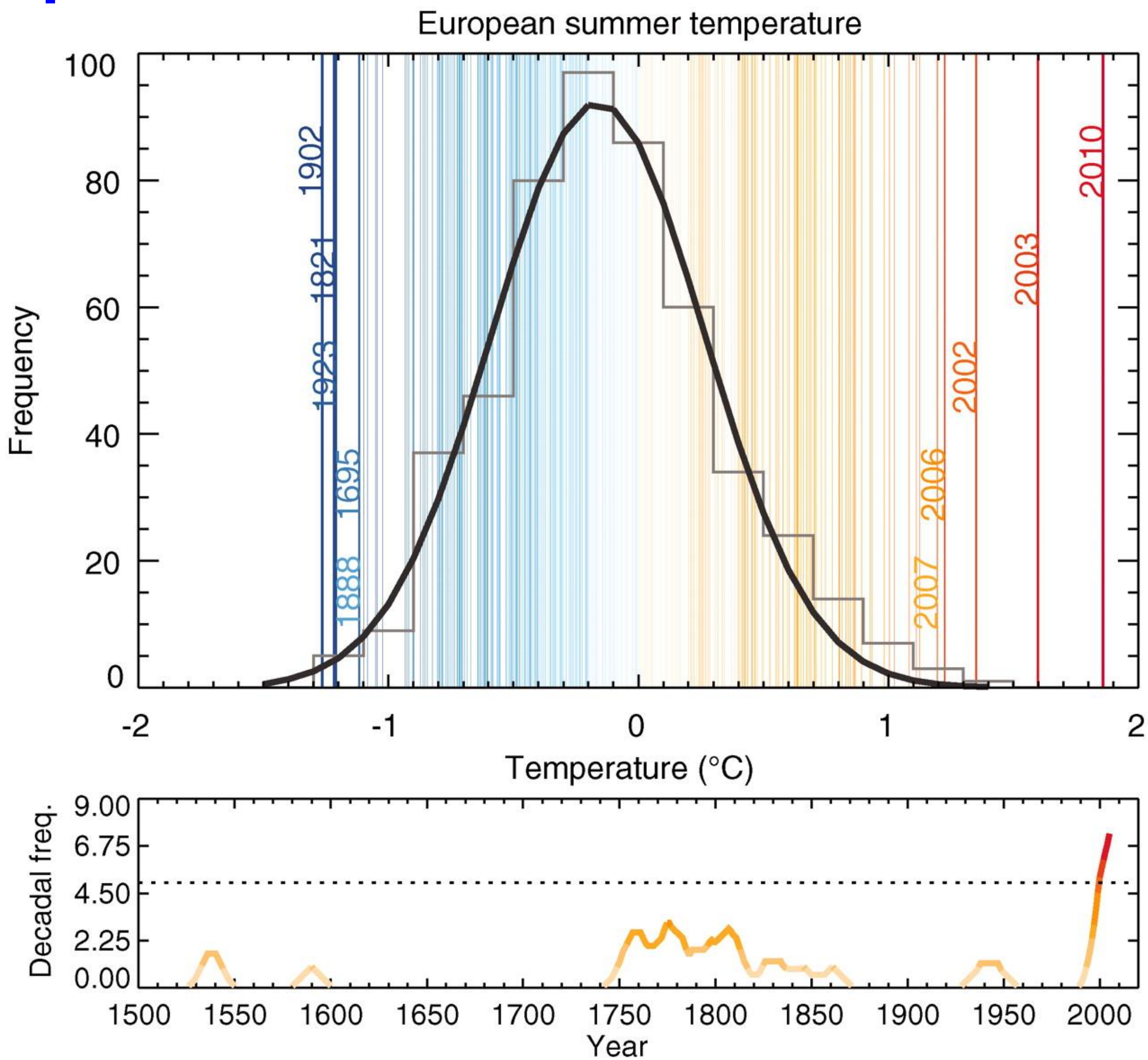




Source: J. L. Lean. Cycles and trends in solar irradiance and climate. Wiley Interdisciplinary Reviews: Climate Change 1, 111-122, doi:10.1002/WCC.18 (2010).

Large impacts from extremes - European summer temperatures for 1500–2010

“Mega-heatwaves” in 2003 and 2010 “likely broke the 500-year-long seasonal temperature records over approximately 50% of Europe”



D Barriopedro et al. Science 2011;332:220-224

Science AAAS

Uncertainty and inadequacy

Earth's climate system is a **complex dynamical system**.

i. Forcing uncertainty, e.g.: solar variability; emissions scenarios

ii. Initial condition uncertainty – well known problem of sensitivity of results

iii. Imperfect models

a. Omitted processes, e.g. carbon cycle, grid resolution etc. Serious – 'missing processes' more likely to exacerbate change rather than moderate it.

b. Parameters or parameterisation schemes (e.g. Clouds, aerosols)

Leading to:

Failure to simulate well many crucial phenomena e.g. "blocking" (key to 2003 and 2010 European summers as well as 2009/10 winter), and the Pacific Decadal Oscillation (in SSTs).

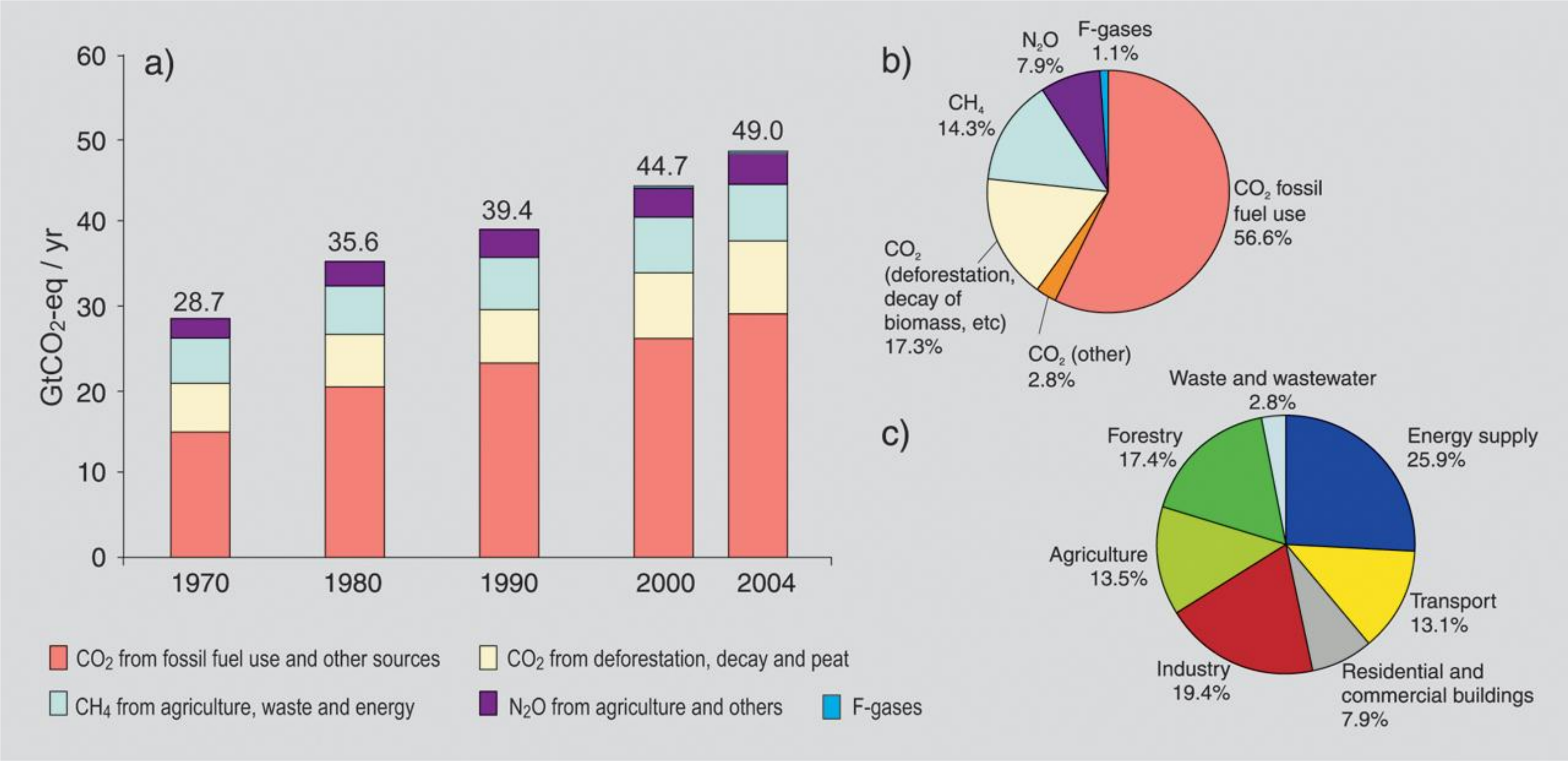
Therefore need better understanding of key physical processes to interpret results and improve models (e.g. better identification and representation of internal decadal variability, earth system feedbacks)

How should we interpret climate projections?

- **There is a cascade of confidence in climate projections**.
- There is **very high confidence** in the occurrence of global warming due to human emissions of greenhouse gases.
- There is **moderate confidence** in aspects of continental scale climate change projections.
- 25km scale climate change information is indicative to the extent that it reflects the large-scale changes modified by local conditions.
- The confidence in the climate change information also depends strongly on the variable under discussion.

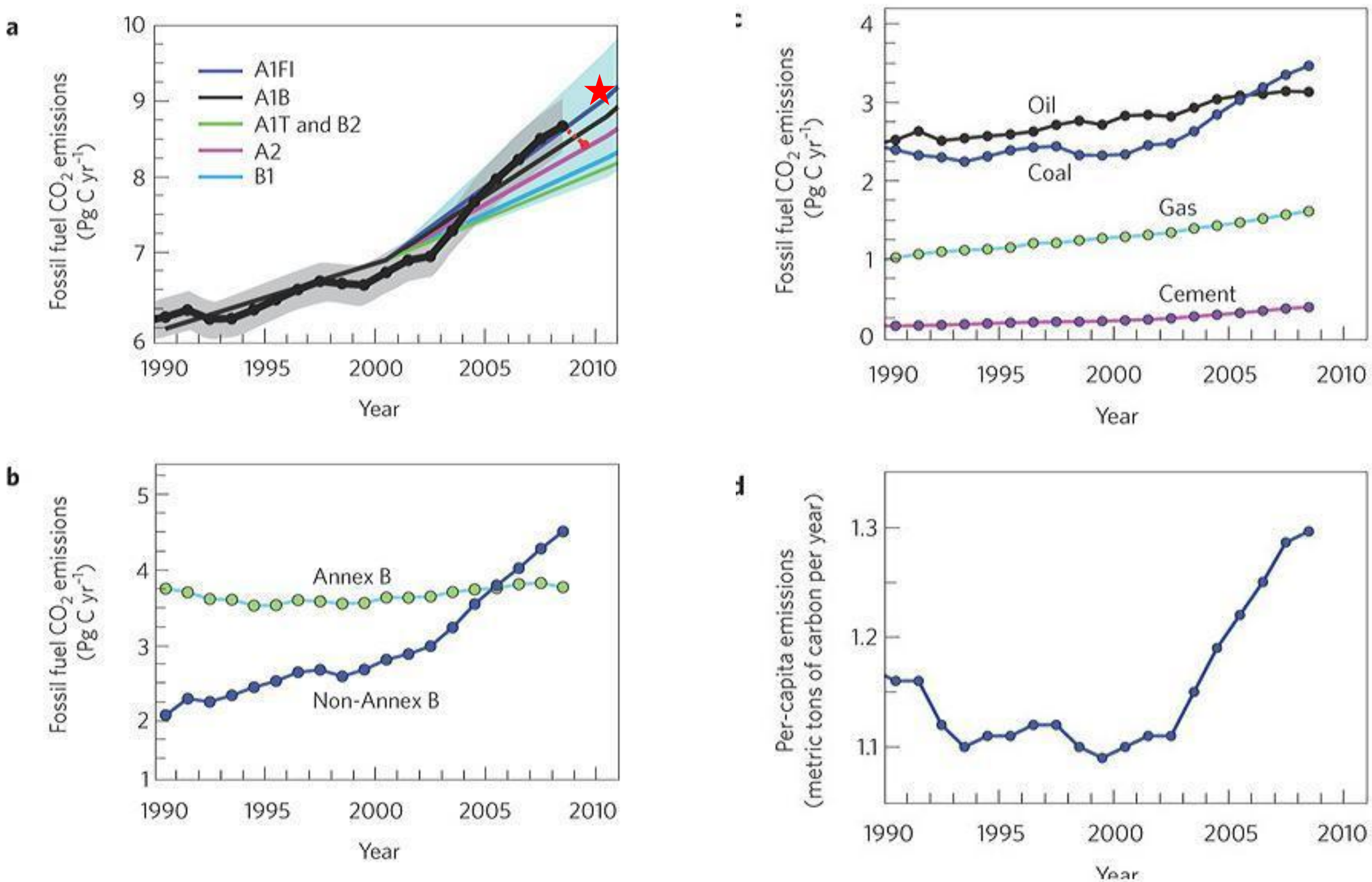
Given level of confidence in regional projections, best adaptive response can often be to build in resilience

Why dealing with CO2 is so difficult



Source: IPCC AR4

Trends in global fossil fuel emissions



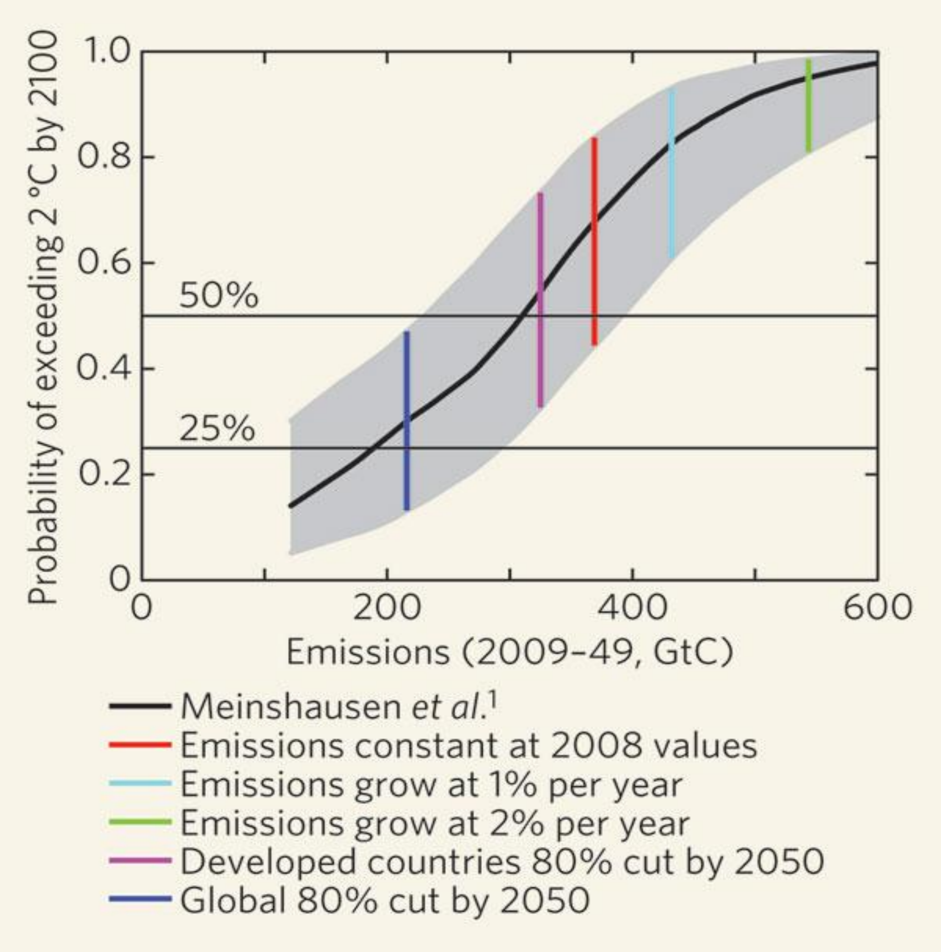
Source: Trends in the sources and sinks of carbon dioxide, Corinne Le Quéré et al. Nature Geoscience 2, 831 - 836 (2009)

Cumulative carbon – two (slightly different) takes

The trillionth tonne ....

> "We find that the peak warming caused by a given cumulative carbon dioxide emission is better constrained than the warming response to a stabilization scenario."

M Allen et al
Nature 458 April 2009
doi:10.1038/nature08019

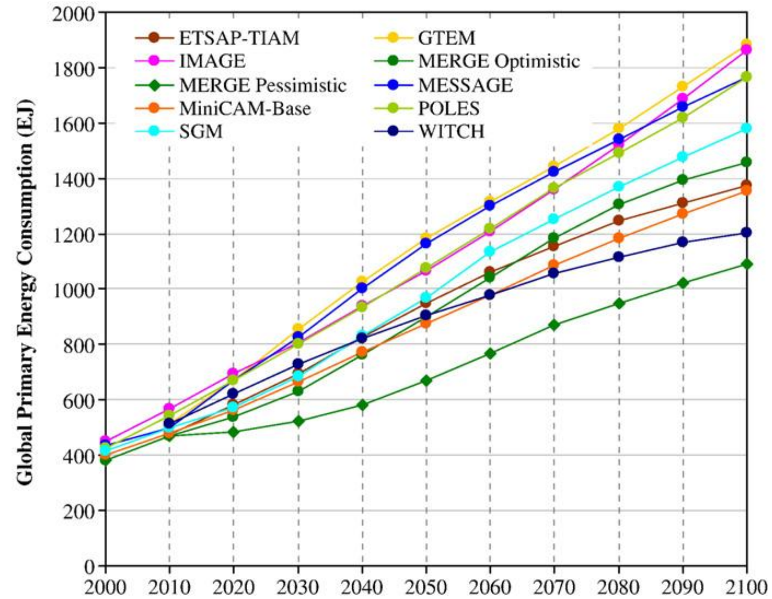


Source: Schmidt & Archer, Nature (2009) based on M Meinshausen et al, Nature 458 (2009)

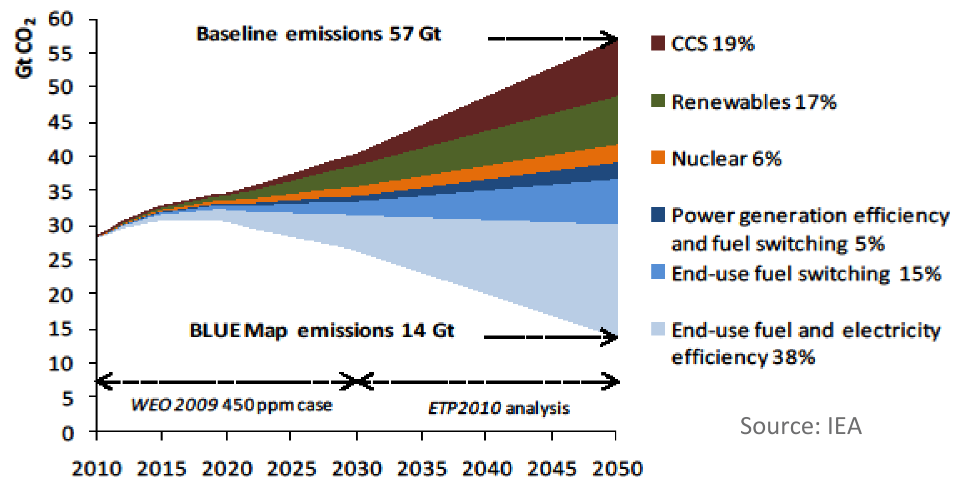
Mitigation Options

1. Reducing energy demand from reference levels.
   Challenging
2. Meeting the large residual demand from:
   i. Low carbon alternatives (nuclear, renewables)
   ii. Fossil fuels with CCS (and possibly BECCS)
   iii. Unabated fossil fuels

Global energy consumption



Source: L. Clarke et al. Energy Economics 31 (2009) S64–S81



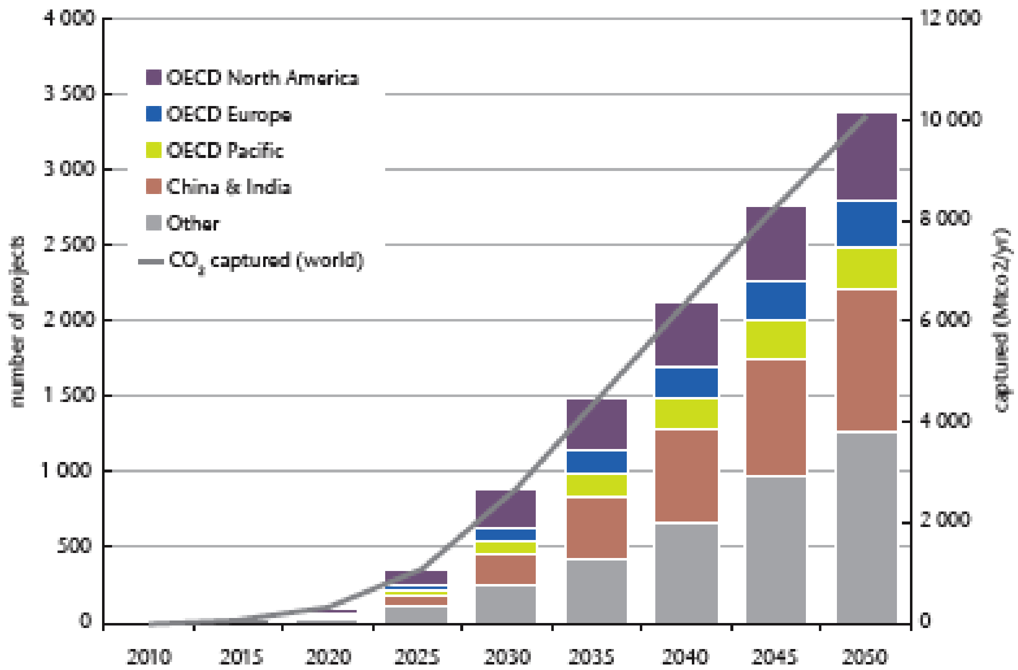
Source: IEA

A wide range of technologies will be necessary to reduce energy-related CO_2 emissions substantially.

Some key considerations

- **Systemic change** and a whole-systems approach required
- **Affordable solutions** will:
  - Deploy a broad mitigation technology portfolio
  - Use fossil fuel for energy generation only with CCS
  - Cut across sectors, integrate supply and demand
  - Exploit demand reduction and efficient/intelligent energy use
- **Some fossil fuel** may still be required **for transport in 2050** (e.g. heavy goods, long distances); emissions will need to be offset. NB competing uses for biomass.
- **Technical and economic feasibility** will depend on:
  - Early demonstration and deployment of key technologies like CCS
  - Overcoming market failures to accelerate low-carbon innovation and uptake

Carbon Capture and Storage (CCS)



No. of projects:

100 by 2020
&
3400 by 2050

A lot of work to do!

IEA, Technology Roadmap, CCS, 2010

- **Urgent need for full-chain demonstration**
- **Need to reduce the cost of capture**
- **CCS can also target industrial emissions**
- **Social and political barriers** (as with some other technologies)

Negative Emissions Technologies

Option 1

CO_2 removed directly from air and stored as CO_2

- Large enough potential to pursue further
- Need to find sufficient low carbon energy sources
- Scale-up to be done. Challenging CO_2 collection problems
- E.g. "Artificial Trees"

Option 2

CO2 removed directly from air and fixed in a stable material

- Further work on monitoring, verification and reporting needed
- Potential co-benefits (reversing ocean acidification, soil improvement)
- Reasonable potential, but time needed for scale-up
- E.g.. Biochar and CaO disposal at sea

Option 3

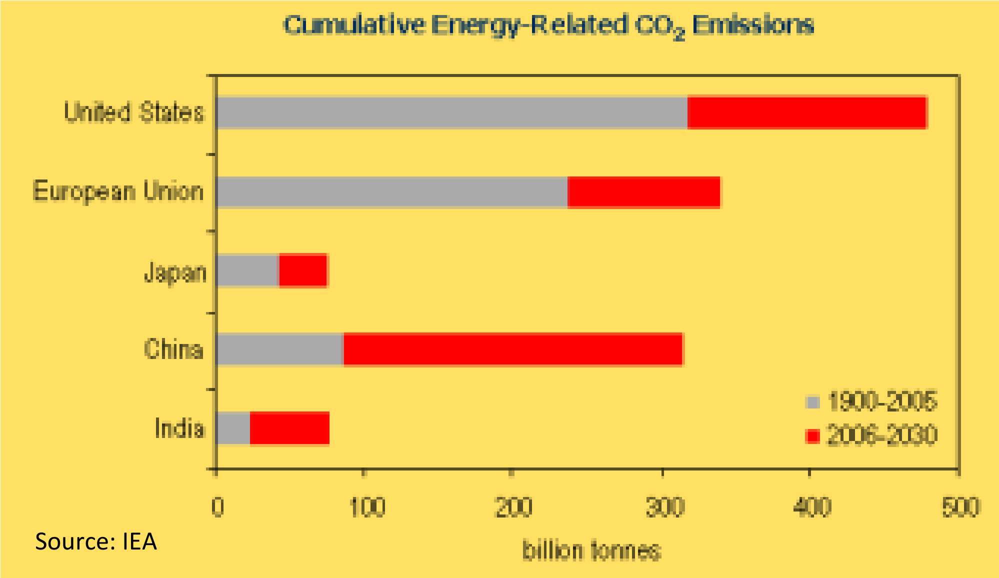
Biomass enhanced CCS (BECCS)

- Can be stand-alone use of biomass or co-firing/gasification
- Fuel diversity (geography and feedstock) important to counteract seasonal availability and regional surpluses
- Must be sensitive to competing uses and land use change
- Can make non-trivial contribution now/soon and unlikely to face CO2 storage capacity constraint in UK context

Overall best technology for deployment pre-2030 is BECCS

UK Potential: 4-15% of emissions, generating 9-32% of power demand

International climate negotiations – past and future CO2 emissions by country/region



Source: IEA

- Fossil-intensive growth of China and India has undermined premises of UNFCCC and Kyoto

- Emissions reductions required from major developing economies even if developed economies stopped emitting today.

International negotiations – a short (selective) history

1987 Montreal Protocol on ozone depletion

1988 UNEP/WMO establish IPCC

1992: Rio Earth Summit and adoption of UNFCCC

"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

"common but differentiated responsibilities"

1997: COP 3 adopts Kyoto Protocol. Average of 5.2% reductions in GHG emissions on 1990. US does not ratify

2002 Delhi Declaration at COP 8 highlights adaptation

2005 Kyoto Protocol enters into force (first commitment period 2008-12)

Adaptation Fund

EU ETS begins

2006 Stern Review [mitigation, carbon prices, adaptation, forests, technology]

2007 Bali Action Plan – nationally appropriate mitigation action

2009 COP 15 in Copenhagen - Accord and national pledges

2010 COP 16 in Cancun – pledges incorporated into UNFCCC process

2011 COP 17 in Durban – agreement applicable to all parties with legal force "from 2020"; EU commitments in a continuation of Kyoto

Why climate policy is so difficult...

- Diverse countries with different endowments (e.g. rich/poor) and preferences over global carbon target
- Developing/developed dichotomy inadequate ... US action requires developing economies to commit to action too (and vice versa). **Durban resolves this in principle.**
- Level of Risk and Distributional issues:
  - Negotiating over size of the ‘carbon pie’
  - Distribution of carbon pie, concerns over mitigation costs and competitiveness, limits on verification and potential for free-riding
- How to make progress?
  - Complex UN mega deal (i.e. carbon budget, finance, technology, adaptation and REDD) or mitigation negotiations amongst major emitters (like arms control)?
  - More likely both: one embedded within the other

Questions?