

An Alternative Scenario to Kyoto

Hansen, Sato, Ruedy, Lacis, Oinas, 2000
Proceedings of National Academy of Science

Many competing natural and anthropogenic forcings

- GHGs cause a global climate warming but other forcings as well
- GHG forcing is largest =>net positive forcing
- Strongest evidence provided by increase of heat storage in ocean

Future Scenarios

- Range of possible scenarios but main simulations use business-as-usual with rapidly increasing GHGs
- Models predict steep increase in Temperature
- Give impression that curtailment almost hopeless
- Kyoto is itself a difficult target
- Would need 30Kyotos to reduce warming to acceptable level

Suggestions

- Alternative more optimistic scenario
- Reduce non-CO₂ GHGs and black carbon during next 50 years
- Thesis : non-CO₂ GHGs have caused most of observed warming
- Still will require limiting CO₂ emissions

Climate Forcing of Industrial Era

- Forcings now differ by several percent of what was estimated previously - more accurate computations

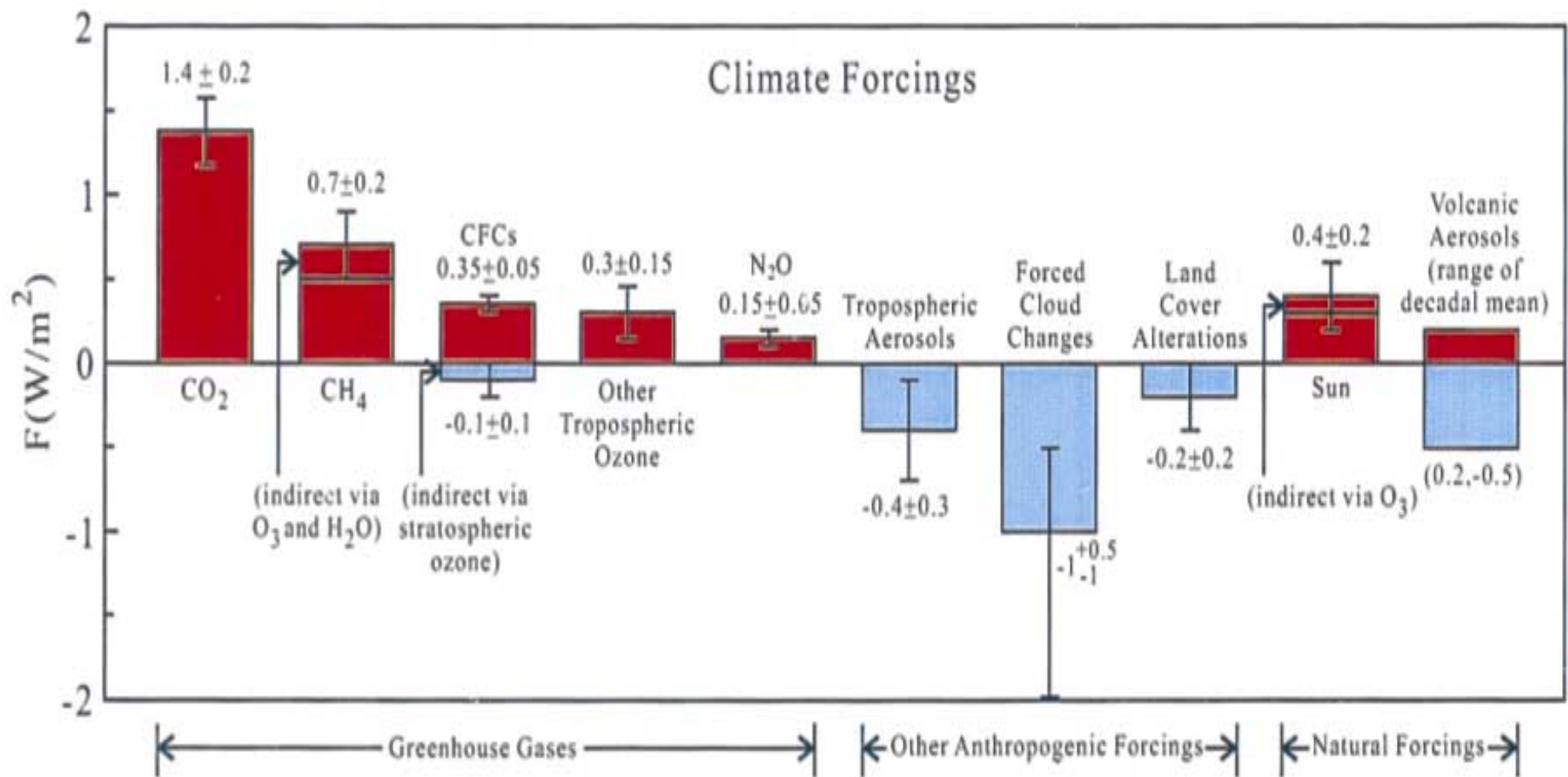


Fig. 1. Estimated climate forcings between 1850 and 2000.

Estimated Forcings

- CO₂, CH₄ and CFCs are produced by different processes that have different gross rates
- Clear role of CH₄ as a climate forcing through direct and indirect effect (on O₃)
- Negative forcing due to stratospheric ozone depletion is smaller than before estimated
- Climate forcing by CO₂ is largest but CH₄ half size

- Fossil fuel burning also main source of aerosols (sulfates, black carbon and organic aerosols)
- Aerosols have a negative direct forcing, except for black carbon, and an indirect effect
- Forcing by aerosol is uncertain but substantial
- Net global forcing due to processes that produce CO₂ are less than 1.4 Wm⁻² (offsetting does not mean that climate effect is negligible)

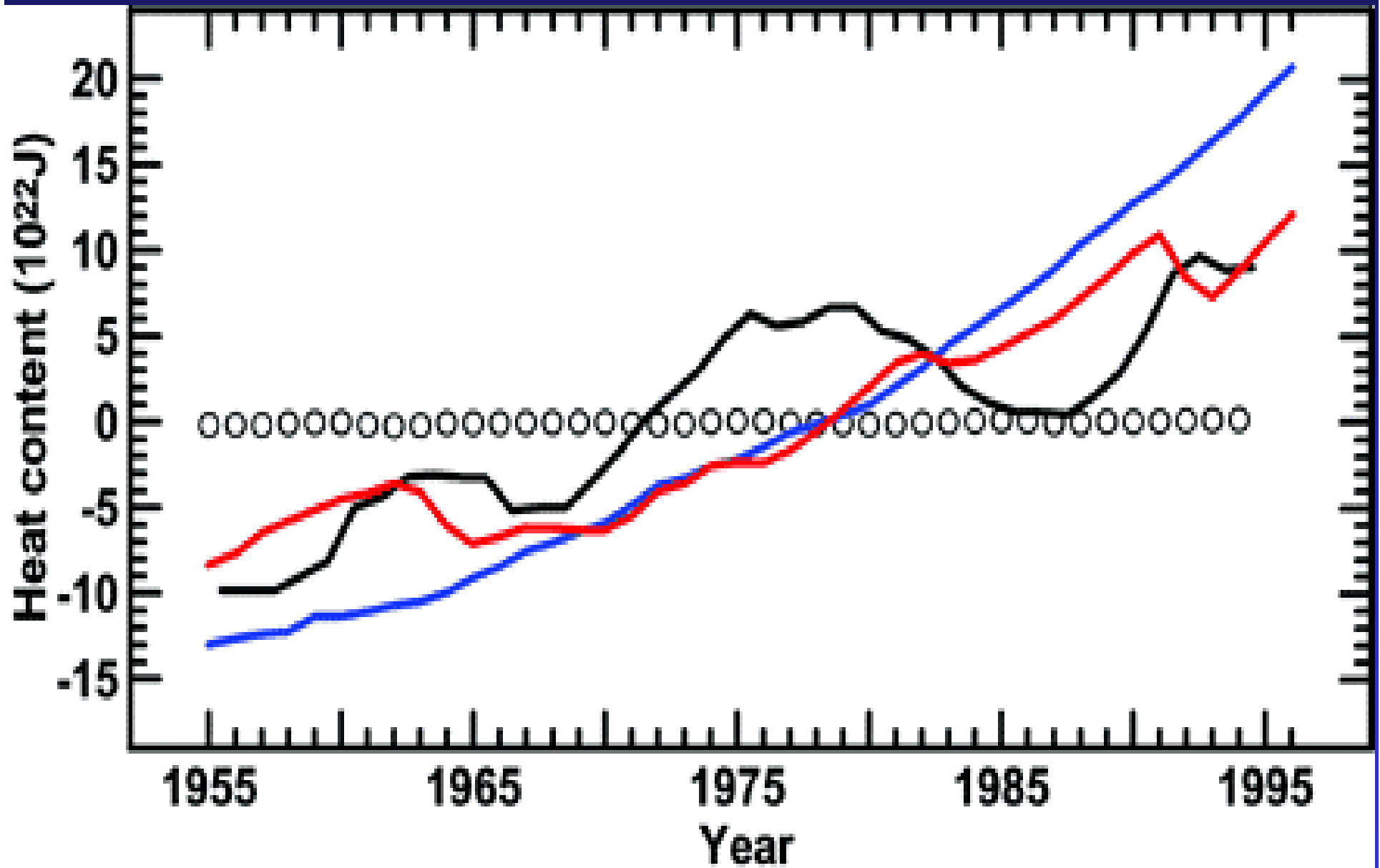
Non-CO₂ forcing

- Climate forcing by non-CO GHGs (~1.4 Wm⁻²) is ~ same value of all known forcings for 1850- 2000
- Assertion: Processes producing non-CO₂ GHGs have been primary drive for climate change in past century

Consistency Checks

- Global warming of past century
- Observed heat storage in ocean
- Paleoclimate data imply forcing $3 \pm 1^\circ\text{C}$ for doubling of CO_2 = sensitivity of climate models
- Implies thermal response in ocean $3/4^\circ\text{C}$ since late 1800
- Consistent with 1.2°C increase for 1.6 Wm^{-2} forcing

Ocean heat Content Change



- Ocean only place where energy can accumulate
- Observed ocean heat content change implies 0.3 Wm^{-2} for 50s-90s that is consistent with what models predict

GHGs Growth Rate

- CO₂ and CH₄ main gases due to anthropogenic effects
- Scenario used in climate projections are uncertain and hints that GHGs growth rate is slower than predicted in 1992 (IPCC FAR)
- Trends better reveals by their annual growth rates

Greenhouse Gas Mixing Ratios

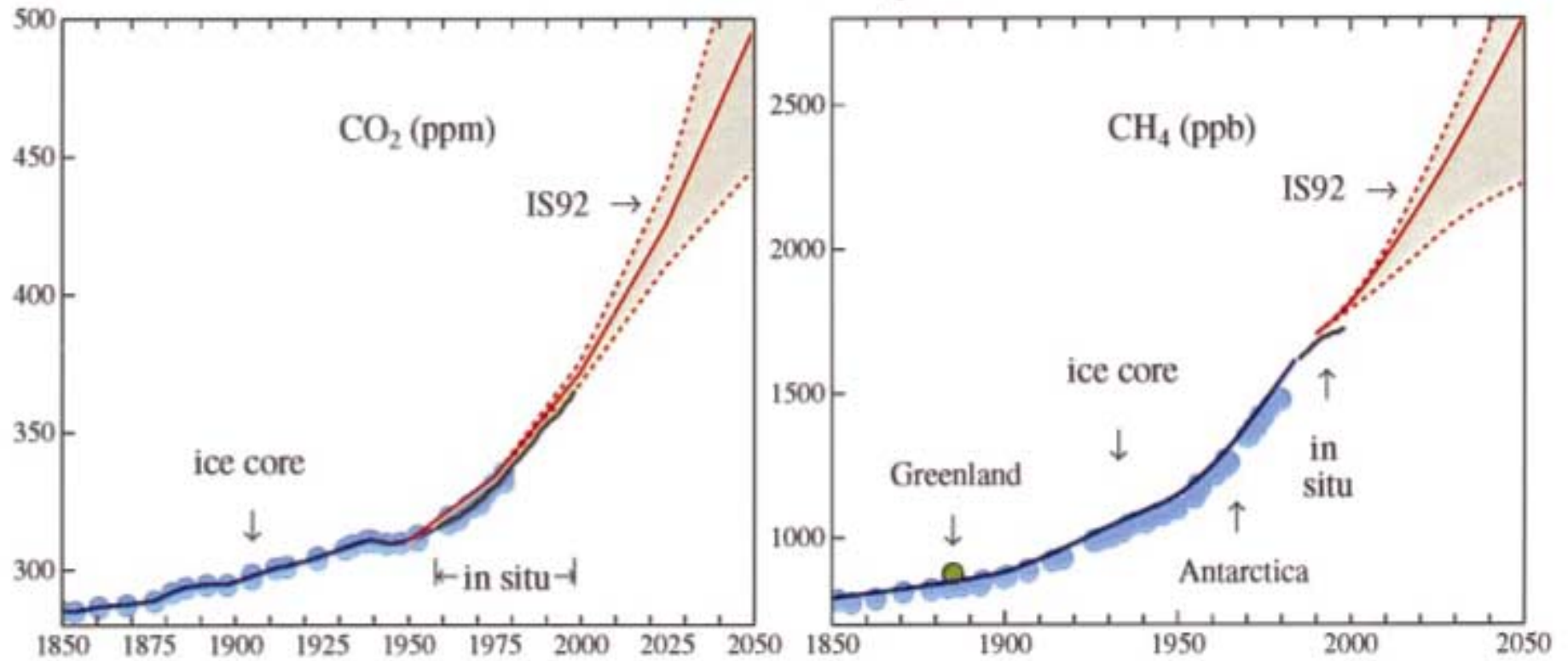


Fig. 2. Atmospheric CO₂ and CH₄ observations and range of IS92 scenarios (the solid red line is IS92a).

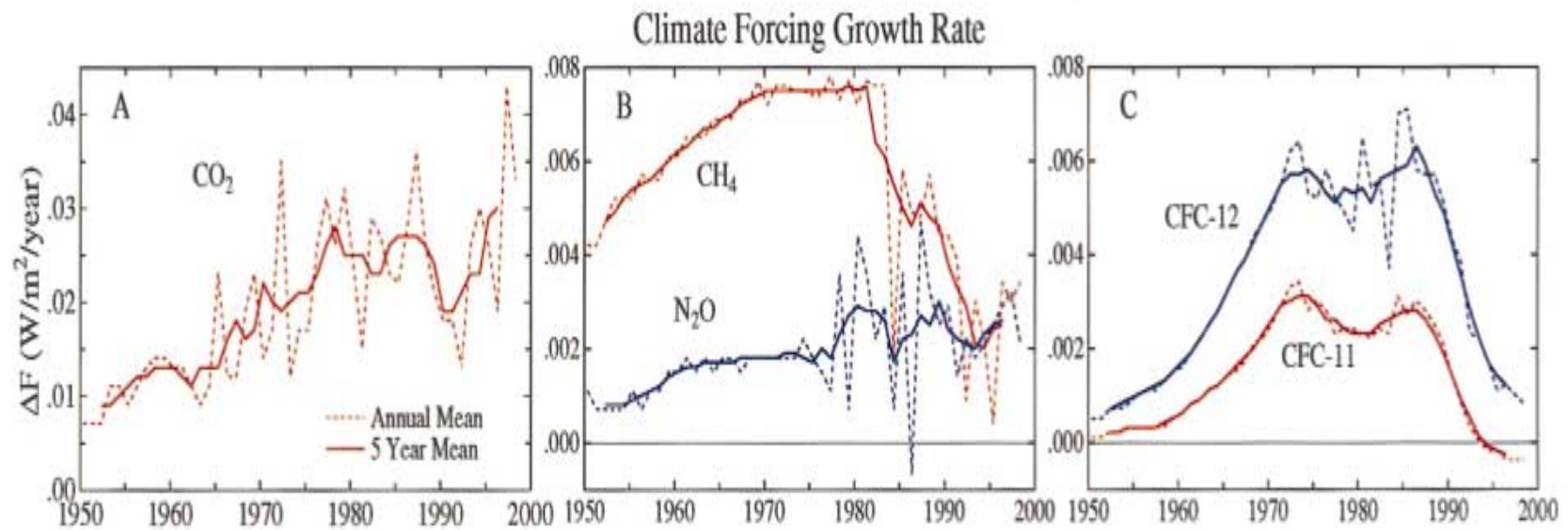


Fig. 3. Growth rates of climate forcings by individual GHGs—CO₂ (A), CH₄ and N₂O (B), and CFC-11 and CFC-12 (C)—based on trace gas data available from the National Oceanic and Atmospheric Administration Climate Monitoring and Diagnostics Laboratory.

CO₂ Growth Rate

- Doubled between 50s - 70s
- Flat 70s until late 90s
- Recent increase in terrestrial and oceanic sinks for CO₂ (temporary?)
- Largest annual increase (2.7 ppm) in 1998

CH₄ and CFCs Growth rate

- Dramatic CH₄ growth rate
- Small interannual variability before 1982
- Growth rate for CFCs ~ 0 since Montreal portocol and negative in future

CO₂, CH₄ and aerosols: Greatest uncertainty for prediction

- Coal and oil about equal sources for CO₂,
- Coal potentially large future emissions (resources much larger)
- Coal use declined in world except USA and China
- Increase in atmospheric CO₂ only half of emissions. Rest taken up by ocean, biosphere and soils
- Slowing down of emission may allow more sequestration
- Maintenance of flat growth rate forcing => flat growth rate of emissions

Methane - CH₄

- Decline in growth rate caused by changes in chemical emissions that affect OH, sink for CH₄
- May be reduction of sources?
- Short lifetime (~8 y) = reduction of major source may cause reduction in growth rate
- Sources and sinks of methane not well known
- Microbial decay major natural source (wetlands)
- Anthropogenic sources (x2 natural) rice cultivation, domestic ruminant, bacterial decay in landfills and sewage leakages

Aerosols

- Largest source of uncertainty about future climate change
- Approximate balance between CO₂ and aerosol forcing may not last indefinitely - as more CO₂ accumulates balance will require more aerosol loading
- Cannot be the solution (detrimental effects)
- Don't even know sign of current trend of aerosol forcing (indirect effects essentially unknown)

An Alternative Scenario

- Adds little forcing over next 50y ($< 1 \text{ Wm}^{-2}$)
- Next 50y most difficult time to affect CO_2 emissions (inertia in system)
- H Proposal: halt and then reverse growth of non- CO_2 GHGs + reduce black carbon emissions
- Such strategy would mitigate an **inevitable growth of CO_2**

What does it mean for CO₂?

- Mean CO₂ growth rate in next 50 y ~ same as past two decade => additional forcing 1Wm⁻²
- Is such rate plausible? Opportunities to achieve reduced emission while developing countries grow
- Will require moderate decrease in CO₂ emission rates as continuation of high terrestrial CO₂ sequestration is uncertainty

- 2000-2025 scenario achieved with improved energy efficiency and decarbonization of sources (e.g., gas in stead of coal)
- Technologies for improved efficient exist
- In 2025-2050 will need much greater use of energy sources that produce little CO₂
- Need to foster research and development on generic technologies at the interface between energy supply and use (e.g., gas turbines, photovoltaics)

Methane

- Aim for forcing of -0.2 Wm^{-2} change in next 50 y
- Reduction of anthropogenic sources by about 30% - will increase OH + reduce trop O₃
- CH₄ from rice cultivation depends on cultivar choices, irrigation management and fertilization - possible mitigation strategies that
- Ruminants potential reduction through diet
- Leaks from pipelines can be taken care of

- Economic benefits of CH₄ capture probably insufficient to reduce CH₄ emission by 30%
- Will need additional incentives, avoid large sources, reduction of CO

CFCs

- If production phase out follows plans forcing 0.145Wm^{-2} less in 2050
- Uncontrolled gas that are ozone depleting likely to increase and cause positive forcing
- Verification requires continued attention and funding

Tropospheric Ozone

- Forcing is now $0.4 \pm 0.15 \text{ Wm}^{-2}$
- Principal precursor = volatile organic compounds
- Primary sources of precursors are transportation, power plants, industrial processes
- Will need some special attention

Aerosols

- Not monitored accurately
- Future forcing unknown
- Black carbon reduces aerosol albedo, cloud cover and reduces cloud particles albedo
- Could obtain a reduction by 0.5 Wm^{-2} if reduction of black carbon from diesel fuel and coal
- Aerosols have to be monitored globally by satellites

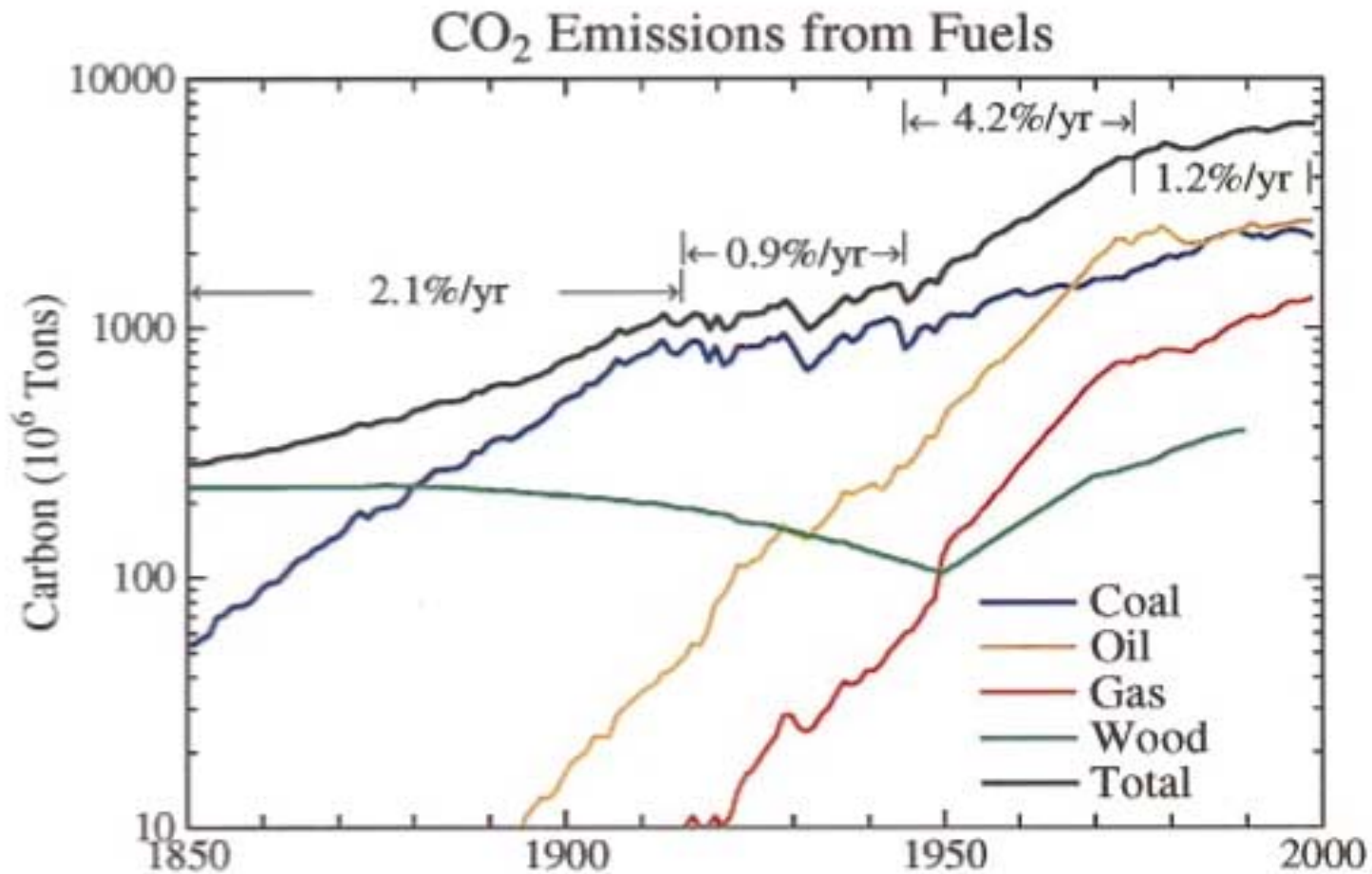


Fig. 4. CO₂ emissions from fuel use (40). The estimate for wood is by N. Makarova (The Rockefeller University; personal communication).

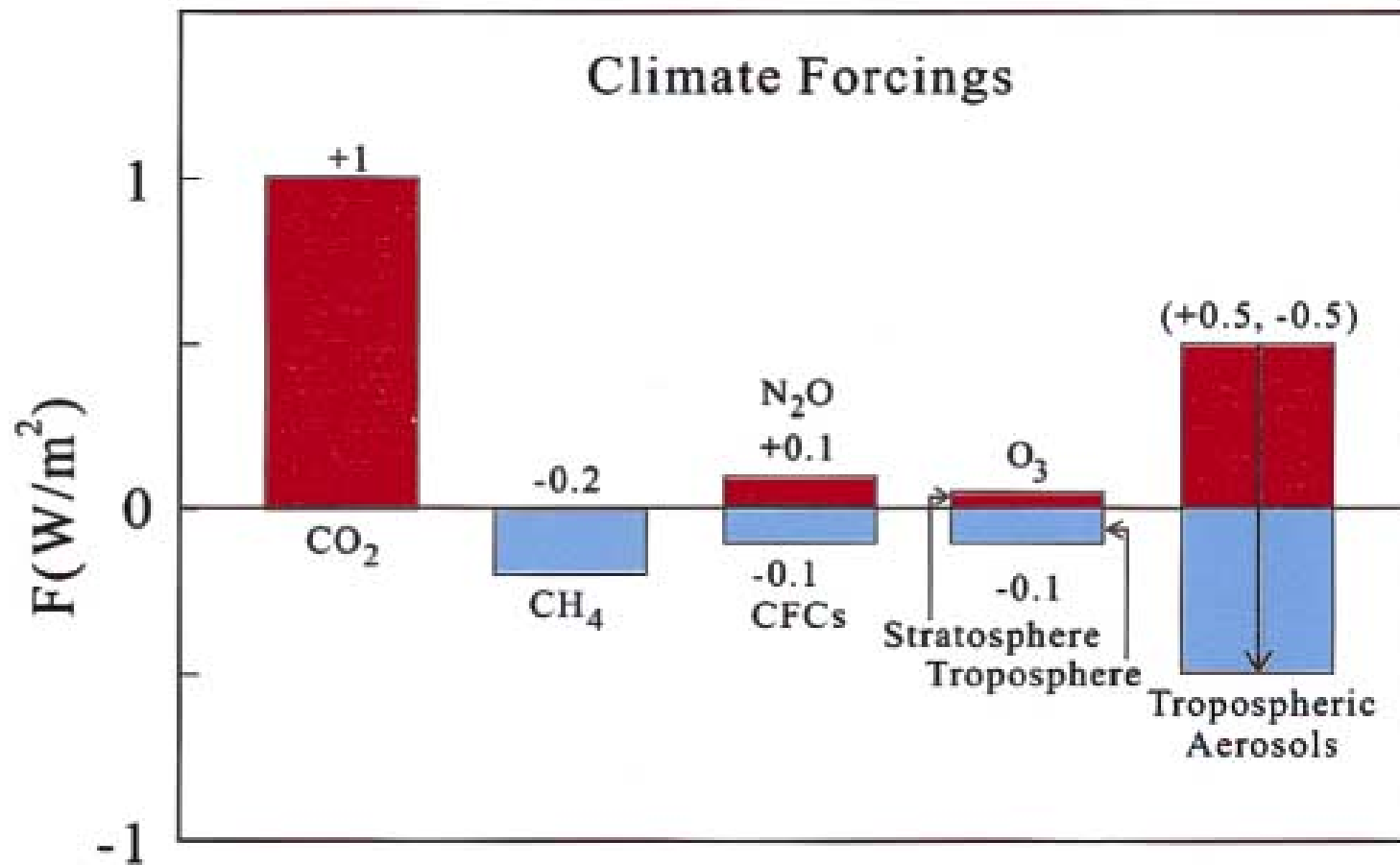


Fig. 5. A scenario for additional climate forcings between 2000 and 2050. Reduction of black carbon moves the aerosol forcing to lower values.