Growing Priority for Understanding Greenhouse Gases in a Policy Perspective

Greenhouse gases in the Earth system:
Setting the agenda to 2030

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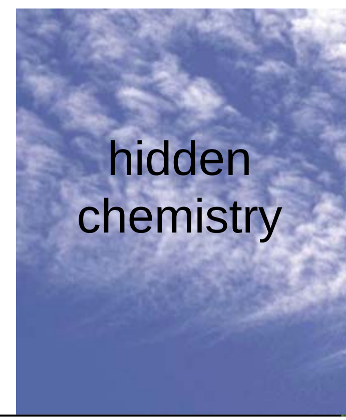
Martin Manning
Andy Reisinger



TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

New Zealand Climate Change Research Institute
Te Pūtahi Hurihanga Taiao

Outline

- Now increasingly important to consider greenhouse gases in context of climate stabilisation
  - They combine through “radiative forcing”
- How do we compare emissions of the gases?
  - Global warming potentials are a very limited way
- Prioritizing scientific research
  - Framework needs to be broader than in policy
  - Major uncertainties – but – two key issues

The Context

- Governments agreed in 1992 on …
  "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."
- Governments now stating that global warming should be kept to 2°C
- Climate scientists increasingly sceptical that this can be achieved
- Very important to understand what will happen to the Earth System …

PERSPECTIVES

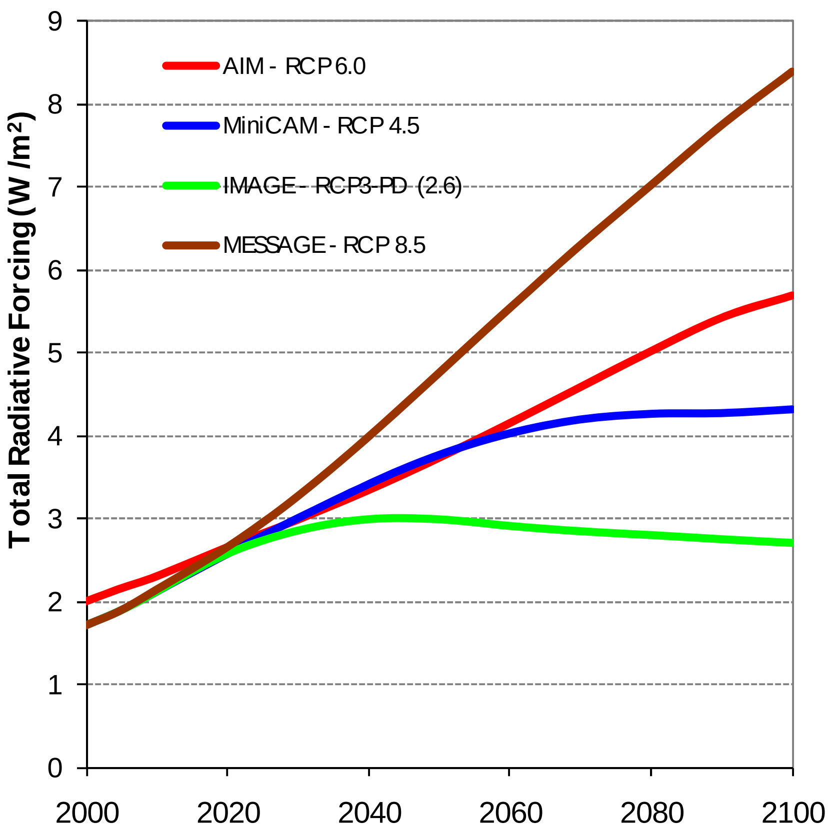
The next generation of scenarios for climate change research and assessment

Richard H. Moss[1], Jae A. Edmonds[1], Kathy A. Hibbard[2], Martin R. Manning[3], Steven K. Rose[4], Detlef P. van Vuuren[5], Timothy R. Carter[6], Seita Emori[7], Mikiko Kainuma[7], Tom Kram[5], Gerald A. Meehl[2], John F. B. Mitchell[8], Nebojsa Nakicenovic[9,10], Keywan Riahi[9], Steven J. Smith[1], Ronald J. Stouffer[11], Allison M. Thomson[1], John P. Weyant[12] & Thomas J. Wilbanks[13]

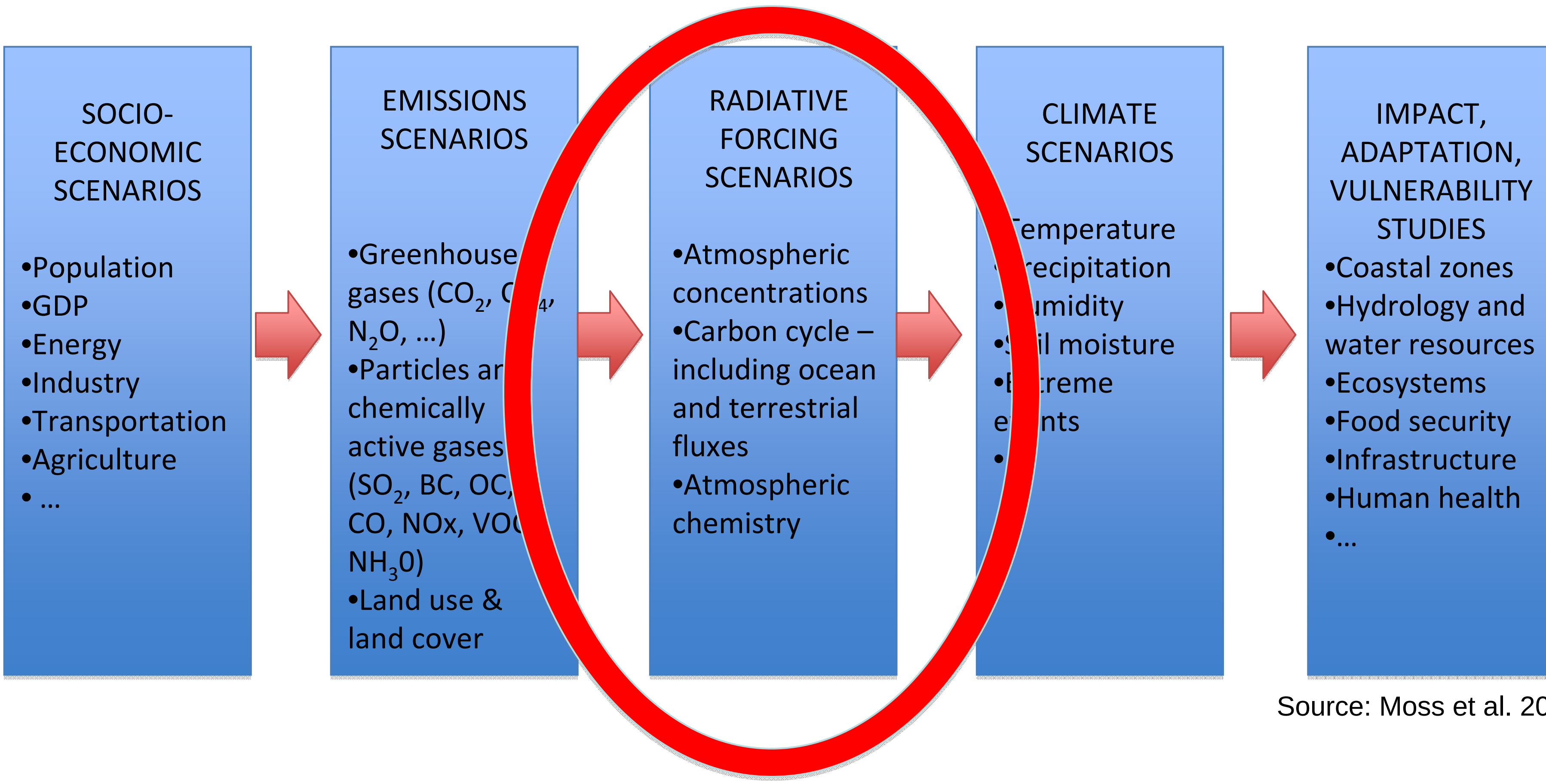
Advances in the science and observation of climate change are providing a clearer understanding of the inherent variability of Earth's climate system and its likely response to human and natural influences. The implications of climate change for the environment and society will depend not only on the response of the Earth system to changes in radiative forcings, but also on how humankind responds through changes in technology, economies, lifestyle and policy. Extensive uncertainties exist in future forcings of and responses to climate change, necessitating the use of scenarios of the future to explore the potential consequences of different response options. To date, such scenarios have not adequately examined crucial possibilities, such as climate change mitigation and adaptation, and have relied on research processes that slowed the exchange of information among physical, biological and social scientists. Here we describe a new process for creating plausible scenarios to investigate some of the most challenging and important questions about climate change confronting the global community.

Representative Concentration Pathways

- **RCP8.5 (IIASA/MESSAGE)**
  - >8.5 W/m² in 2100,
  - Rising
- **RCP6.0 (NIES/AIM)**
  - ~6 W/m² at stabilization after 2100
  - Stabilization without exceeding target
- **RCP4.5 (PNNL/MiniCAM)**
  - ~4.5 W/m² at stabilization after 2100
  - Stabilization without exceeding target
- **RCP2.6 (PBL/IMAGE)**
  - <3 W/m² in 2100
  - peak & decline stabilization

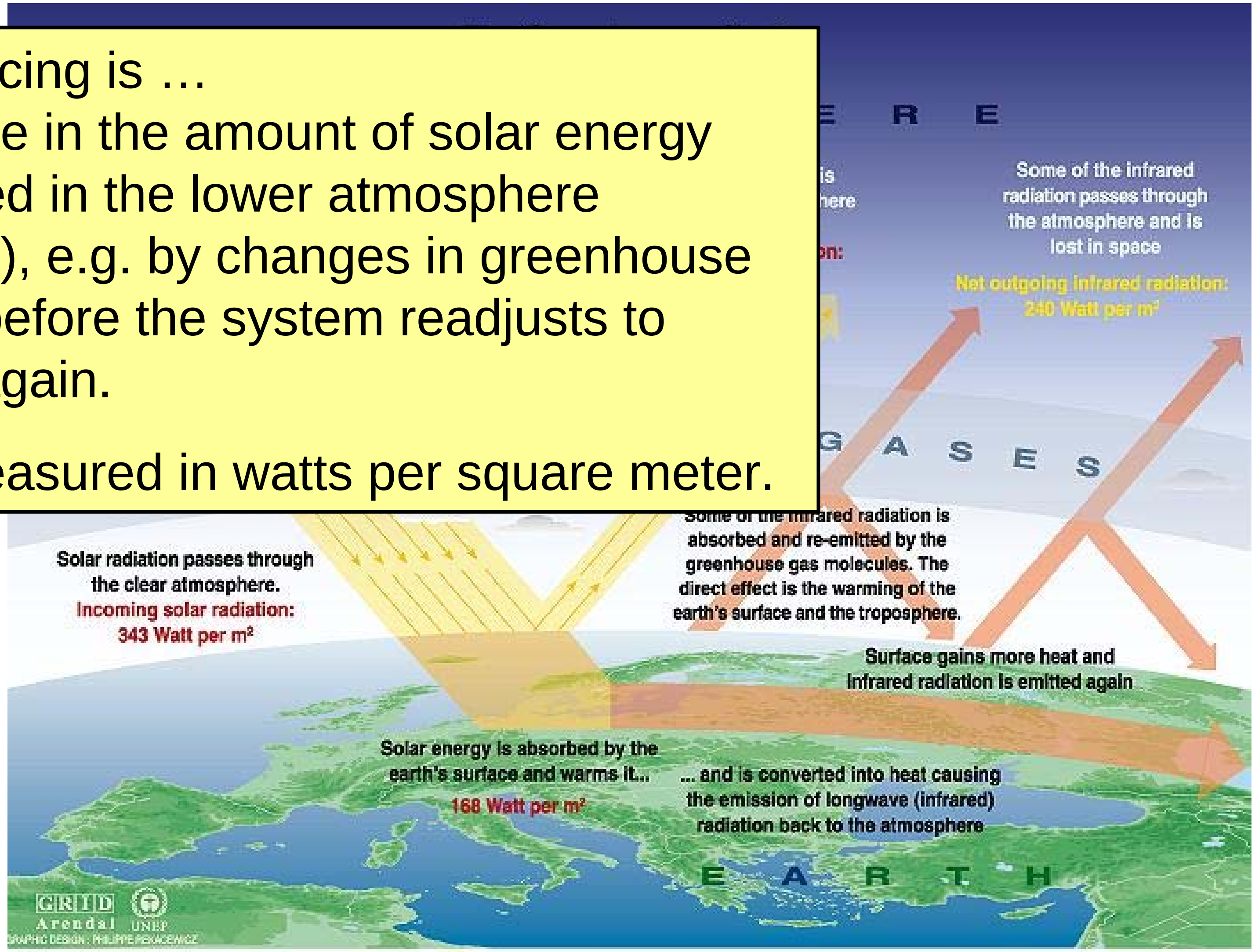


Greenhouse gases are central issue



Source: Moss et al. 2010

Radiative Forcing



Radiative forcing is …

… the change in the amount of solar energy that is trapped in the lower atmosphere (troposphere), e.g. by changes in greenhouse gases, and before the system readjusts to equilibrium again.

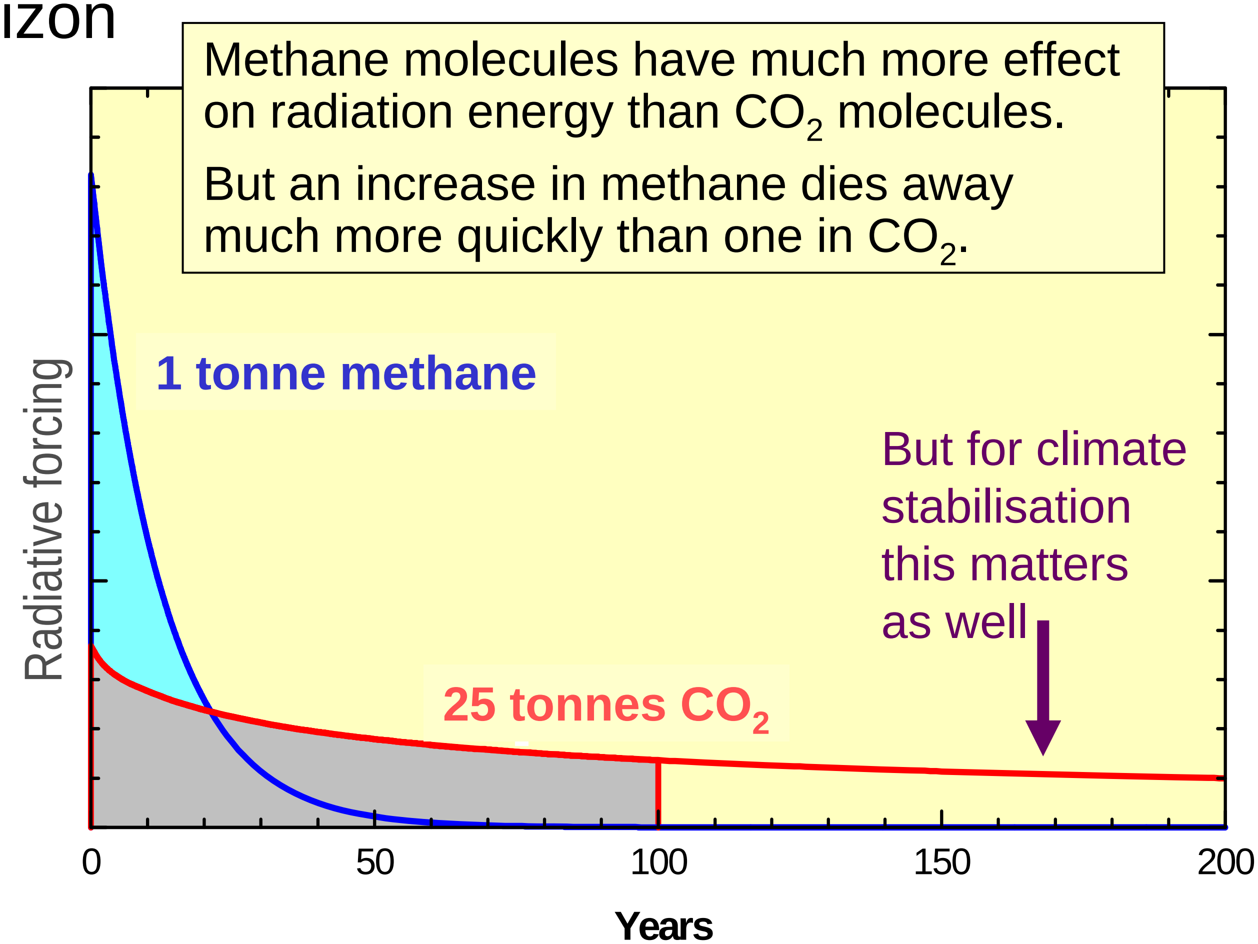
Usually measured in watts per square meter.

Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Global Warming Potentials

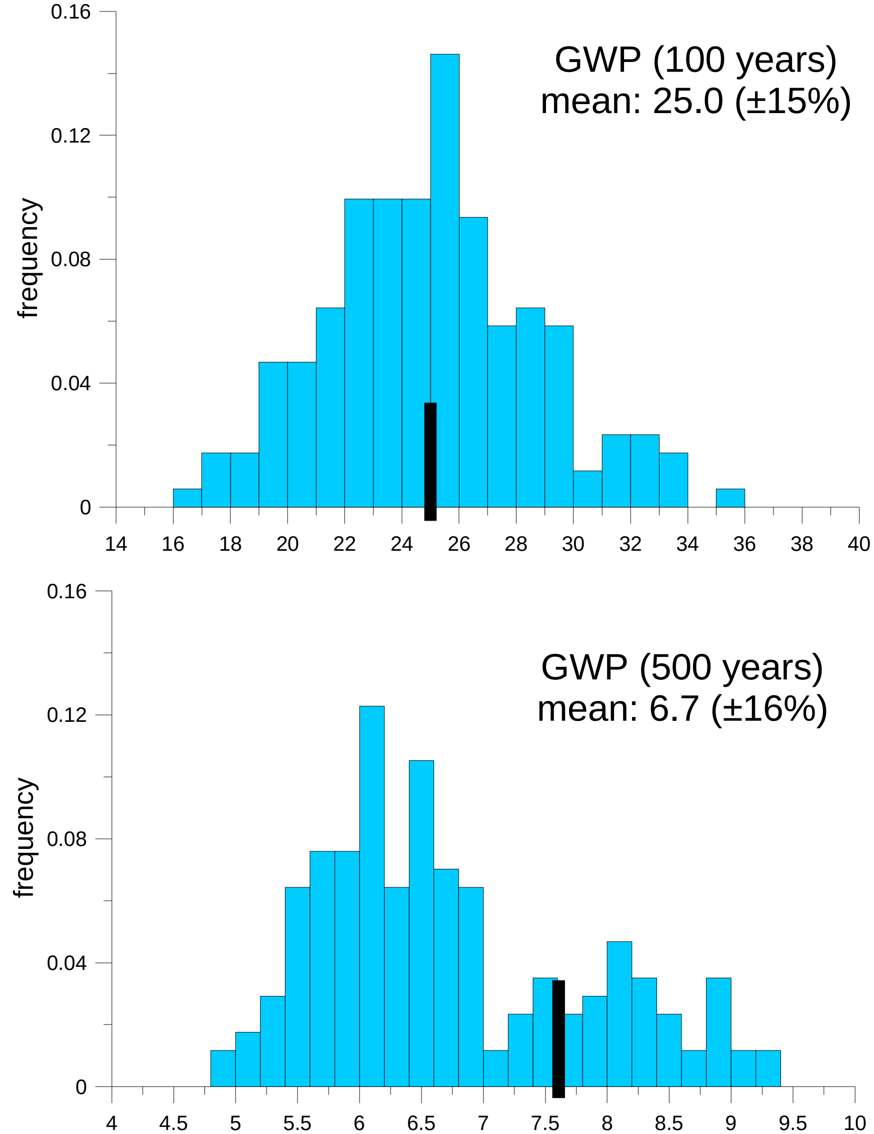
Global Warming Potentials (GWPs) compare gases by the radiative forcing caused by pulse emissions integrated over a fixed time horizon

Over a 100 year time horizon, 1 tonne of methane causes the same integrated effect as 25 tonnes of CO_2.



Uncertainty in estimating GWPs

- New analyses covering the range of climate and carbon cycle models in the WG1-AR4, imply higher GWP uncertainties than was in that report. Figure to right does not include all uncertainties. (Reisinger et al, submitted)
- A new study of the indirect effects of methane on aerosols suggest its GWP should be 30% larger and with higher uncertainty (Shindell et al, 2009)



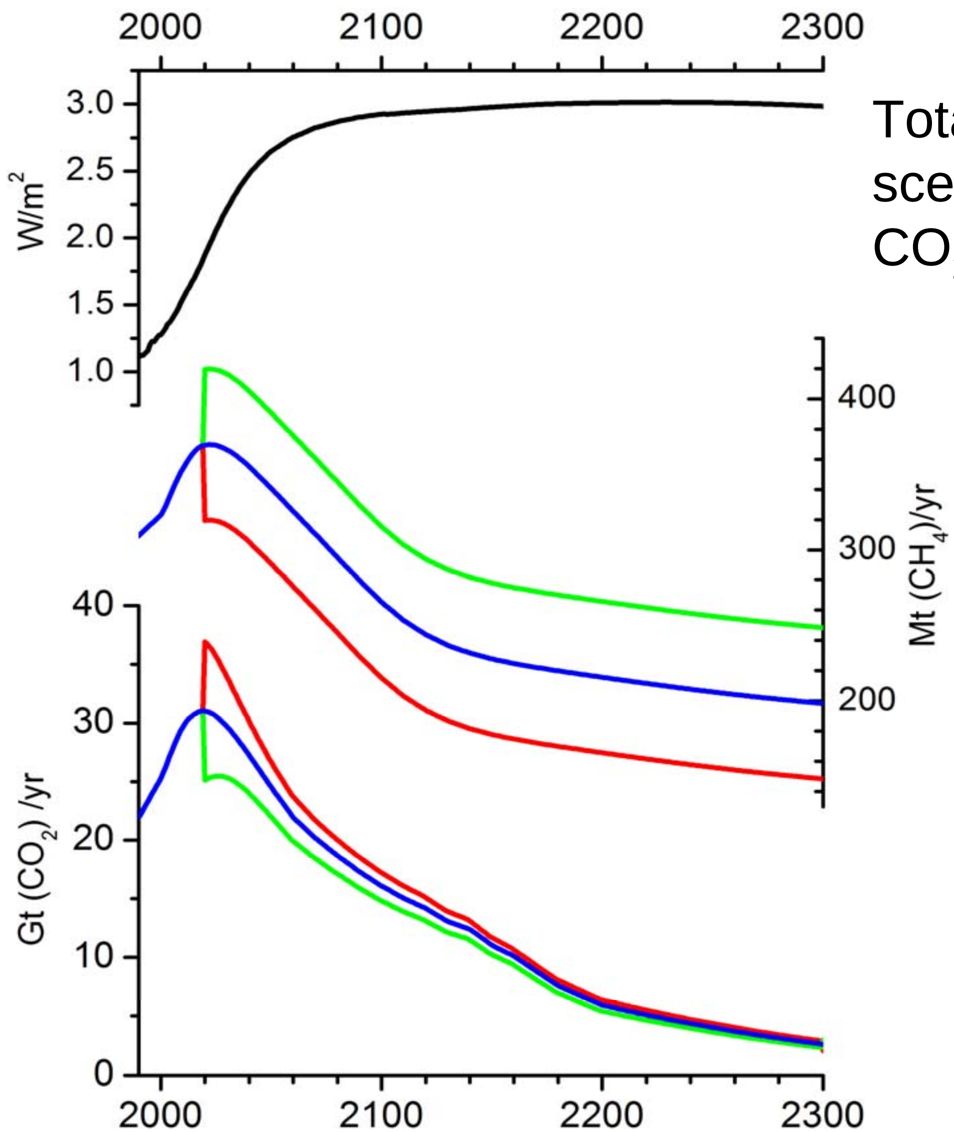
Systematic problems with GWPs

- GWPs are being updated in IPCC reports and increase each time because the CO_2 concentration is increasing!
- If this continues, then following a stabilisation pathway to keep to 2^{o}C would put an increasing emphasis on reducing methane.
- Could be improved by defining GWPs for the atmosphere as it was in year 2000.
- But using a fixed time horizon for considering the relationship between greenhouse gases with different lifetimes is inconsistent with pathways to stabilisation.

Comparing GHGs along stabilisation paths

- Compare adjustments in emissions that keep to exactly the same pathway for total radiative forcing
- Introduced by Tom Wigley as the Forcing Equivalence Index (FEI).
- A permanent reduction in methane allows a temporary increase in CO_2 that must diminish steadily over time.
- No matter how we reduce short lived gases – we still have to drop CO_2 emissions to zero over time.

Sticking to a stabilisation scenario



Total radiative forcing for a stabilisation scenario, based on reducing methane & CO_2 as shown in the blue curves below.

Green / red curves show constant increases / decreases in methane emissions

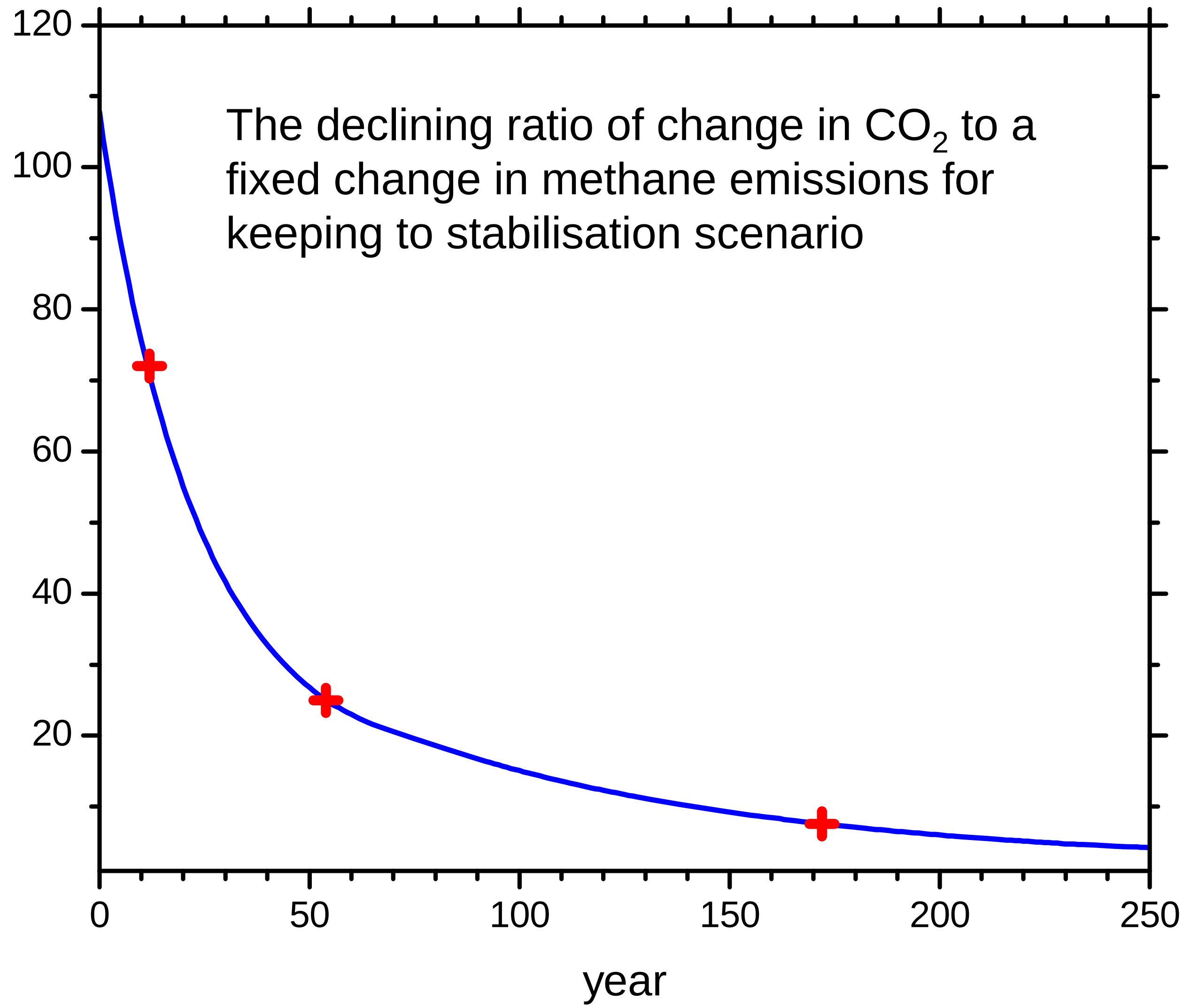
.. And here corresponding changes in CO_2 emissions necessary to keep to the same radiative forcing

Ratios of changes for stabilisation scenario

FEI for stabilisation at 550 ppm CO2-eq (global warming of about 3ºC)

Crosses show GWP values for fixed time horizons of 20, 100 and 500 years now being passed at 12, 54 and 172 years after the change in emissions.

The ratios vary for different stabilisation levels – but not by much.

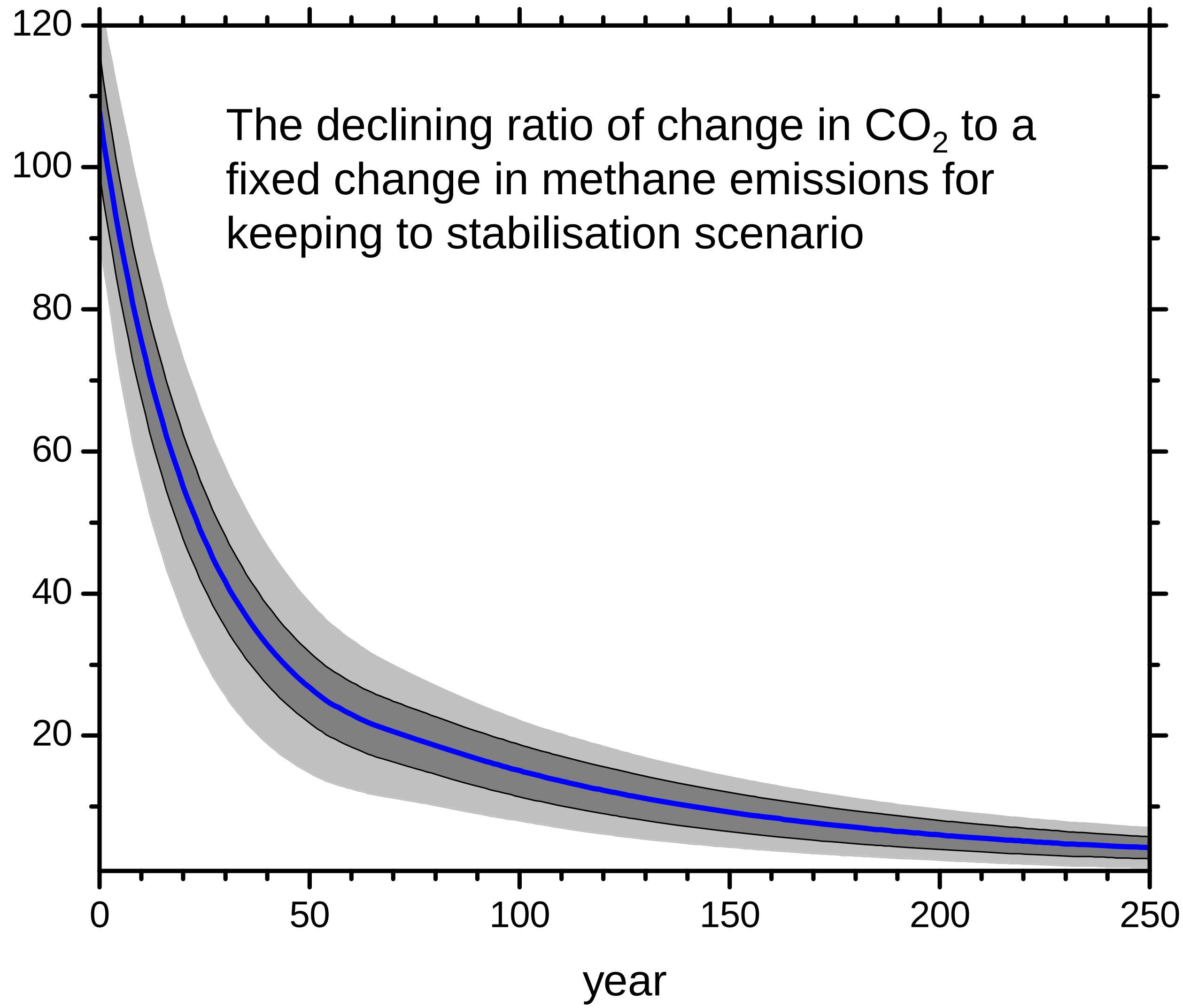


Uncertainties in the ratio

The FEI has a relative uncertainty that increases with time.

The 5 – 95% range due to uncertainties in the carbon cycle is ±33% at 100 years.

However, this does not include uncertainties in the methane lifetime and its indirect effects.



A summary so far

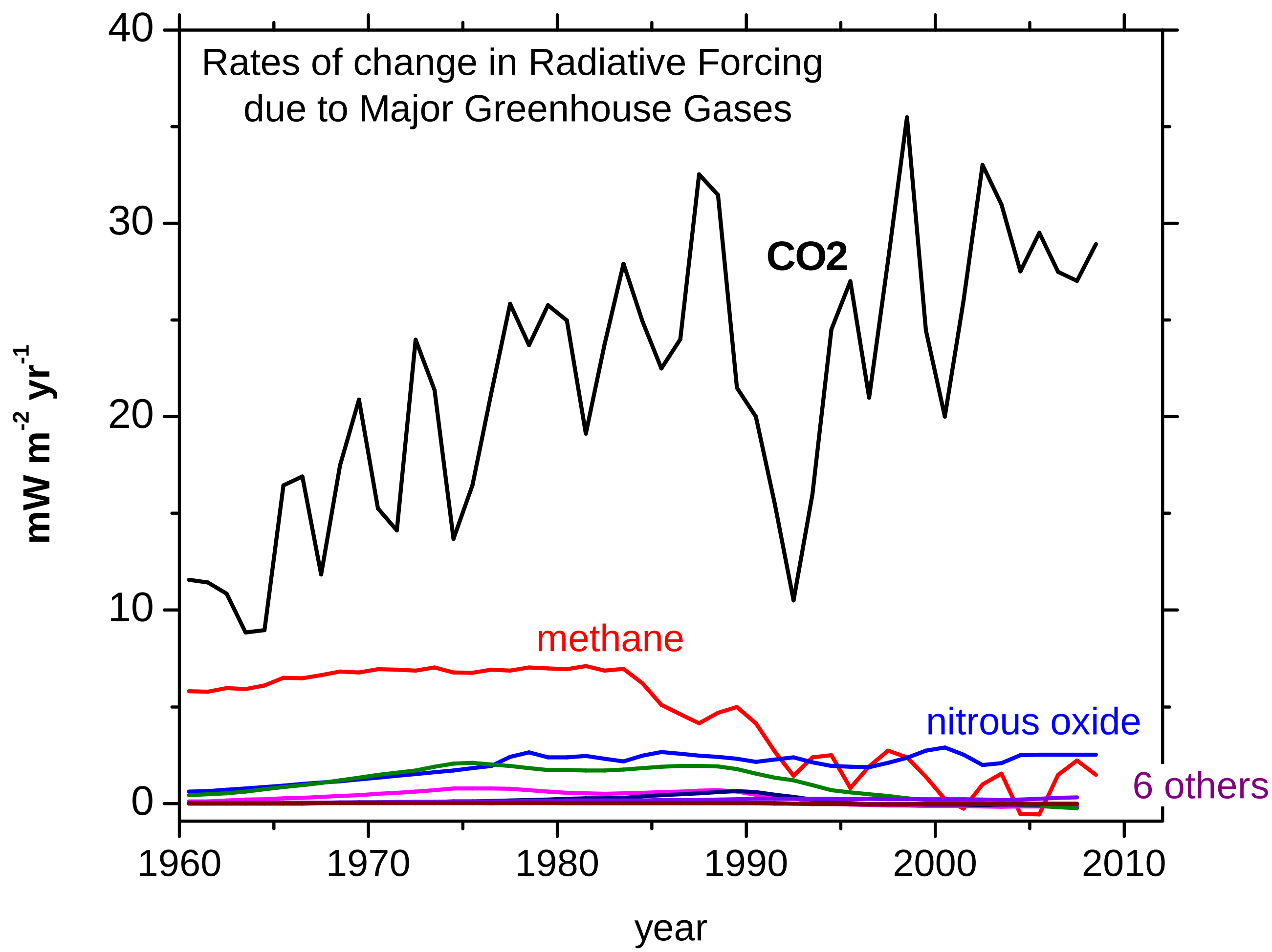
- Quantifying contributions of emissions of different greenhouse gases to long term climate change is difficult.
- In the economic world this can raise issues for strategic priorities – e.g. for new technology on energy or on agriculture.
- Comparing different gases in context of climate stabilisation requires a more sophisticated framework than used in policy so far, but …
- … the uncertatinties in quantifying relative effects of emissions of different greenhouse gases are large over the long term.

A science approach to the uncertainties

- Need more accurate quantification of removal rates of greenhouse gases, and …
- Clear sense of how these will change as the climate does.
- Given the limited resources and the urgency, we need a clear sense of priorities.
- So next is a framework for considering priorities …

Much of current focus is on net changes

Observed changes are net result of emissions and removals. Here showing the 9 most significant gases.

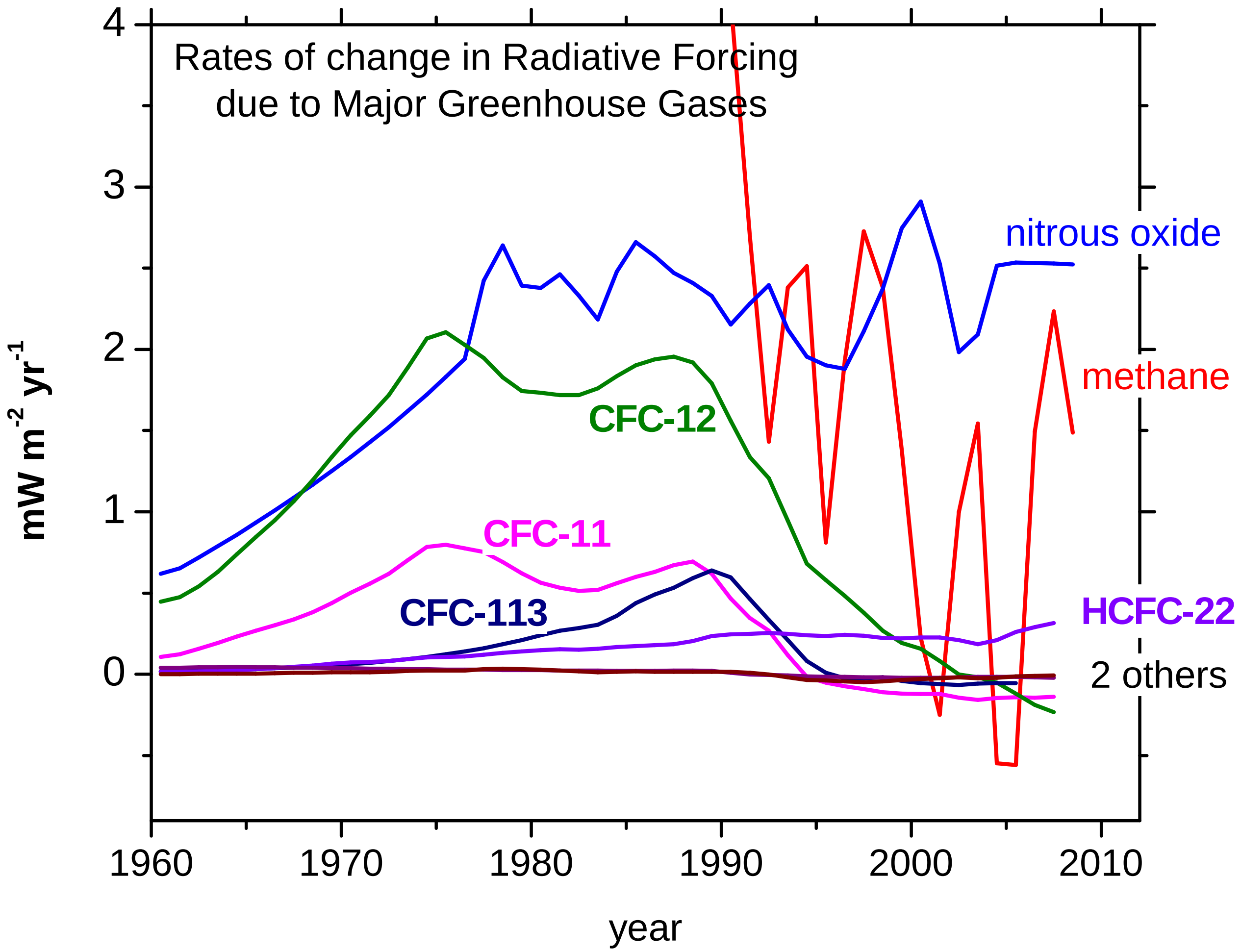


NB – am still using radiative forcing for all quantification of greenhouse gases.

Much of current focus is on net changes

Expanding the scale to show the minor gases.

CFCs are decreasing because of Montreal protocol.



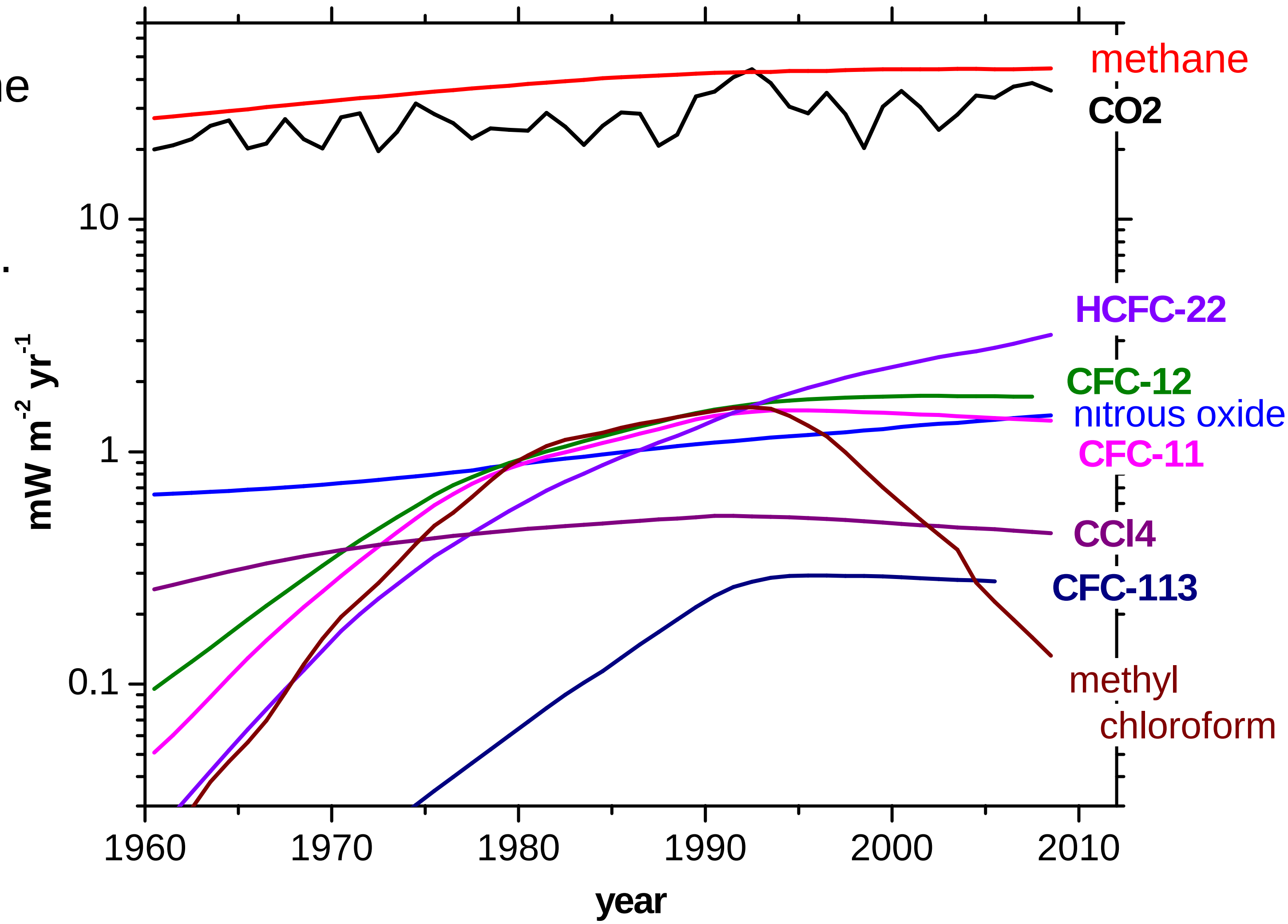
Future depends on changes in removal

- A focus on the current net effects of the sources and removals can mask out the priority for understanding changes in the future.
- Ranking what is going on by the magnitude of removal rates gives a different perspective than looking at net changes.

Removal rates of top 9 GHGs

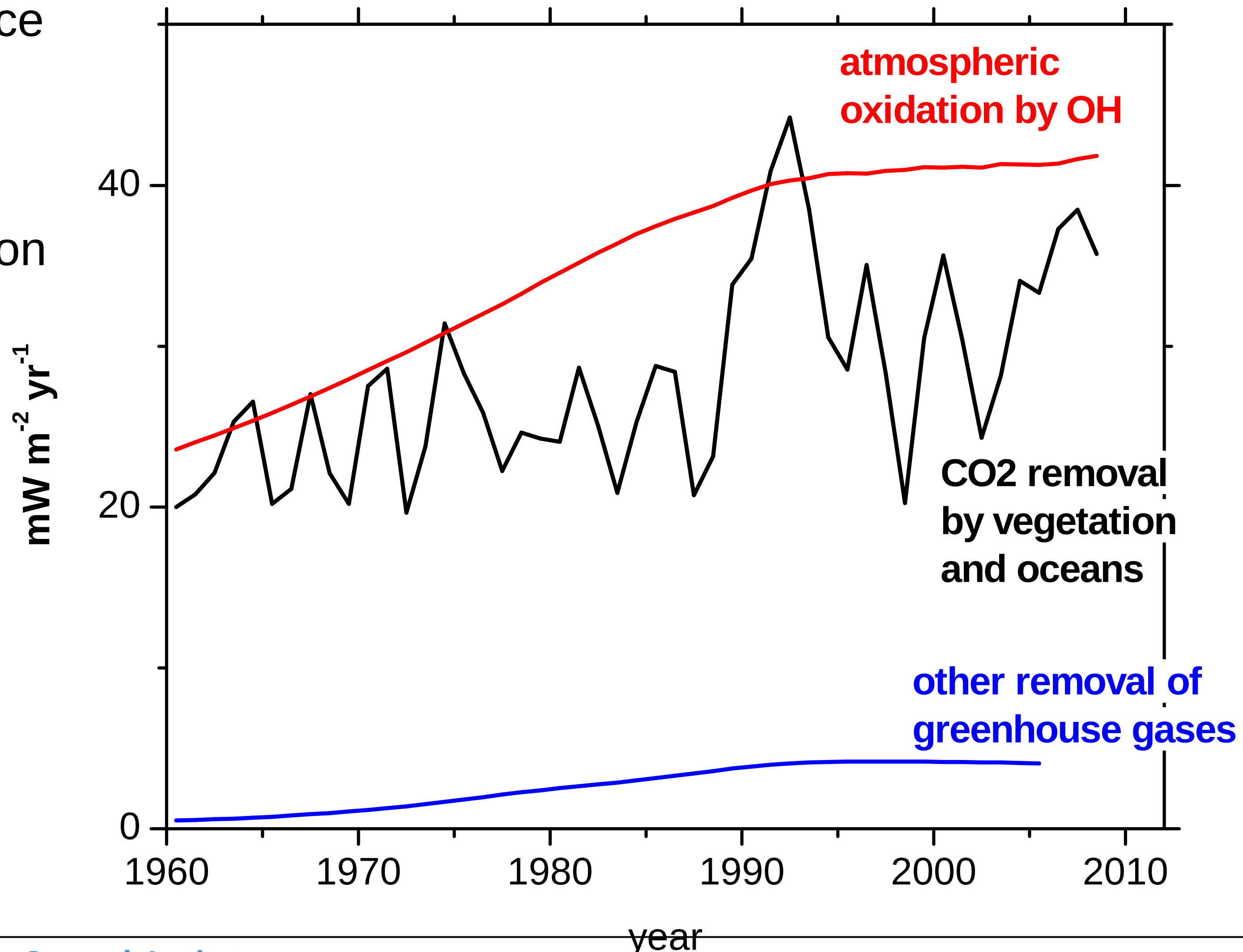
Removal rates for 1960 – 2008 as the amount by which total radiative forcing is reduced.

Logarithmic scale !



Removal rates by process

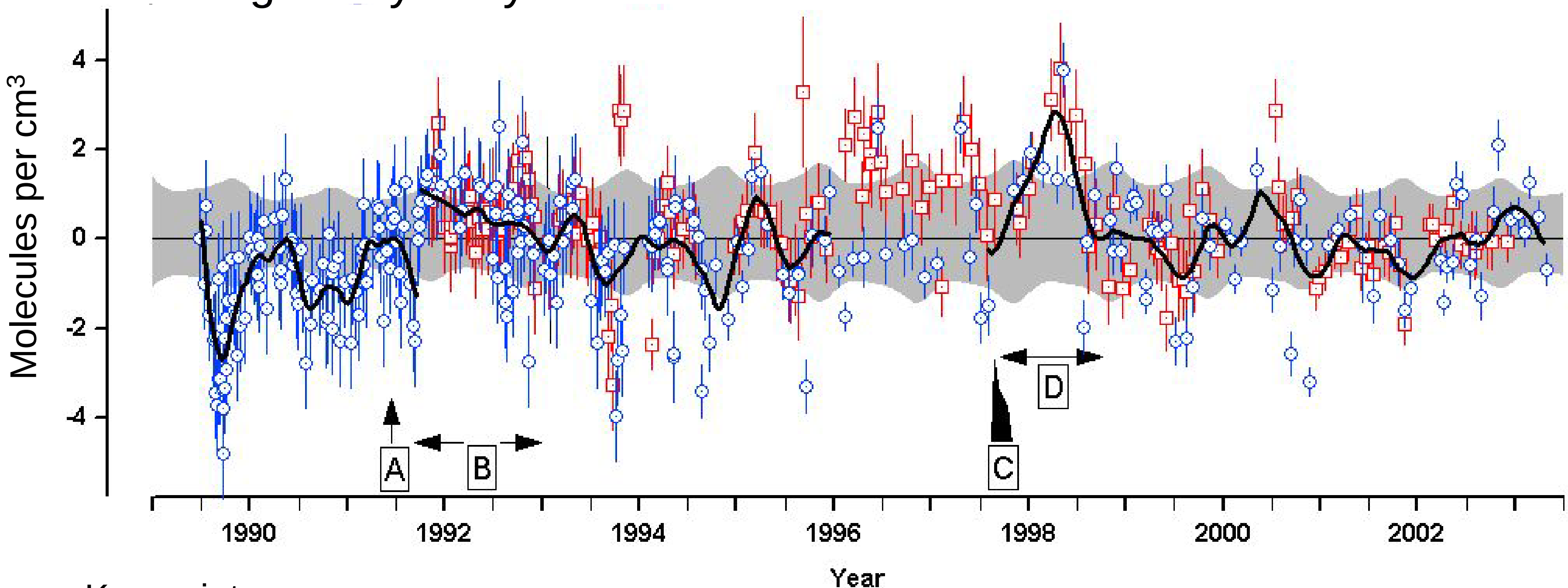
The dominant processes that reduce radiative forcing are hydroxyl (OH) oxidation and CO_2 removal by the carbon cycle



Removal by OH is likely to be more variable than shown here.

Evidence for fluctuations in hydroxyl

Deviations of ^{14}CO in the southern hemisphere from its seasonal cycle driven by hydroxyl removal rates and its 11-yr solar cycle of changes in production rates.
The grey shaded region shows the effect that a 10% change in hydroxyl would have.



Key points are:

A: Mt Pinatubo eruption

B: Period of high methane in the southern hemisphere

C: Large fires in Indonesia

D: Period of higher CO, but which can not explain high ^{14}CO

Manning et al, Nature, 2005

Conclusions

- Science needs a framework for prioritisation of greenhouse gas research based on the relative importance of different gases for climate stabilisation.
- GWPs do not provide a basis for considering that, … FEIs do.
- In the long term CO_2 is critical, but also …
- Comparing natural processes shows that the removal of CO_2 and atmospheric oxidation processes are about equal in importance.
- We definitely need a better understanding of how each of these may change in future.