Atmospheric response to CH_4 pulse emissions

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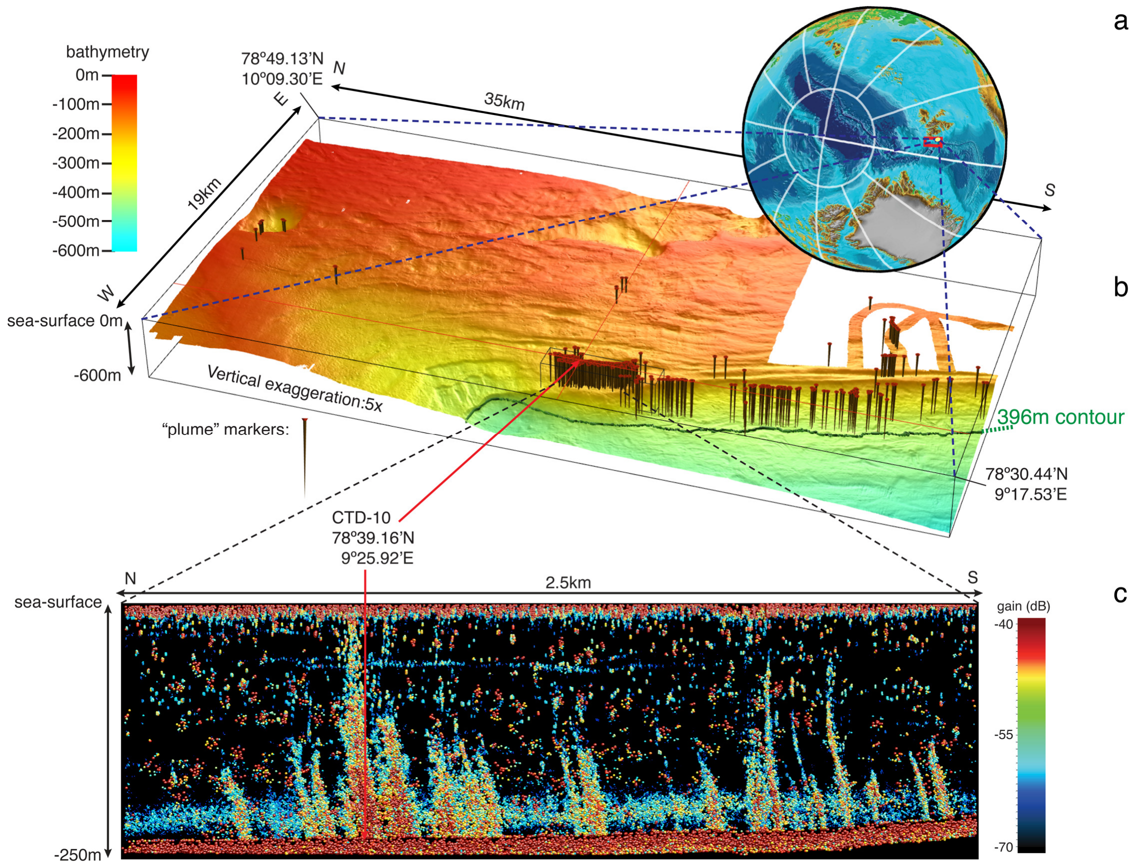
Talk Outline

- 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

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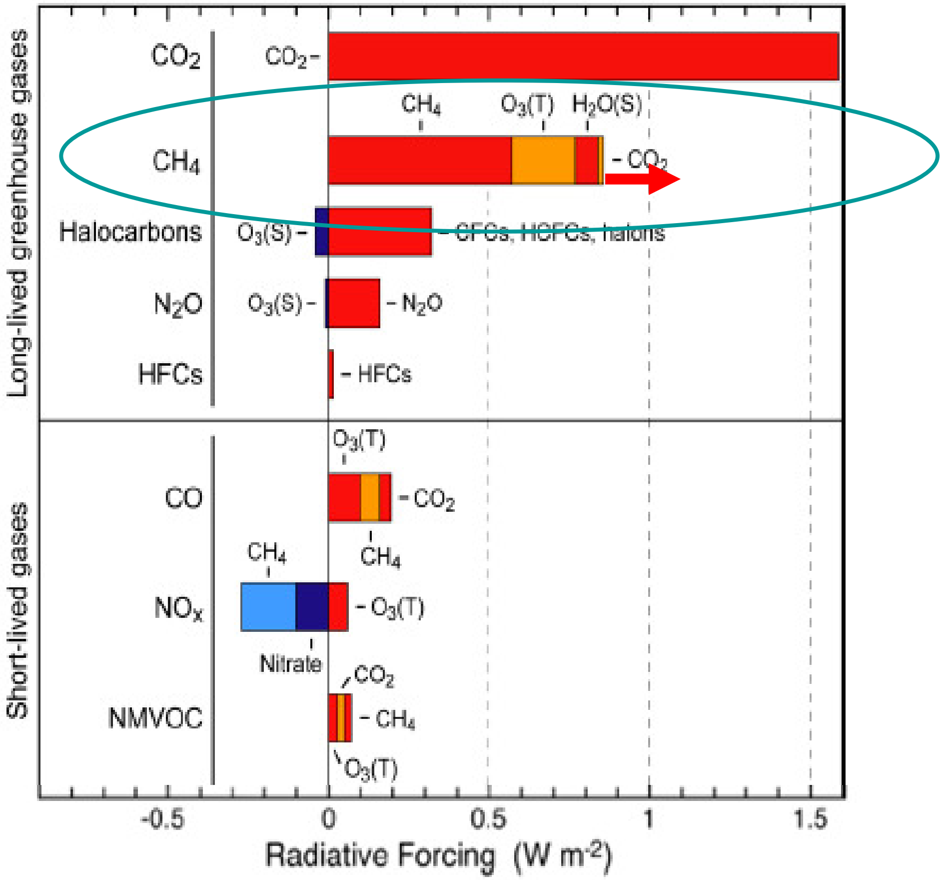
- Oxidation of CH_4 results in the formation of trop. O_3, strat. H_2O, and CO_2
- In steady state, CH_4 is removed with an e-folding lifetime of 8.6 years
- An increase in CH_4 causes a reduction in its own sink, leading to a perturbation lifetime longer than the steady state lifetime
- CH_4 may influence 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

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- 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_2O, Sulphate)

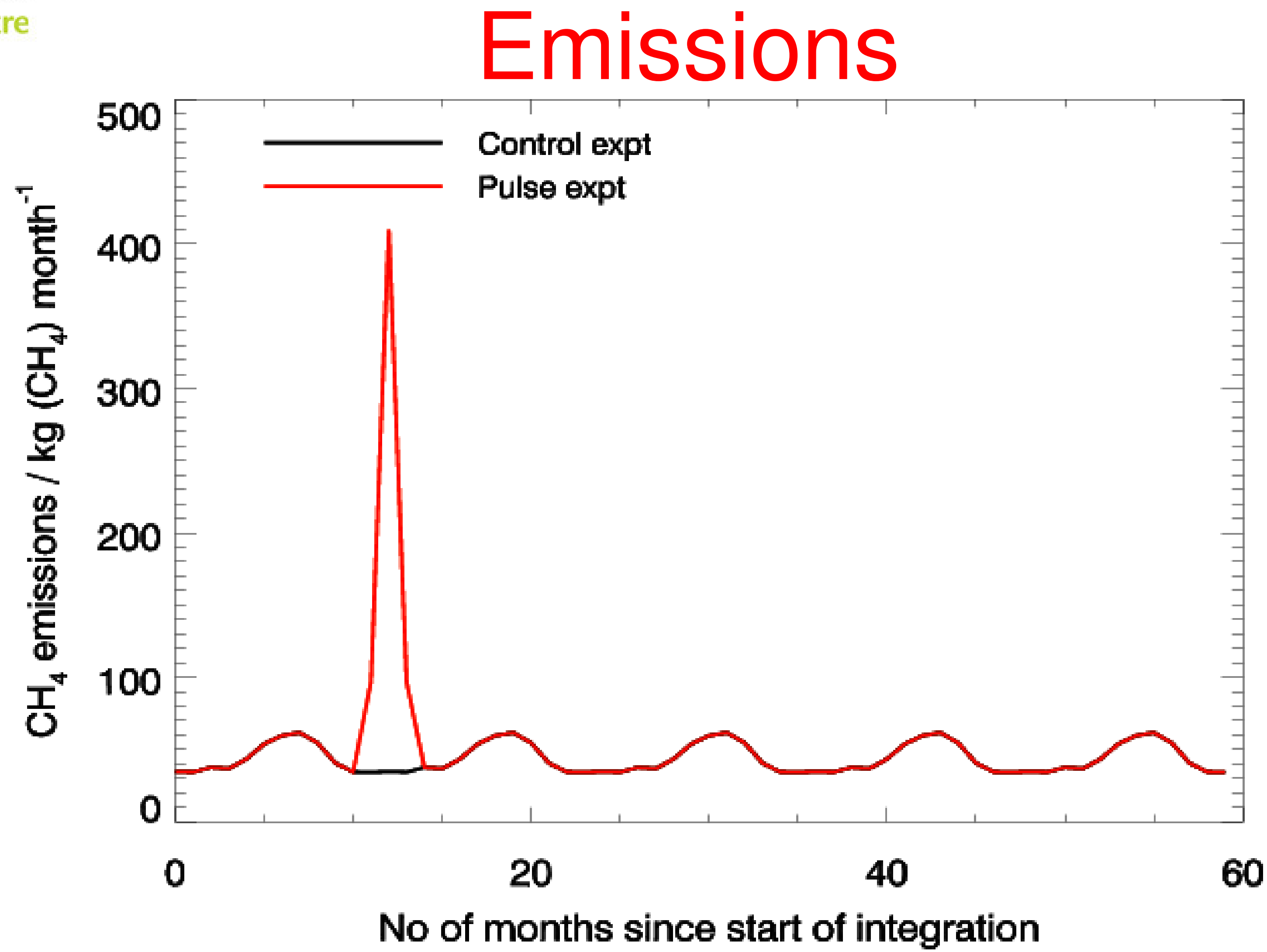
Gas-Phase Chemistry: Experimental Setup (1)

- 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)

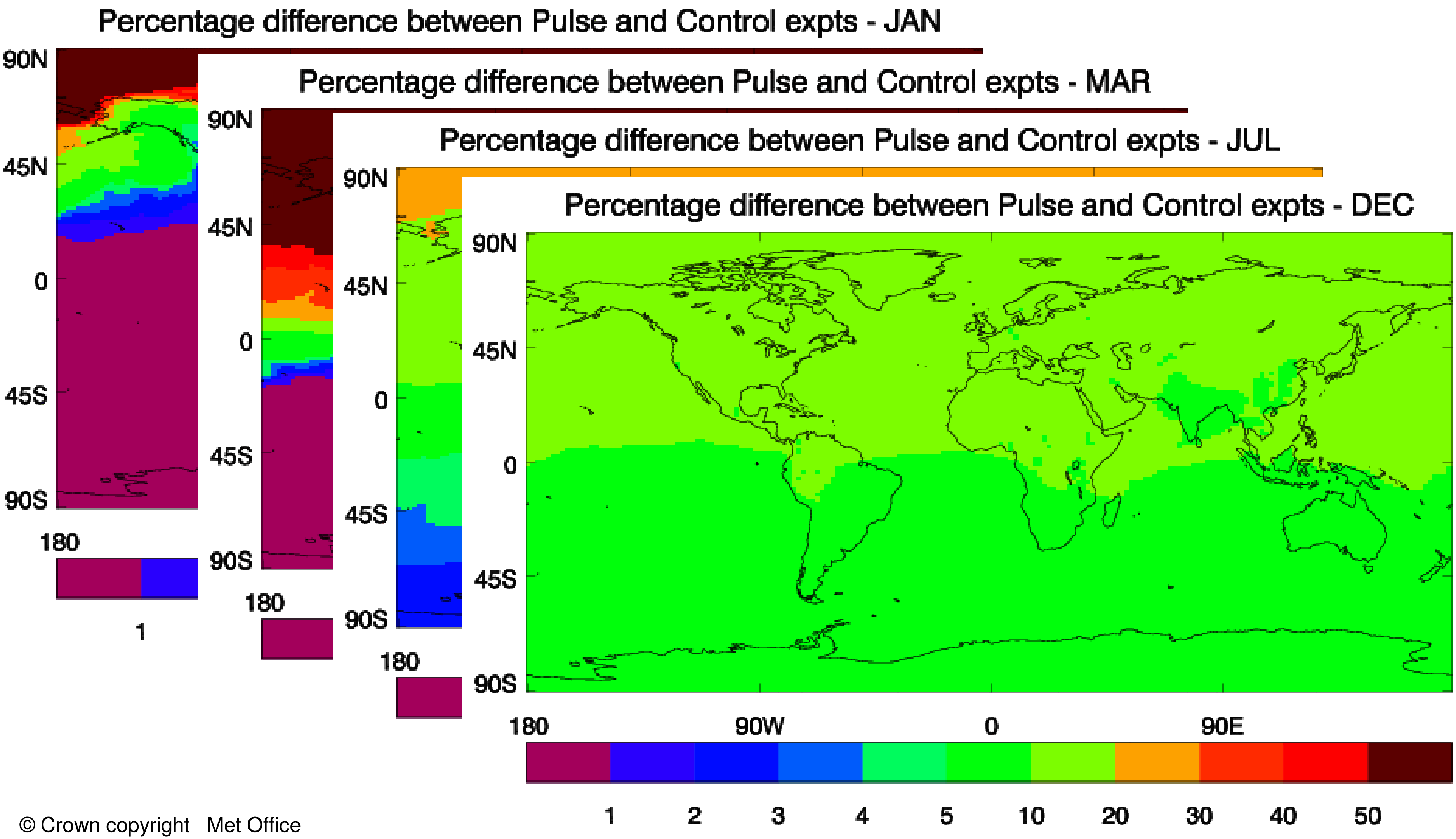
Atmosphere-only version of HadGEM2-ES using Yr-2000 AR5 ems (526 $TgCH_4$/year)

Small pulse: ~ 50 $TgCH_4$
Large pulse: ~ 500 $TgCH_4$

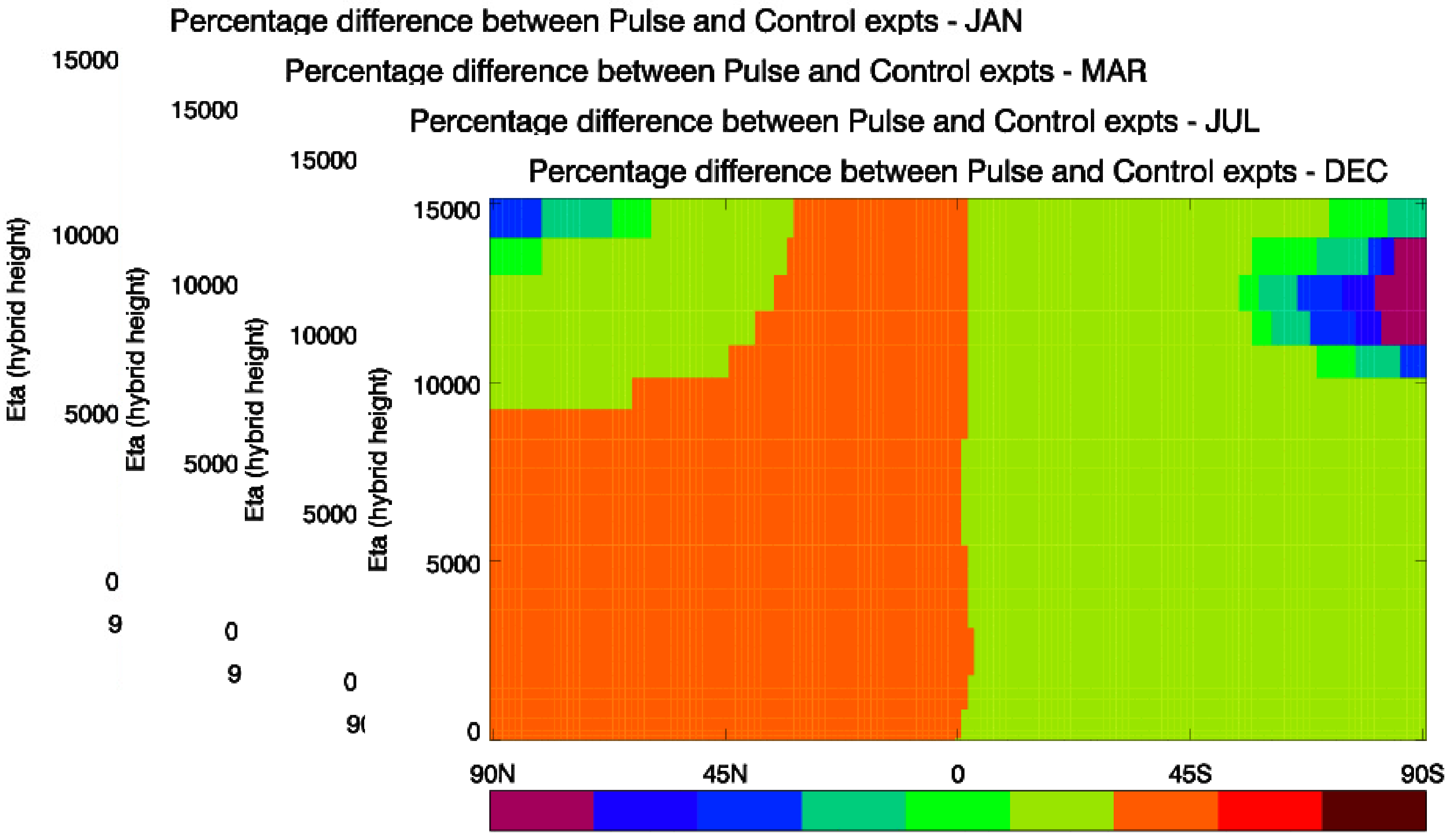
Gas-Phase Chem. Results



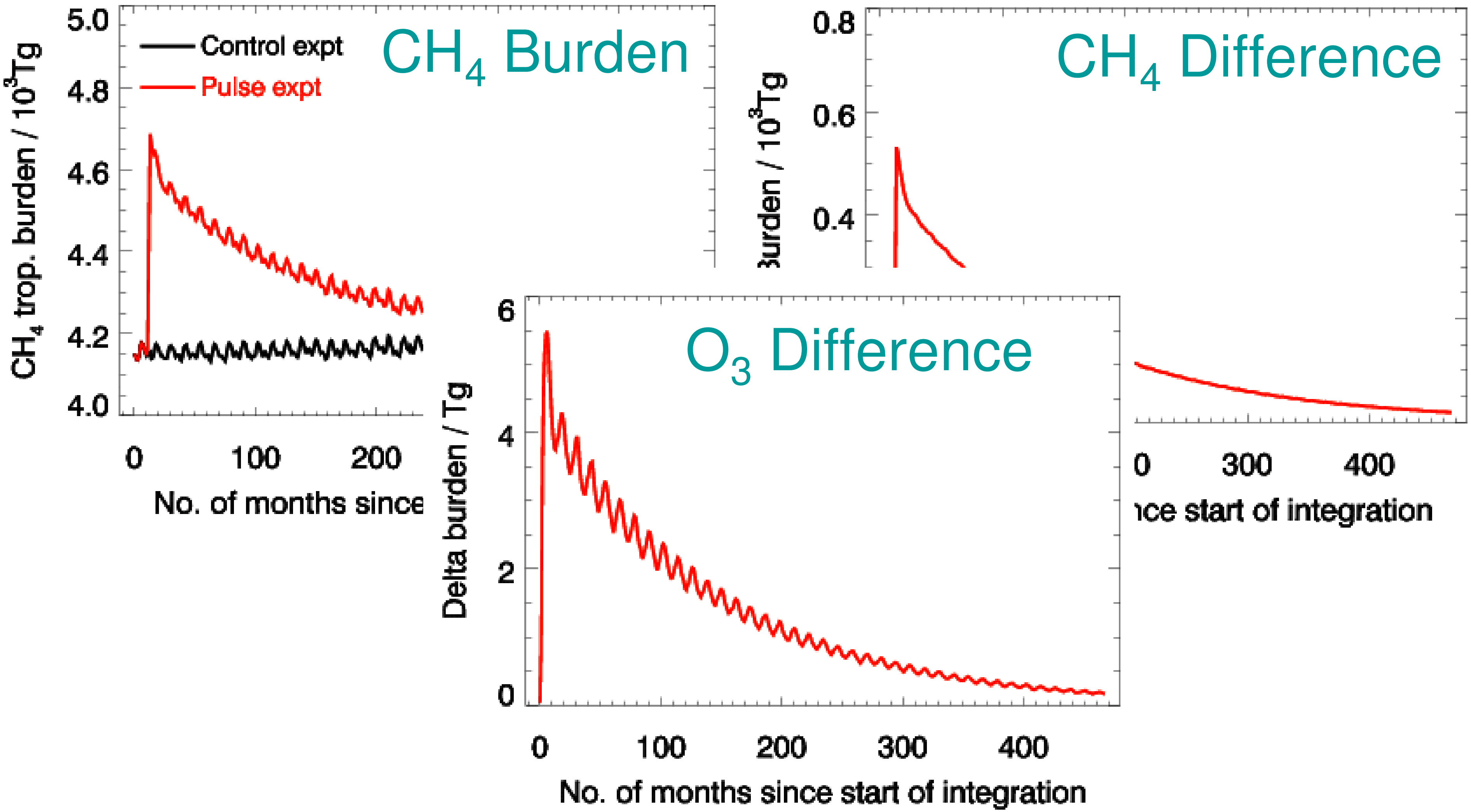
Gas-Phase Chem. Results



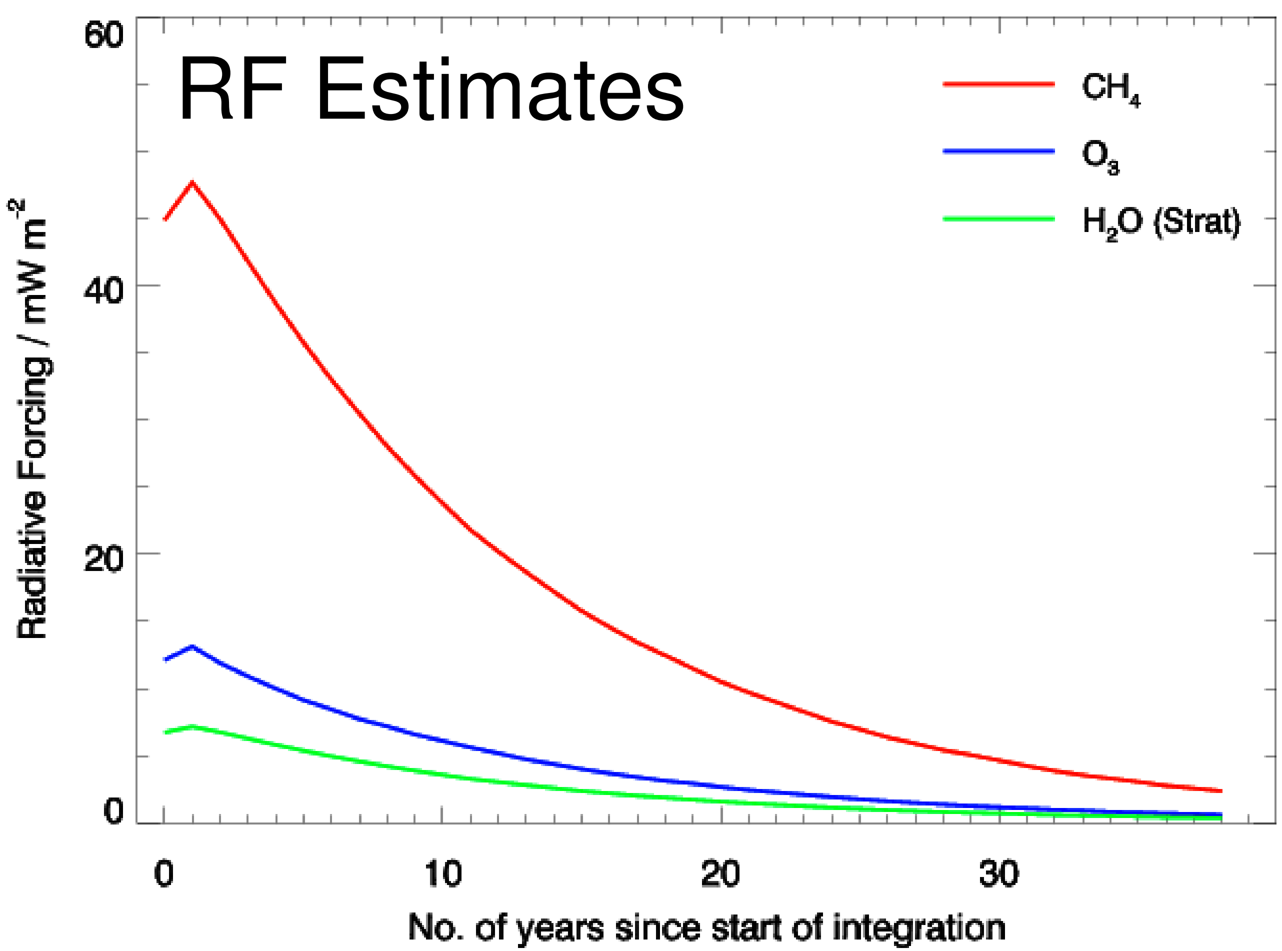
Gas-Phase Chem. Results



Gas-Phase Chem. Results



Gas-Phase Chem. Results



$$GWP_{100yr} = 17.7\ (CH_4) + 4.0\ (O_3) + 2.3\ (H_2O)$$
$$= 24.0$$

Chemistry-Aerosol Coupling: Experimental Setup (2)

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

Coupling between gas-phase chemistry and sulphate aerosol is on

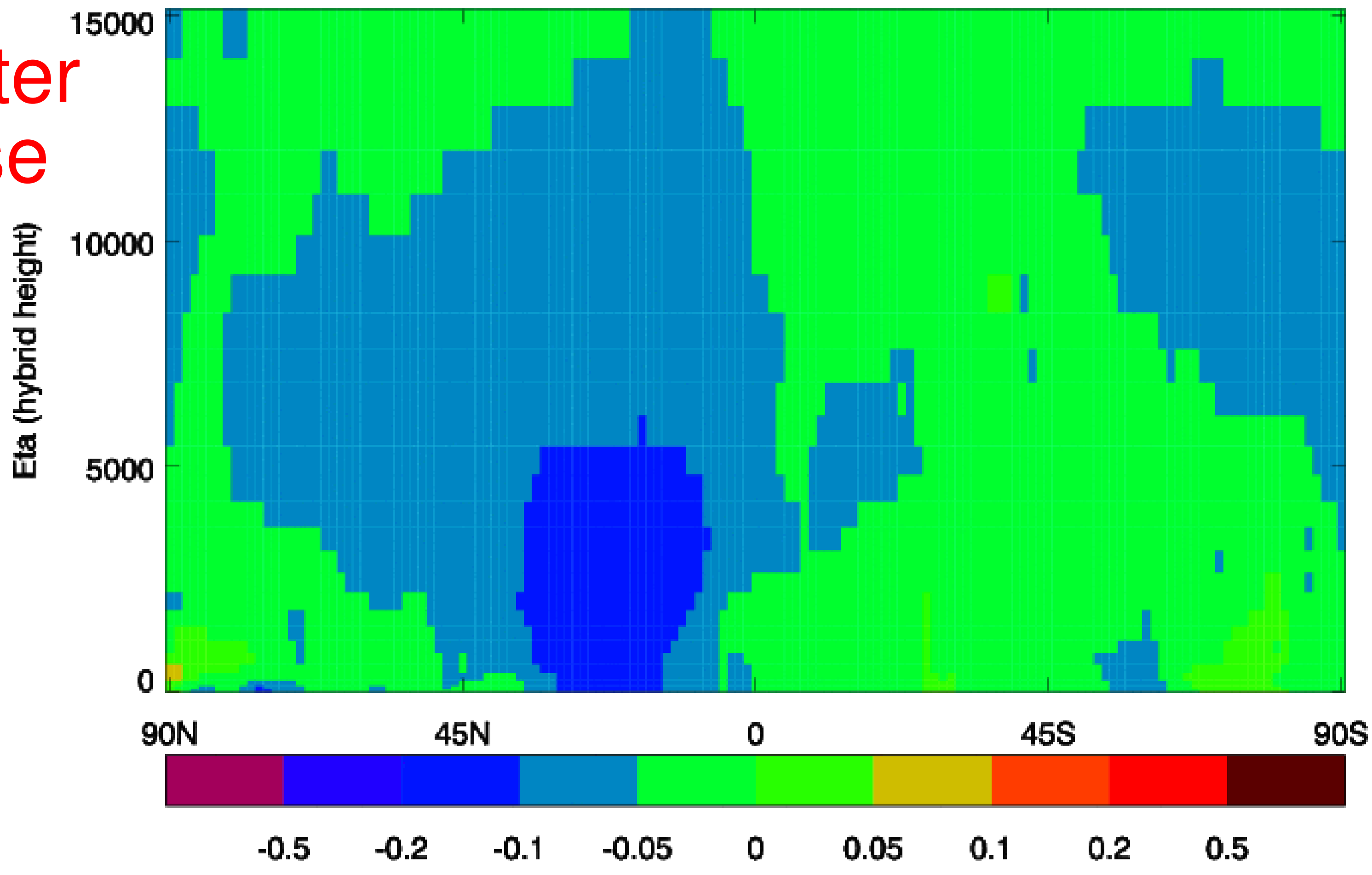
Atmosphere-only version of HadGEM2-ES using Yr-2000 AR5 ems (526 $TgCH_4$/year)

Small pulse: ~ 50 $TgCH_4$

Chemistry-Aerosol Results

Reduction in Accum. mode sulphate aerosol

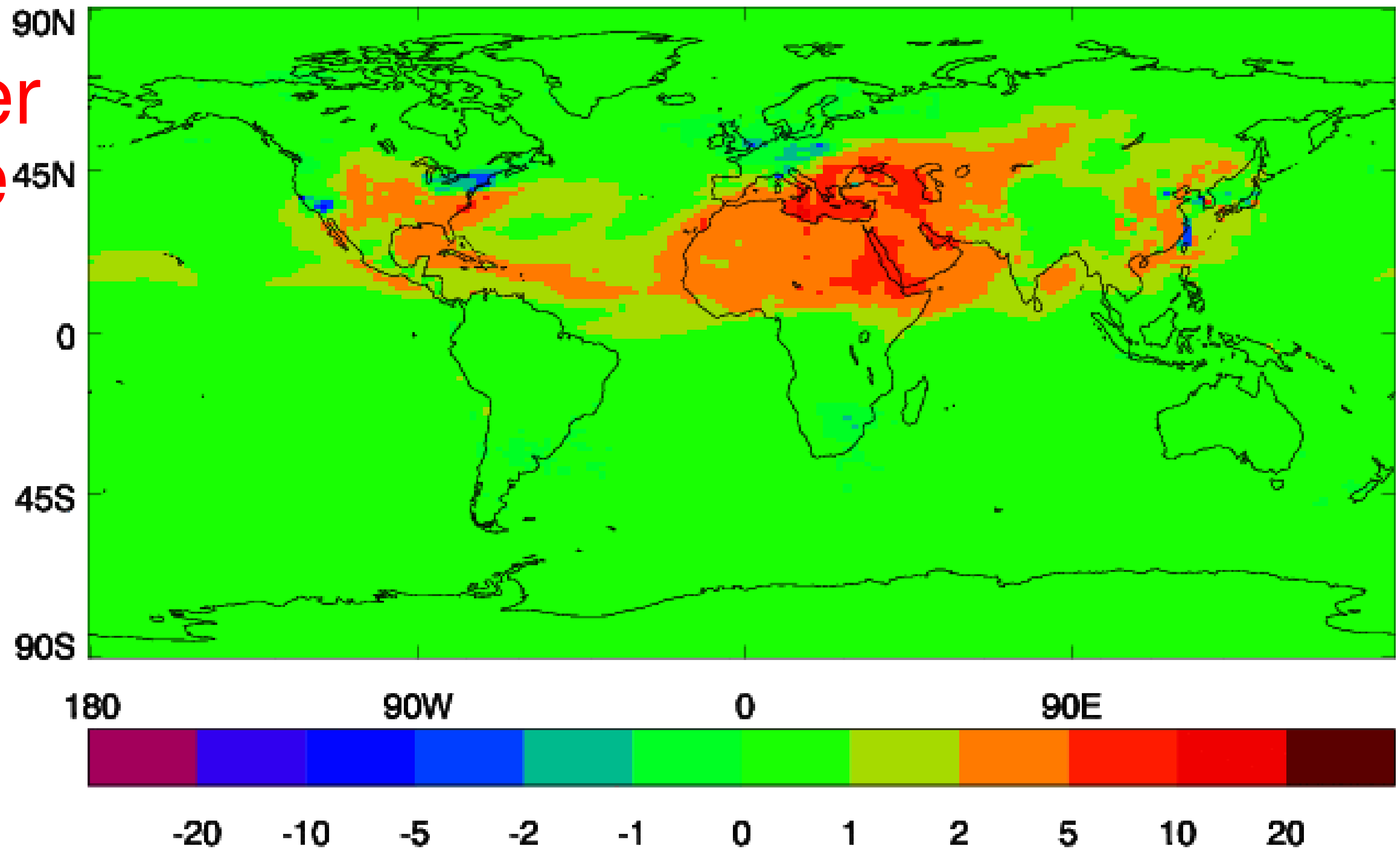
JUL:
6 mths after
CH_4 pulse



Chemistry-Aerosol Results

JUL:
6 mths after
CH_4 pulse

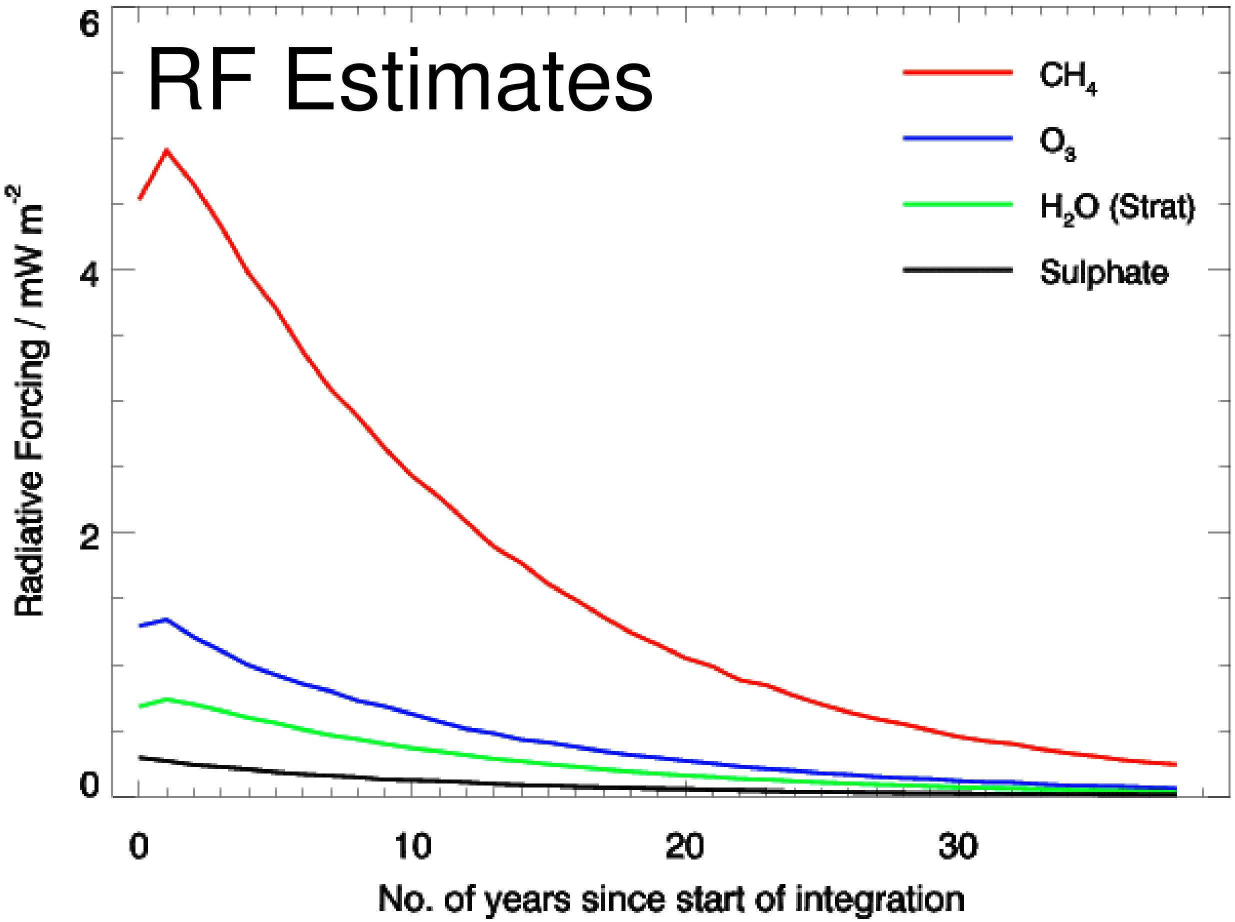
SW All-sky TOA forcing (mW/m^2)



Global mean TOA forcing = 0.64 (mW/m^2)

Chemistry-Aerosol Results

50 Tg pulse



$$GWP_{100yr} = 17.7 + 4.0 + 2.3 + 0.8 \text{ (direct effect)}$$
$$= 24.8$$

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 x 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_2O)

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 ems on sulphate 1^{st} indirect effect
- Impact of CH_4 ems on nitrate aerosol

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Thank you for listening!
Any questions?