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

- **CO₂**
  - 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
- 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

CFC, HCFC, $N_2O$: $RF = -0.15 \pm 0.15$

Strat $O_3$: $RF = -0.05 \pm 0.10$

Trop $O_3$: $RF = 0.40 \pm 0.20$

$NO_x, CH_4, VOC$: $RF = 0.50 \pm 0.20$
TIMESCALES
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 CO₂

Can get quick climate response by cutting back on soot or methane
- But only short-term relief
- Cutting sulphur warms climate!

Cutting CO₂ is the only solution for long-term climate change
Climate metrics

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

GWP:
- $\Delta F$ 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 $T_{\text{surf}}$ 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\times10^{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
- \( L \Delta P + \Delta SH = \Delta Q_{atm} \); Allan et al. Surv. Geophys. 2013
- \( L \Delta P \sim k \Delta T - \Delta F_{atm} \);
  - \( k = 2 \ \text{Wm}^{-2}\text{K}^{-1} \),
  - \( L = 2.5 \times 10^6 \ \text{Jkg}^{-1} \)
POLICY SCENARIOS
Temperature perturbation: Baseline relative to constant 2005 emissions

- SO2
- NOx (surface)
- NH3
- VOC
- BC
- CO
- CO2
- Net baseline
Potential for mitigation

- Control measures to cut CO$_2$ also cut sulphur
  - Coal, oil $\rightarrow$ gas, renewables
  - Sulphur acts quickly; CO$_2$ slowly
- CO$_2$ measures alone don’t keep us below 2$^\circ$
  - Co-emitted SO$_2$
- $\Rightarrow$ need measures to reduce CH$_4$ and soot
  - 0.4$^\circ$ cooling
  - Stays below 2$^\circ$
Comparison of UNEP & IPCC

• 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

- 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
• 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 $\Delta T$?
  - Patterns become more complex

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

- May not be simple relationship between regional climate ($\Delta T, \text{ppn}$) and regional forcing
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