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Near-term climate forcing

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Outline

Motivation

- Near-term climate forcers

  Timescales

  - Calculating climate effects (metrics)
    - RF, GWP, GTP

Policy uses

Spatial scales

- Regional impacts

Summary

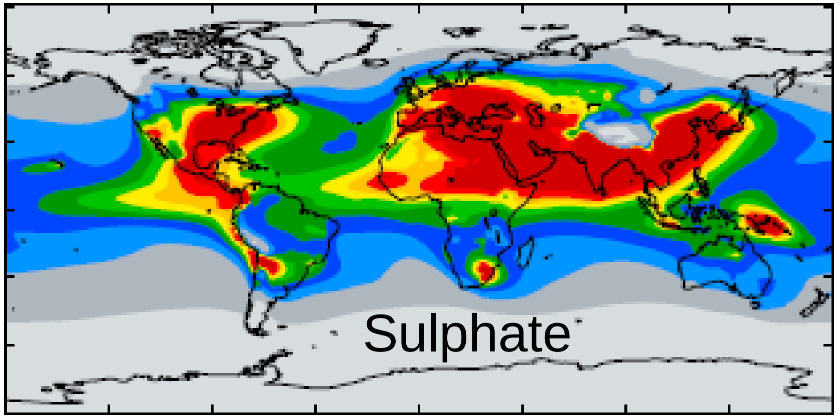
Near-term climate forcers: NTCFs

IPCC AR5 chapter 8:

- Common property is the timescale over which their impact on climate is felt.
    - Primarily within the first decade after emission.
- Short lifetimes in the atmosphere, sometimes referred to as “short-lived climate pollutants”.
- Includes methane (also a WMGHG), as well as ozone and aerosols, (or precursors) and some halogenated species.
- Do not accumulate in the atmosphere at decadal to centennial timescales .

Time and spatial scales

- CO_2
  - Remains in the atmosphere for centuries
  - Evenly spread across the globe
- Methane
  - Remains in the atmosphere for around 12 years
  - Relatively evenly spread
- Ozone and Aerosols
  - Remain in the atmosphere for a few weeks
  - Concentrated over source regions



IPCC AR5

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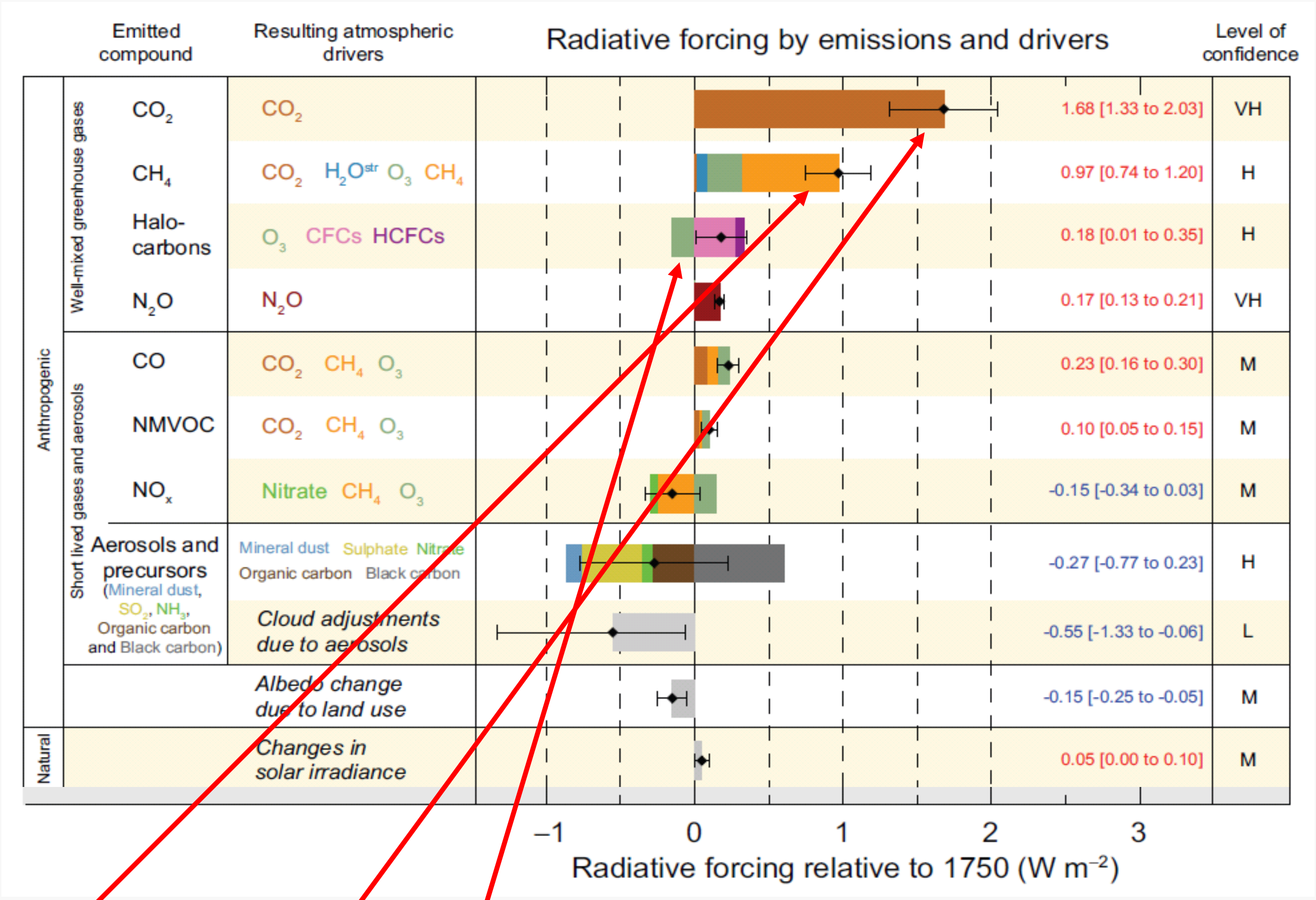
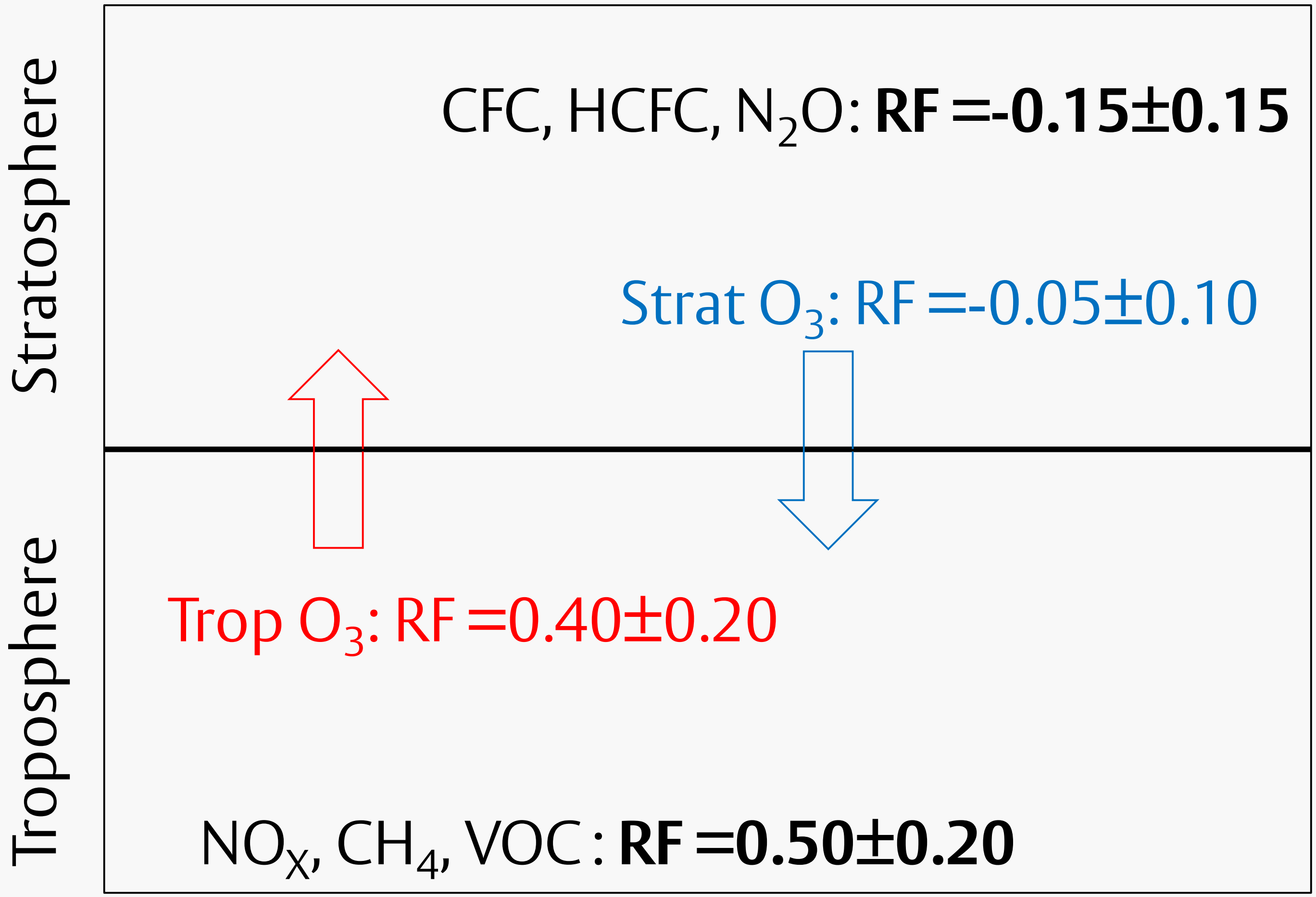


- Emission-based approach emphasises role of CH_4
  - CH_4: 0.97 Wm^{-2} , CO_2: 1.68 Wm^{-2}
- Halocarbon RF offset by strat O_3 depletion

Ozone RF in AR5



TIMESCALES

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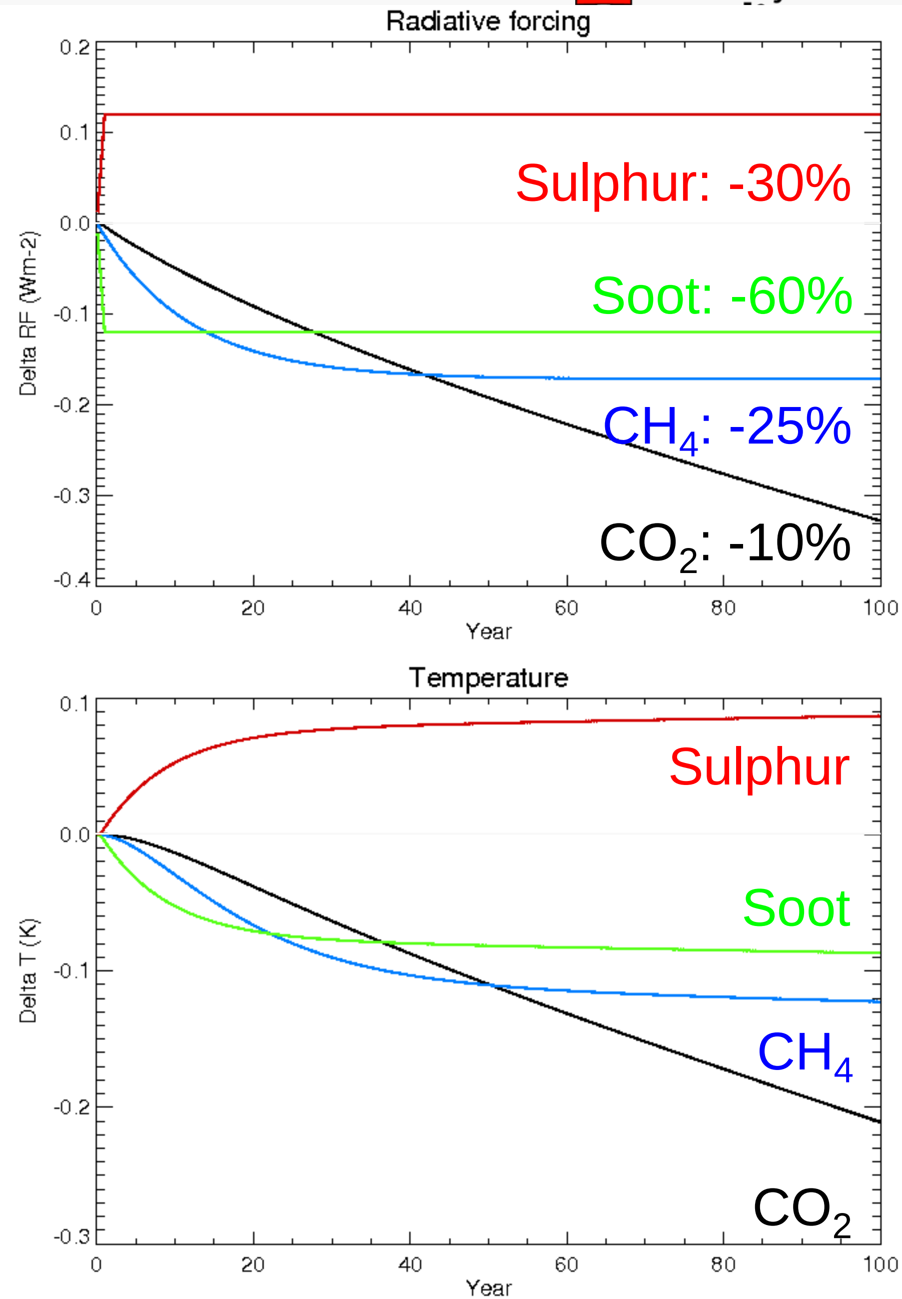
- How quickly does the surface temperature respond to a change in concentration?
  - Only about 10 years to get 2/3 of the full response
  - Slow rate of climate change is due to slow growth of CO_2
- Can get quick climate response by cutting back on soot or methane
  - But only short-term relief
  - Cutting sulphur warms climate!
- Cutting CO_2 is the only solution for long-term climate change



Climate metrics

- Metrics quantify a climate impact for a 1kg pulse emission

GWP:

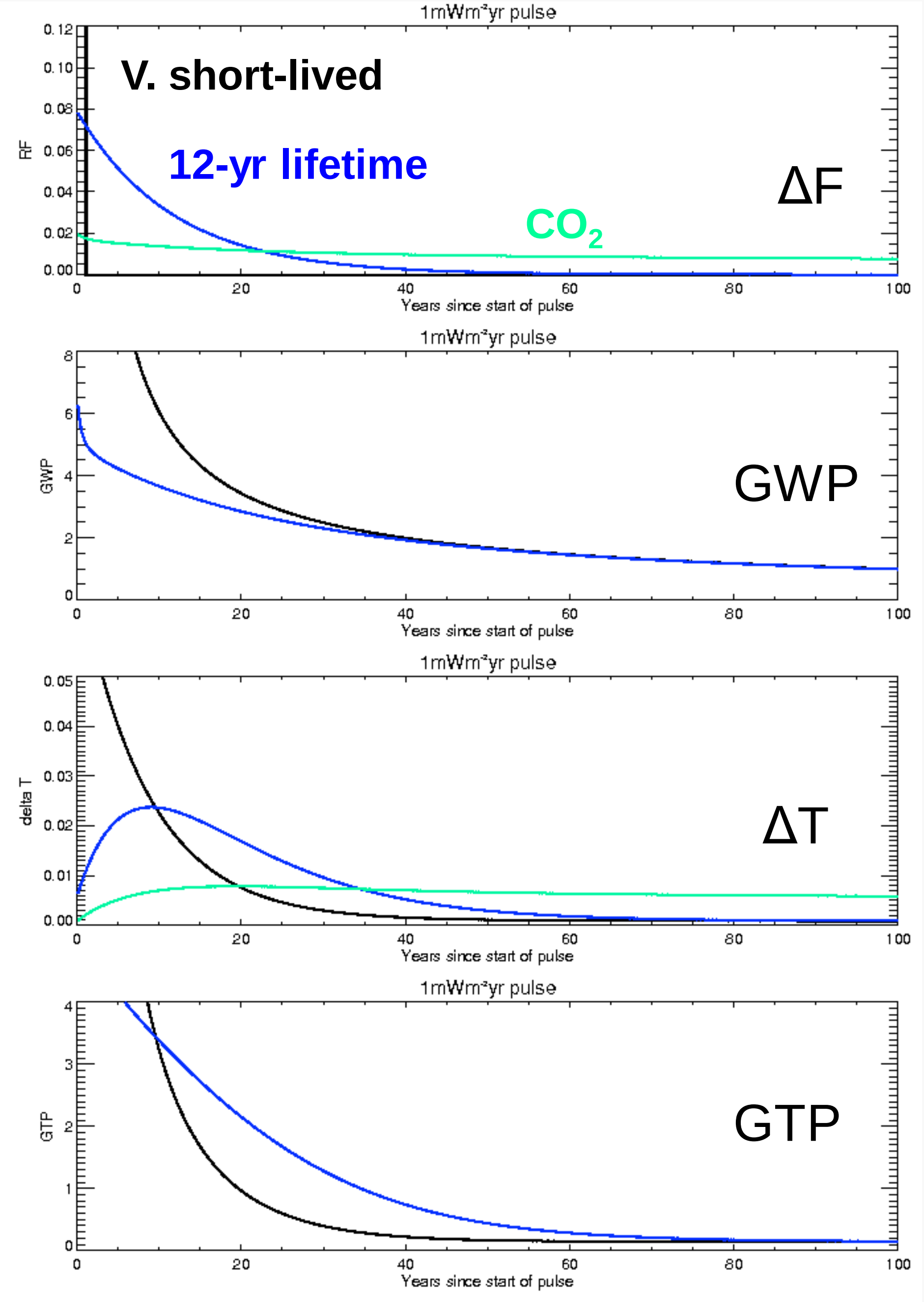
- ΔF integrated out to time horizon H divided by the same for CO_2
  - AGWP(H)=$\int_0^H \Delta F(t)dt$ in Wm^{-2} yr kg^{-1} or J kg^{-1}

GTP:

- Change in T_{surf} at time H divided by the same for CO_2
  - Depends on timescale of climate response: R(t) (K(Wm^{-2} yr)$^{-1}$ or K J^{-1})
  - AGTP(H)=$\int_0^H \Delta F(t)R(H-t)dt$ in K kg^{-1}
    - Parameterise climate response (sum of two exponentials 8.4 yr, 410 yr)
- GTPs give a measure of the temperature-change impact of an emission
- Can apply them to any emission scenarios to estimate net temperature effect

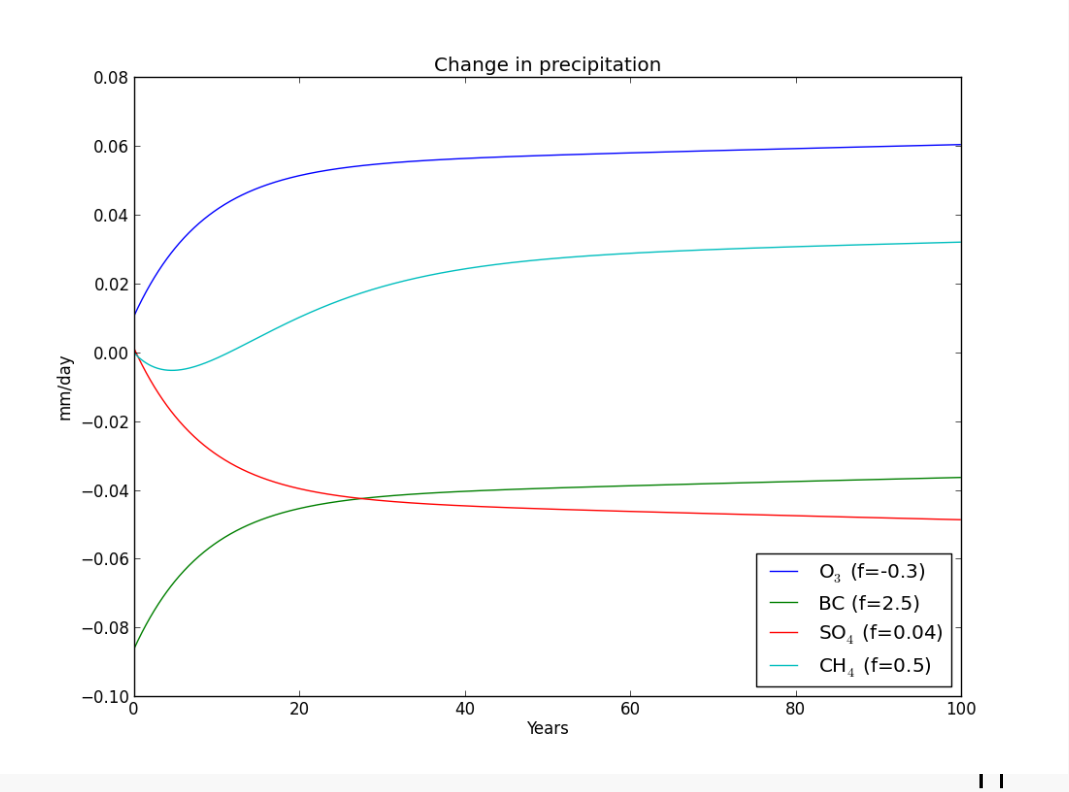
Timescales

- 1mWm^{-2}yr pulses (1.6×10^{19}J)
  - Different lengths, but equal areas
  - v.short-lived (O_3, aerosol)
  - 12-year lifetime (methane)
  - 1.2, 18.5, 173 years (CO_2)
- GTP is a stronger function of time than GWP
- 2 tracers have very different GTP_{20}, but similar GTP_{100}



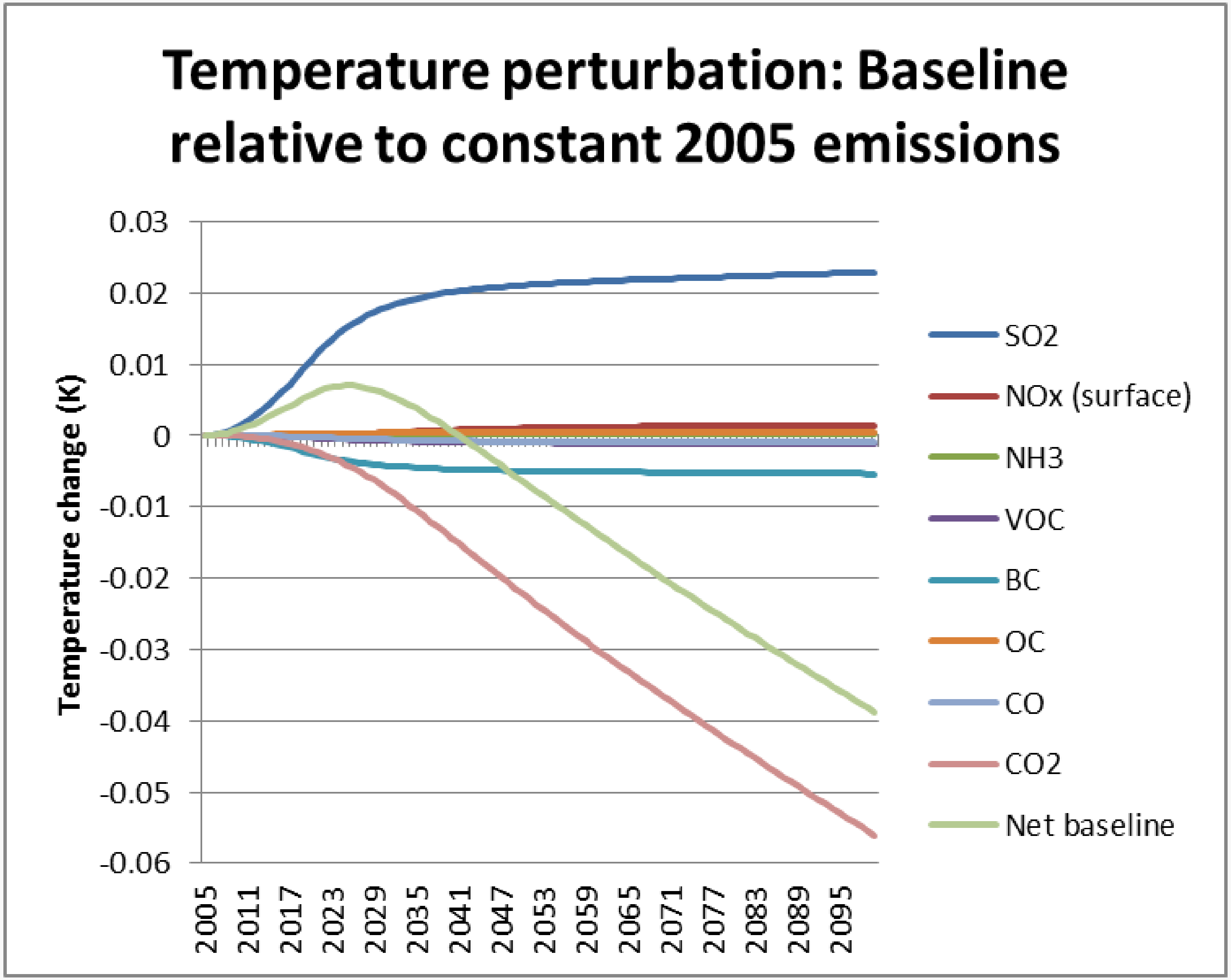
Global precipitation

- Can estimate precipitation change by atmospheric energy balance
- LΔP +ΔSH =ΔQatm; Allan et al. Surv. Geophys. 2013
- $L\Delta P \sim k\Delta T - \Delta F_{atm}$;
  - $k=2\ Wm^{-2}K^{-1}$,
  - $L=2.5\times10^{6}\ Jkg^{-1}$



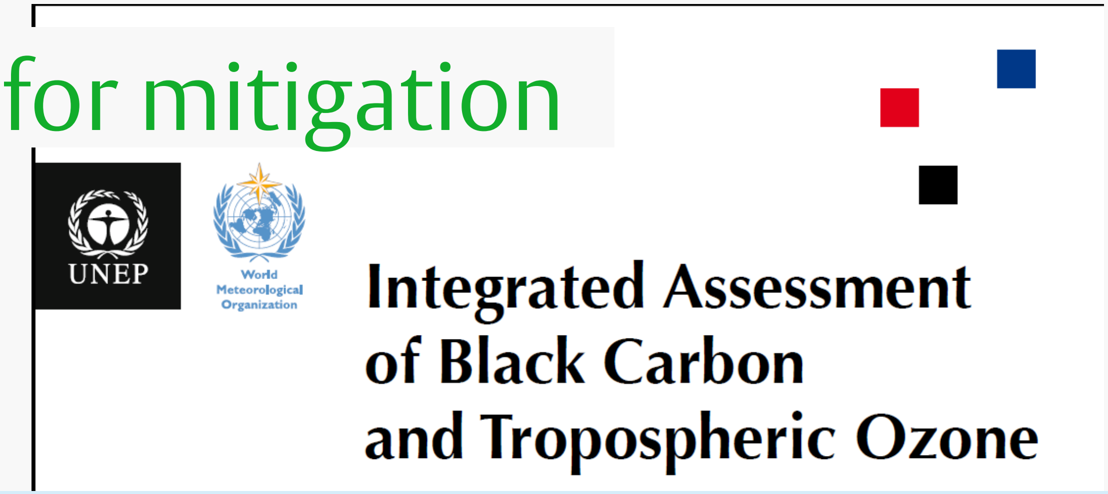
POLICY SCENARIOS

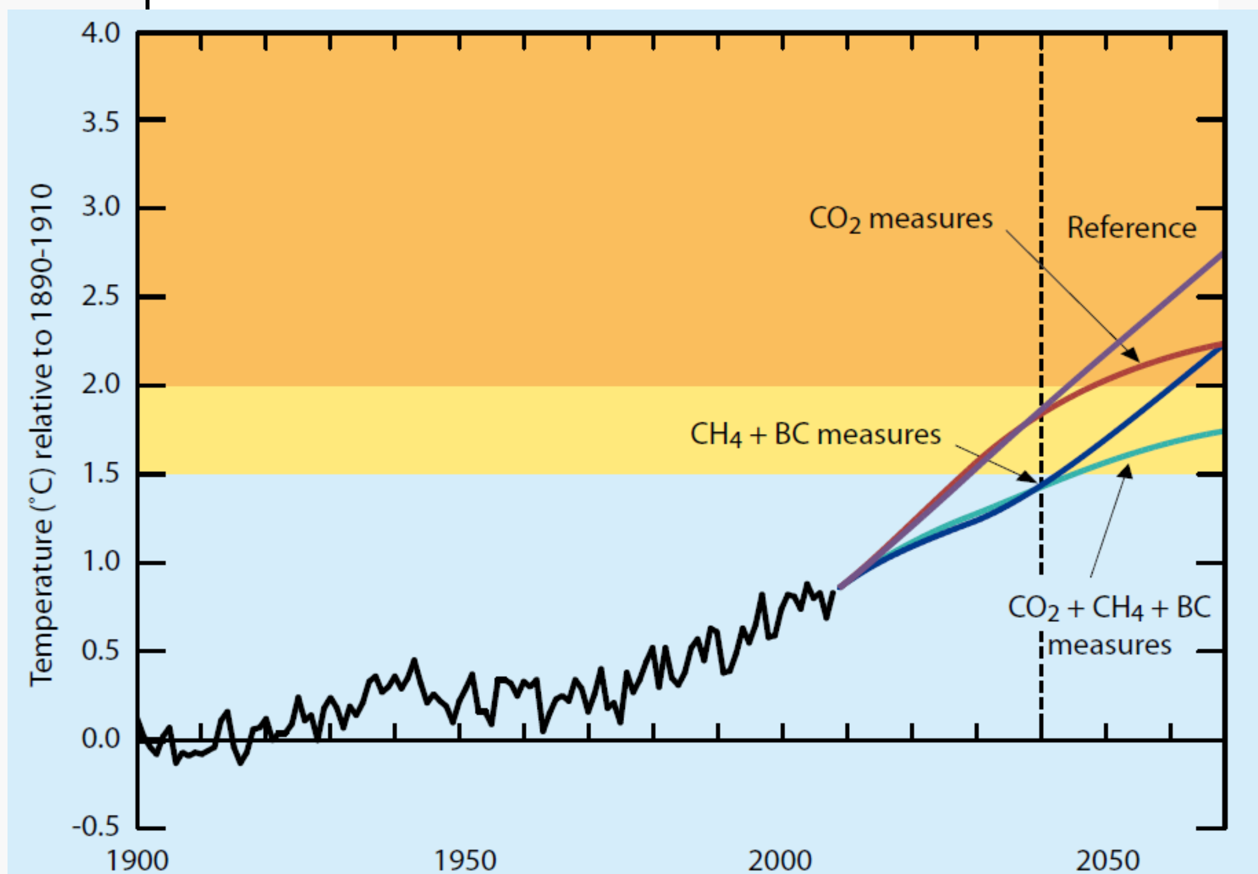
Gothenburg Protocol + EU CO_2 targets



Potential for mitigation

- Control measures to cut CO_2 also cut sulphur
  - Coal, oil → gas, renewables
  - Sulphur acts quickly; CO_2 slowly
- CO_2 measures alone don't keep us below 2°
  - Co-emitted SO_2
- => need measures to reduce CH_4 and soot
  - 0.4° cooling
  - Stays below 2 °





Comparison of UNEP & IPCC

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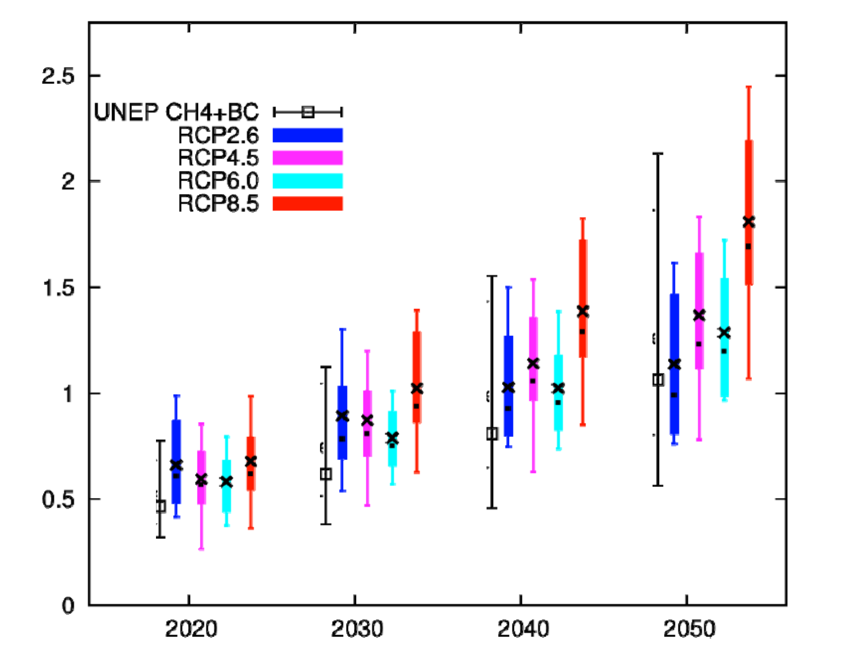
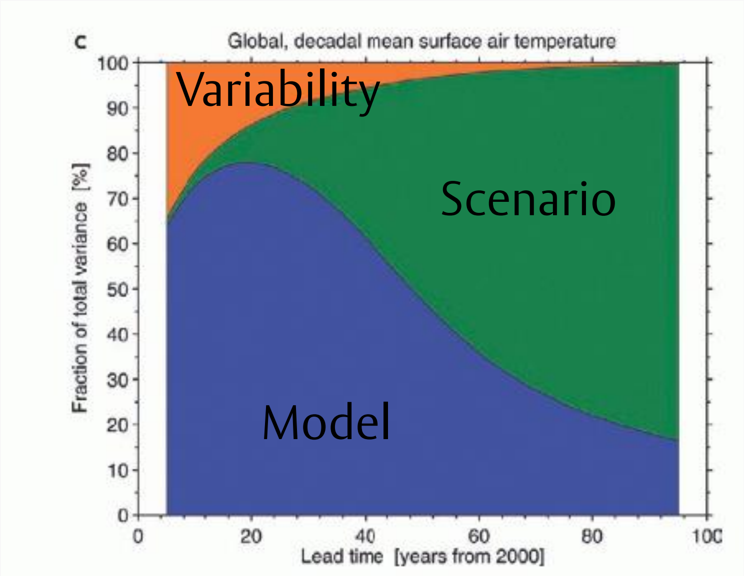
- Before 2050 IPCC scenarios don't show a consistent pattern of warming from "cleanest" to "dirtiest"
  - Different assumptions on chemistry and aerosols
- UNEP scenario lies below the IPCC range
- →Over confidence in short-term predictions from IPCC scenarios
- →Future climate for next 30 years isn't fixed





SPATIAL SCALES

Regional emissions

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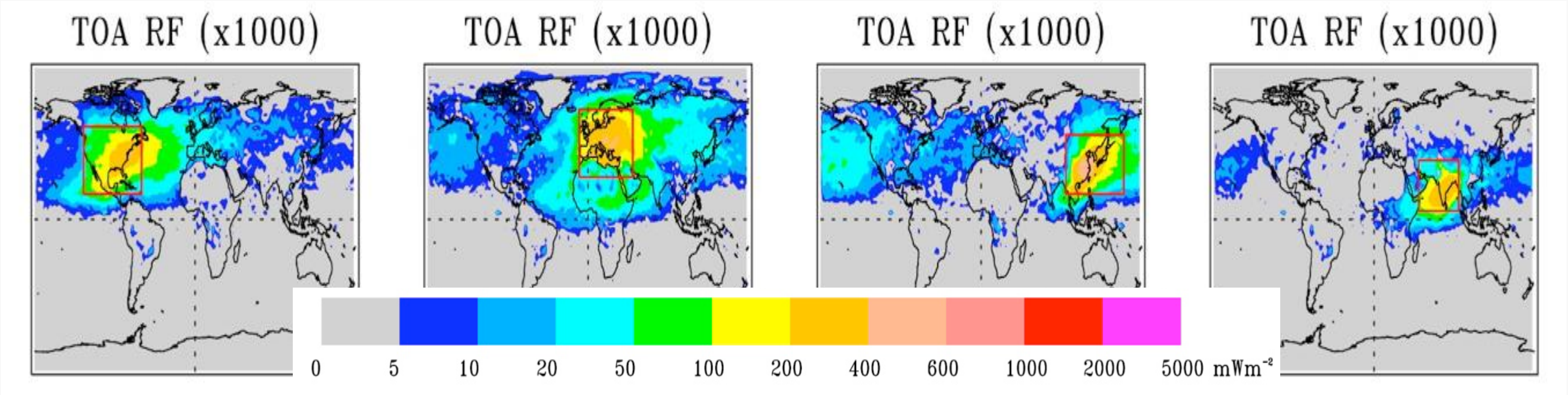
- Emissions of near-term climate forcers from different regions can have different climate metrics
- Use multi-model study of aerosol and chemistry models
  - 4 continents E. Asia, Europe, N. America, S. Asia
  - Changing emissions 1 continent at a time



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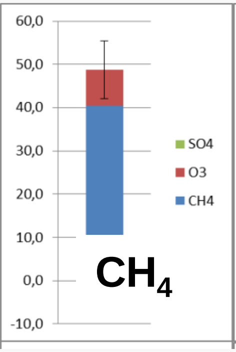
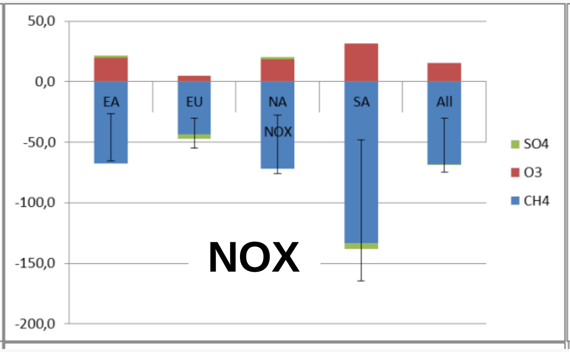
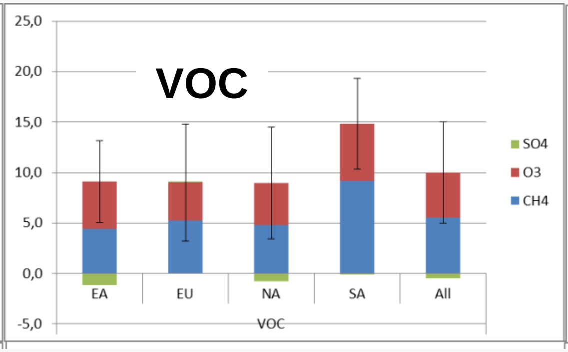
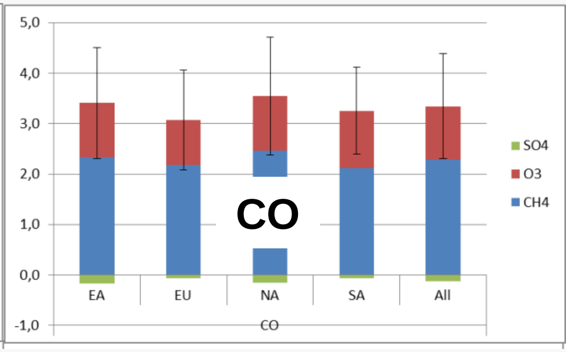
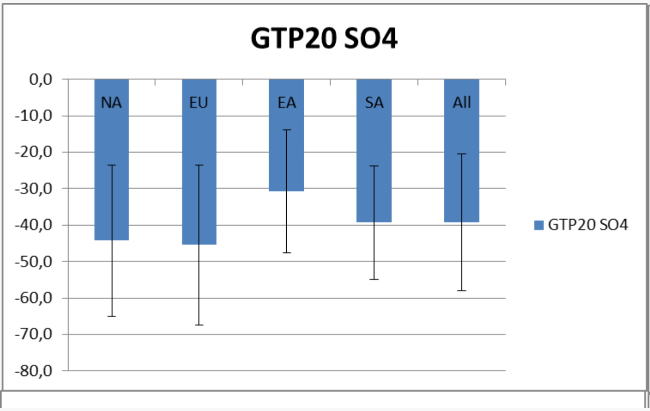
- Ozone precursors: climate impact can differ depending on emission region
- Aerosols: less dependence on emission region

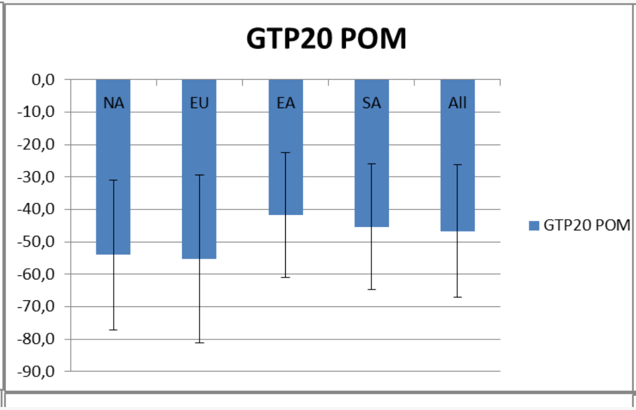


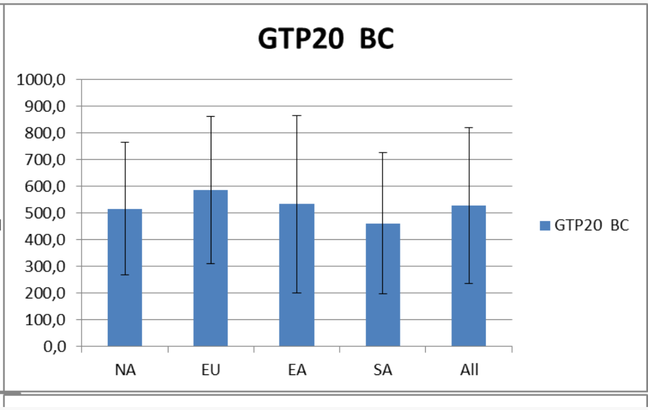




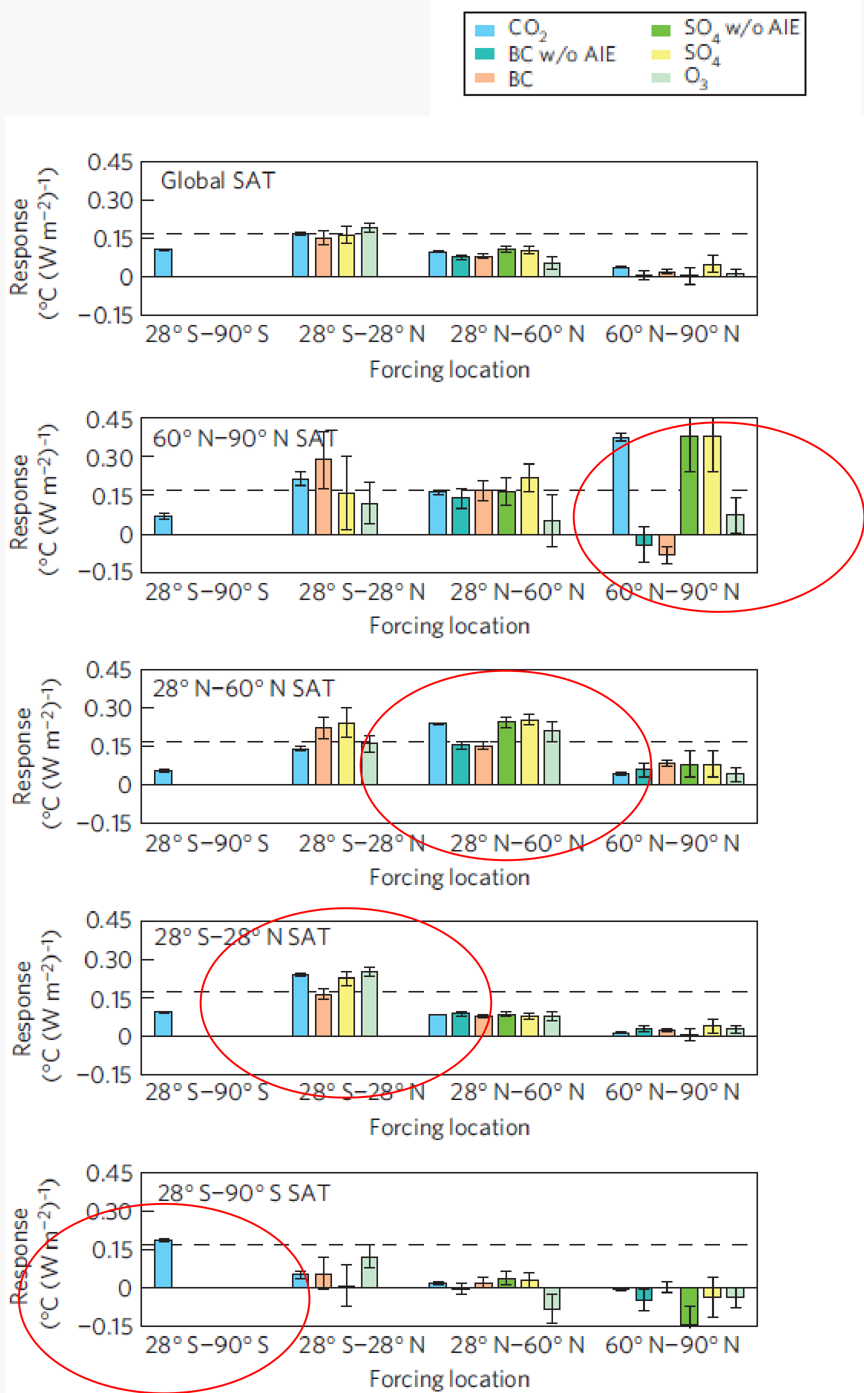






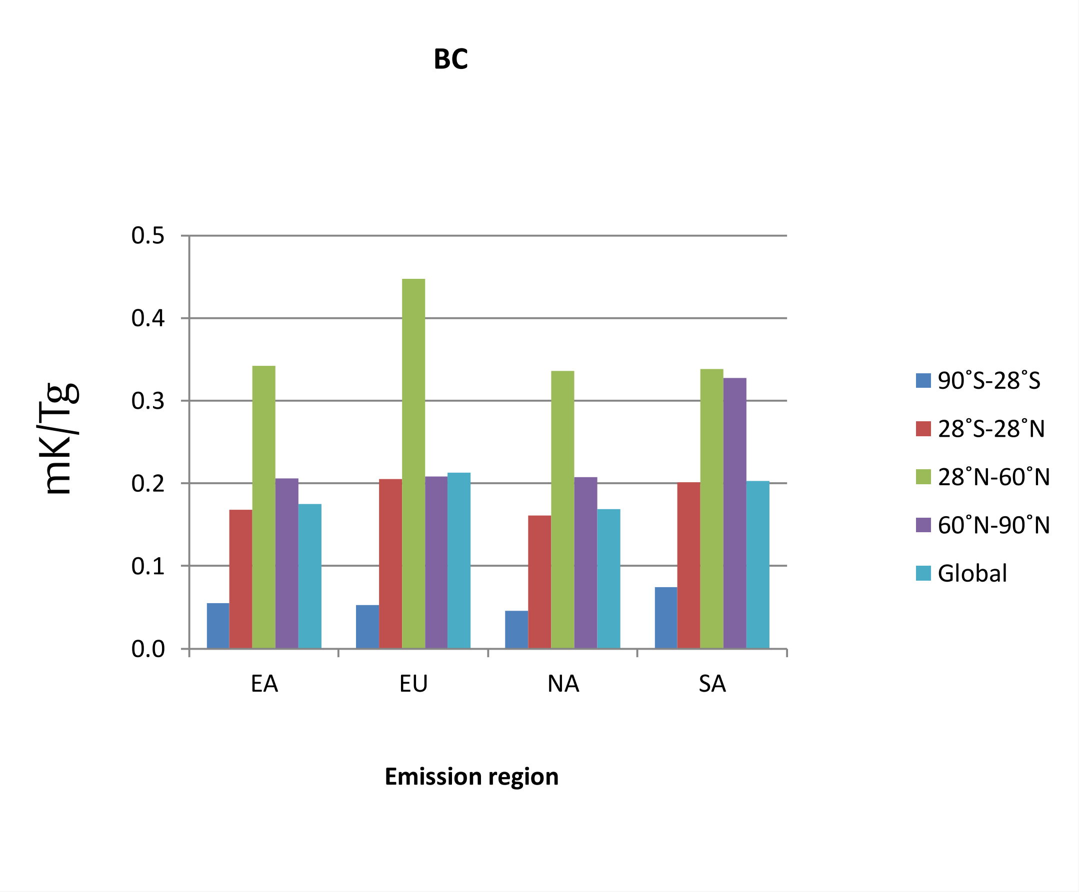


- Above analysis just looked at global mean temperature response
- Shindell and Faluvegi 2009 calculated latitudinal temperature responses to latitudinal forcing changes
  - (slab ocean model)
- Diagonal elements generally strongest
  - Strongest temperature change in same latitude band as forcing



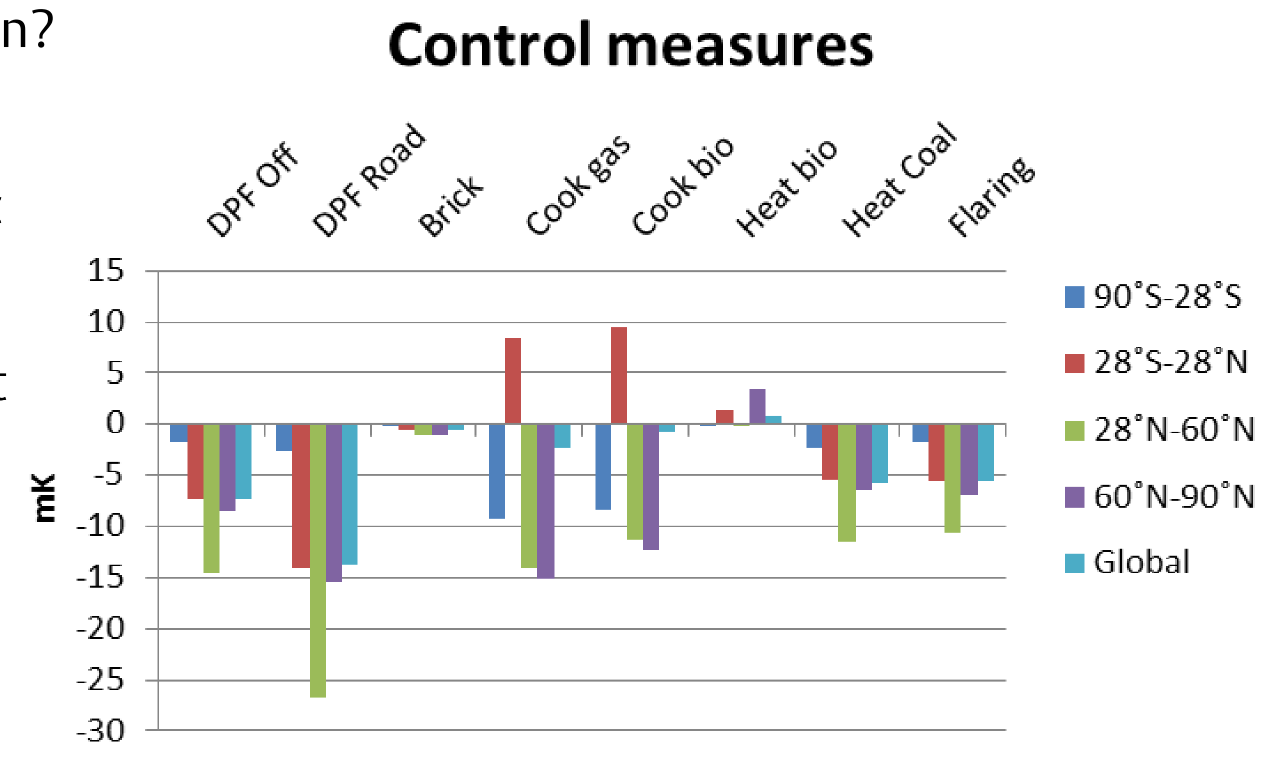
Black Carbon example

- Global → Regional
- GTPs → RTPs
- N. mid latitude emissions:
  - Temperature Response is larger over the latitude of the emission
  - ~twice the global response
  - Response is very small in S. hemisphere



Applications

- Can use regional climate metrics (ARTPs) to identify regional climate impacts of any emission profile
  - Aerosols, ozone and methane
- Local impacts
  - Do regional controls benefit that region?
- Sensitive areas
  - Impacts on Arctic
- Example:
  - UNEP Assessment control measures
  - Temperature change at 2050

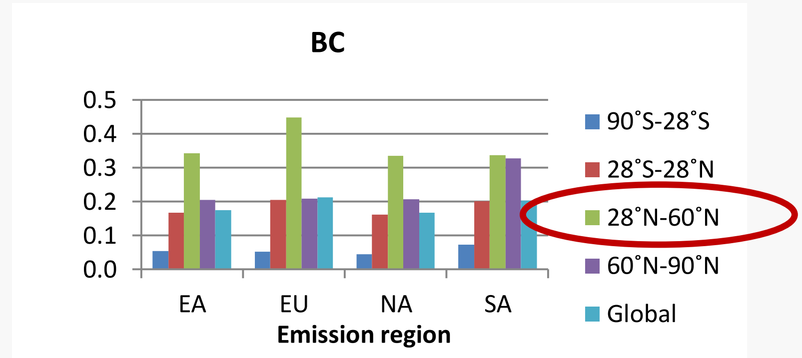


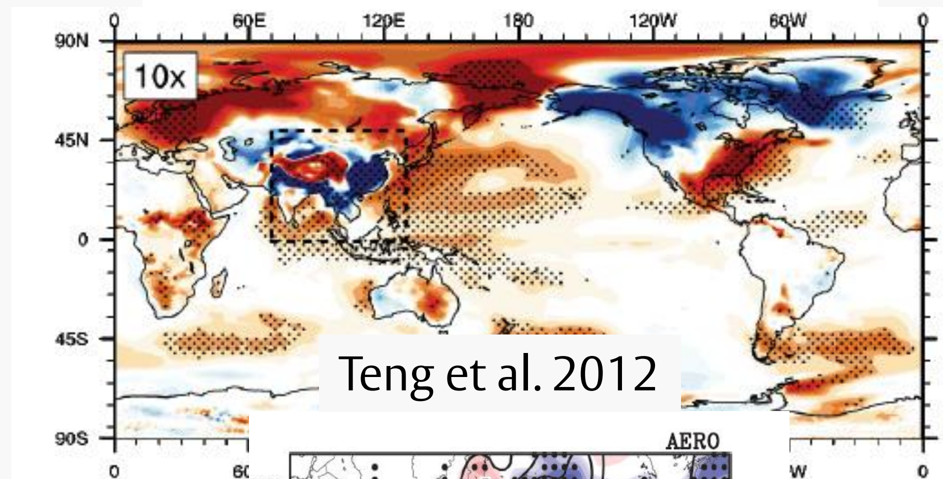
How much further can we take this?

- Continental-scale ΔT?
  - Patterns become more complex

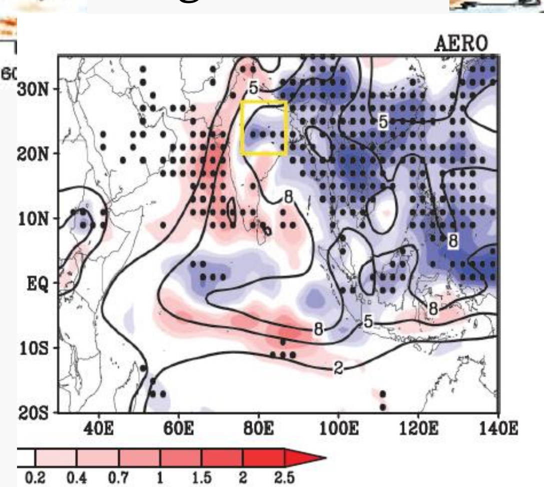
- Precipitation
  - Asian monsoon (Bollasina et al. 2011)

- May not be simple relationship between regional climate (ΔT, ppn) and regional forcing





Teng et al. 2012



Summary

- Near-term climate forcers can have significant climate effects over the next few decades
  - Opportunities for near-term mitigation
- Act on a variety of timescales
  - Can capture these through climate metrics (GTP)
  - Large uncertainty in the timescales of the climate response
- Forcing is non-uniform, so is temperature response
  - Regional impacts (e.g. Arctic) can be significantly larger than global average
- Breaking the response down further is challenging