Atmospheric response to CH$_4$ pulse emissions

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Talk Outline

- Motivation
- Objectives of current study
- Experimental setup
- Results and analysis
- Conclusions and further work
Motivation (1) – Potential increase in CH$_4$ ems in future

Westbrook et al., GRL 2009
Motivation (2) – Atm. Chemistry

• Oxidation of CH₄ results in the formation of trop. O₃, strat. H₂O, and CO₂

• In steady state, CH₄ is removed with an e-folding lifetime of 8.6 years

• An increase in CH₄ causes a reduction in its own sink, leading to a perturbation lifetime longer than the steady state lifetime

• CH₄ may influence formation of aerosols
Motivation (3) – Radiative Forcing

RF is attributed to primary emissions by Shindell et al., 2005.

RF attributed to CH$_4$ ems may be even higher if aerosol formation and ozone damage to vegetation are considered (Sitch et al., 2007; Shindell et al., 2009)
Objectives of Study

• Examine the atmospheric response to CH$_4$ pulse emissions (CH$_4$, O$_3$, OH, Lifetime)

• Explore sensitivity of response to:
  - Size of emission pulse
  - Location of emission pulse
  - Season of emission pulse

• Chemistry-Aerosol Coupling (Sulphate)

• Radiative Forcing (CH$_4$, O$_3$, H$_2$O, Sulphate)
Gas-Phase Chemistry: 
Experimental Setup (1)

- Control
- Expt 1 – Small Arctic pulse (Jan)
- Expt 2 – Small Arctic pulse (Jul)
- Expt 3 – Large Arctic pulse (Jan)
- Expt 4 – Small Tropics pulse (Jan)
- Expt 5 – Small Tropics pulse (Jul)

Atmosphere-only version of HadGEM2-ES using Yr-2000 AR5 ems (526 TgCH$_4$/year)

Small pulse: ~ 50 TgCH$_4$
Large pulse: ~ 500 TgCH$_4$
Gas-Phase Chem. Results

Emissions

- Control expt
- Pulse expt

CH₄ emissions / kg (CH₄) month⁻¹

No of months since start of integration
Gas-Phase Chem. Results

CH₄ Burden

O₃ Difference

CH₄ Difference
Gas-Phase Chem. Results

GWP\textsubscript{100yr} = 17.7 (CH\textsubscript{4}) + 4.0 (O\textsubscript{3}) + 2.3 (H\textsubscript{2}O)

= 24.0
Chemistry-Aerosol Coupling: Experimental Setup (2)

• Control
• Expt 1 – Small Arctic pulse (Jan)

Coupling between gas-phase chemistry and sulphate aerosol is on

Atmosphere-only version of HadGEM2-ES using Yr-2000 AR5 ems (526 TgCH$_4$/year)

Small pulse: ~ 50 TgCH$_4$
Chemistry-Aerosol Results

Reduction in Accum. mode sulphate aerosol

JUL: 6 mths after CH₄ pulse
Chemistry-Aerosol Results

JUL:
6 months after CH$_4$ pulse

Global mean TOA forcing = 0.64 (mW/m$^2$)
Chemistry-Aerosol Results

50 Tg pulse

\[ \text{GWP}_{100\text{yr}} = 17.7 + 4.0 + 2.3 + 0.8 \text{ (direct effect)} \]

= 24.8
Consideration of Potential CH$_4$ Releases (1)

• Pulse sizes: 50 Tg CH$_4$ and 500 Tg CH$_4$

• With a global mean temperature rise of 1.5°C, wetlands may emit an extra 50 Tg CH$_4$/year

• Terrestrial hydrates: 4-16 x 10$^5$ Tg CH$_4$

• Marine hydrates: 1-6 x 10$^6$ Tg CH$_4$
Consideration of Potential CH$_4$ Releases (2)

- Terrestrial hydrates: $4 - 16 \times 10^5$ Tg CH$_4$
- Consider a global mean temp. rise of 2.5°C
- Harvey and Huang (1995) suggest a cumulative release of 0.5% within 500 years
- Max. forcing of 0.3 -> 1.2 Wm$^{-2}$
  Mean forcing of 0.1 -> 0.4 Wm$^{-2}$ over 100 years
Conclusions

Gas-phase chemistry
• Perturbation lifetime of 12.0 years
• Independent of size, location, and season
• 100-year GWP of CH$_4$ is 24 (CH$_4$, O$_3$, H$_2$O)

Chemistry-Aerosol Interactions
• Reduction in accum. mode sulphate aerosol
• Global mean positive SW forcing at TOA
• Sulphate adds 0.8 to 100-year GWP of CH$_4$
• RF estimates for future potential releases
Further Work

- Process-based assessment of impact on sulphate
- Impact of CH$_4$ emissions on sulphate 1$^{st}$ indirect effect
- Impact of CH$_4$ emissions on nitrate aerosol
Thank you for listening! Any questions?