Convention on Long-range Transboundary Air Pollution

emep

Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Meteorological Synthesizing Centre - West (MSC-W)

Norwegian Meteorological Institute

Impact of background methane & regional and global emission reductions on surface ozone

Willem van Caspel, Hilde Fagerli, Dirk Olivié, Agnes Nyiri & others at IIASA
EMEP/MSC-W, Norwegian Meteorological Institute

Overview

Central questions

1. CH_4 pathways and its impact on regional (European) surface O_3
2. Impact of regional and global emission reductions

In this talk

- IIASA CLE and LOW emission scenarios up to 2050
- Box-model CH_4 concentrations
- Global and regional simulations using the EMEP MSC-W CTM

Emission scenarios

Base (CLE) and LOW (MFR + diet changes) scenarios from IIASA

Table 1: Emission totals in the *base* and *low* scenarios. Units are $\mathrm{Tg\,yr^{-1}}$ (units for NOx are in $\mathrm{Tg[NO_2]\,yr^{-1}}$).

Species	Scenario	2015	2020	2025	2030	2035	2040	2045	2050
NOx	base	116.733	108.108	103.199	99.557	98.353	99.741	100.843	102.766
NOx	low			96.709	72.091	50.457	31.333	28.489	25.479
VOC	base	109.639	108.605	108.009	106.493	106.244	106.106	107.054	108.001
VOC	low			82.816	63.786	52.607	40.325	38.682	37.975
CO	base	520.696	478.156	452.961	431.273	422.837	416.719	413.736	412.045
CO	low			311.963	202.579	162.562	111.974	108.771	107.165
CH_4	base	337.869	348.738	363.545	374.668	388.444	404.783	419.621	431.086
CH_4	low			231.155	219.031	208.302	202.947	195.578	168.966

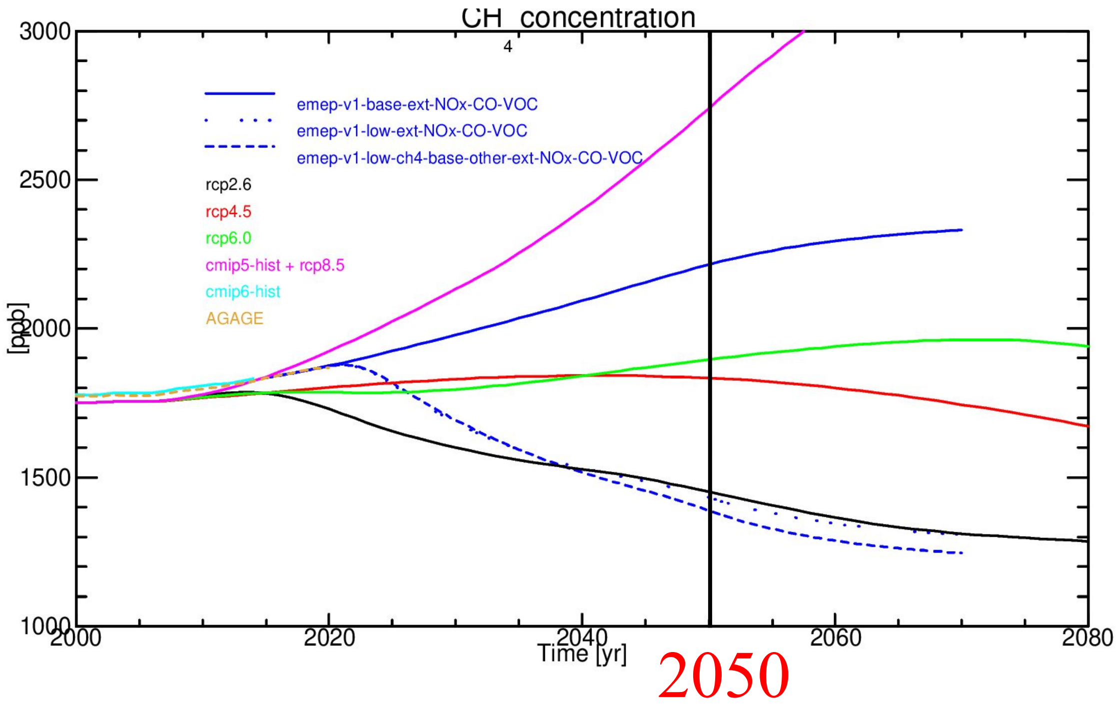
Anthropogenic CH_4 emissions reduced by 50% relative to 2015, 60% relative to 2050 CLE

Background CH_4 pathways

Natural $CH_4 \approx 240$ Tg/yr by tuning to observed 2015-2019 global average

	CLE	LOW	LOW CH_4 only
2015	1834	1834	1834
2030	1979	1683	1692
2050	2215	1431	1389
2070	2331	1307	1245

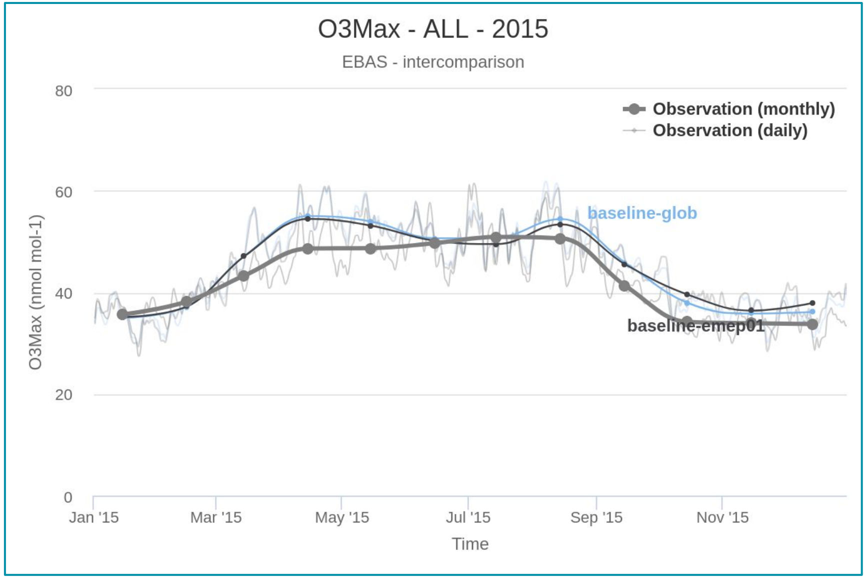
~10% decrease from 2050 to 2070 when 2050 LOW emissions are continued



Norwegian Meteorological Institute

EMEP MSC-W model

- Global 0.5° x 0.5° and regional (nested) 0.1° x 0.1° EMEP domain simulations
- 2015 meteorological year based on IFS, including 100 hPa O_3 BC
- Annual mean background [CH_4] specified in the chemistry



N = 138 EU stations from the EBAS dataset vs. global and regional EMEP models

Nearly identical O_3 results between the coarse and fine grids

Impacts of CH_4 and other emission reductions compared to 2015 (base)

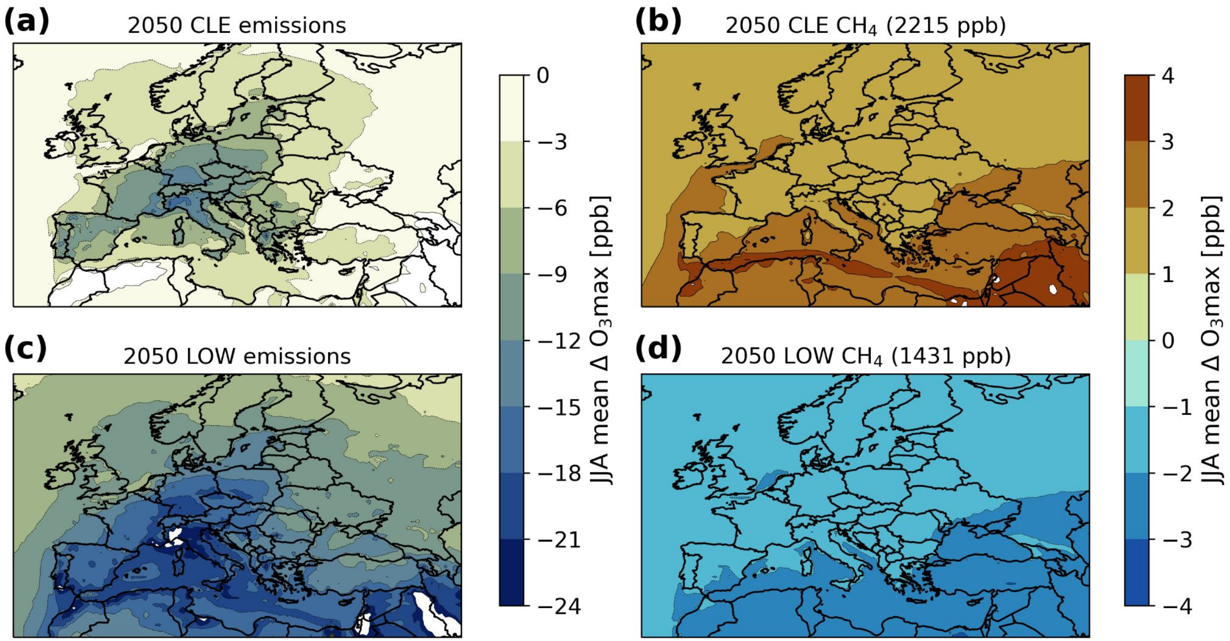
Global simulations for JJA O_3max

(a) {BaseEm,BaseCH_4} - {CLE2050,BaseCH_4}

(b) {CLE2050,BaseCH_4} - {CLE2050,CLE2050CH_4}

(c) {BaseEm,BaseCH_4} - {LOW2050,BaseCH_4}

(d) {LOW2050,BaseCH_4} - {LOW2050,LOW2050CH_4}



By 2050 compared to present day:
Global LOW: 6-24 ppb
CH_4: 1-2 ppb

Note the different colour scales
Baseline CH_4 = 1834 ppb

Norwegian Meteorological Institute

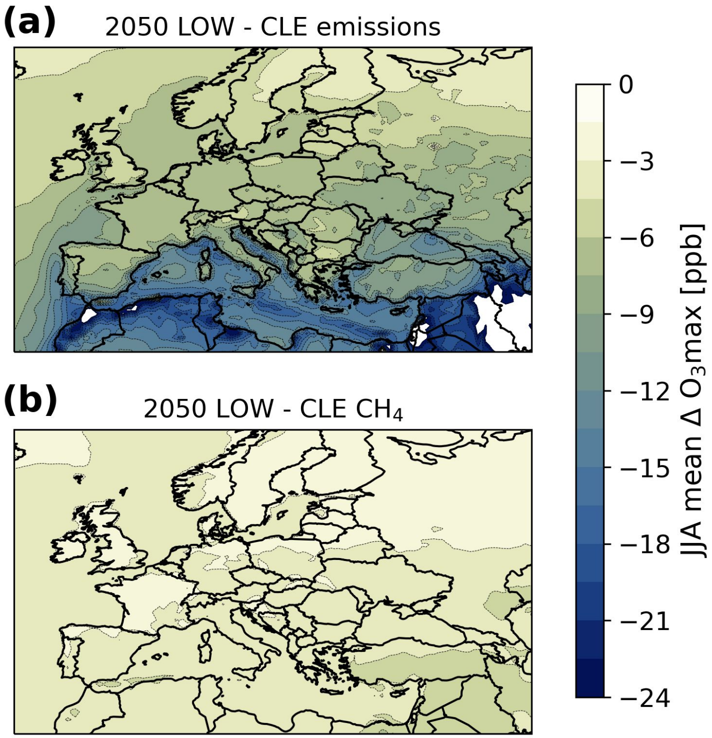
Impacts of LOW emission reductions and CH_4 relative to 2050 CLE

Global simulations

(a) {CLE2050,CLE2050CH_4} - {LOW2050,CLE2050CH_4}

(b) {LOW2050,CLE2050CH_4} - {LOW2050,LOW2050CH_4}

784 ppb difference between LOW (1431) and CLE (2215) CH_4

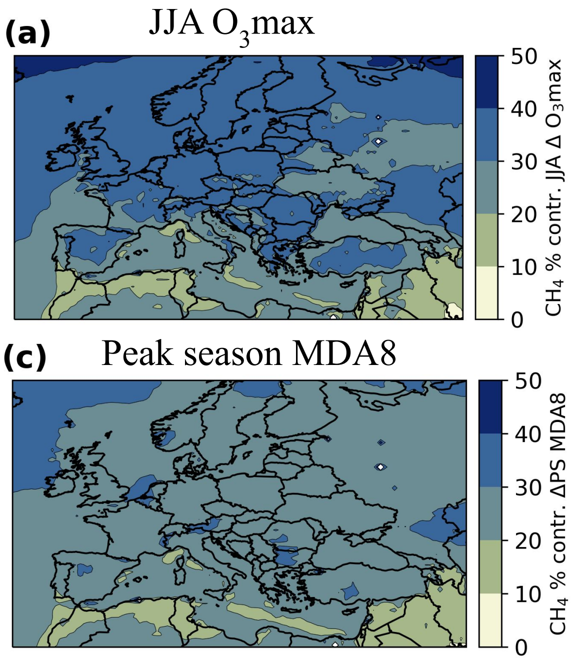


Compared to 2050 CLE, LOW scenario EU O_3max reductions ⅔ from emission reductions, ⅓ from CH_4

Relative impact CH_4 on O_3 reductions compared to 2050 CLE

Percentage total O_3 reductions due to CH_4 relative to 2050 CLE

a. JJA O_3max
c. Peak season MDA8



~⅓ contribution of CH_4 in total reductions relative to 2050 CLE

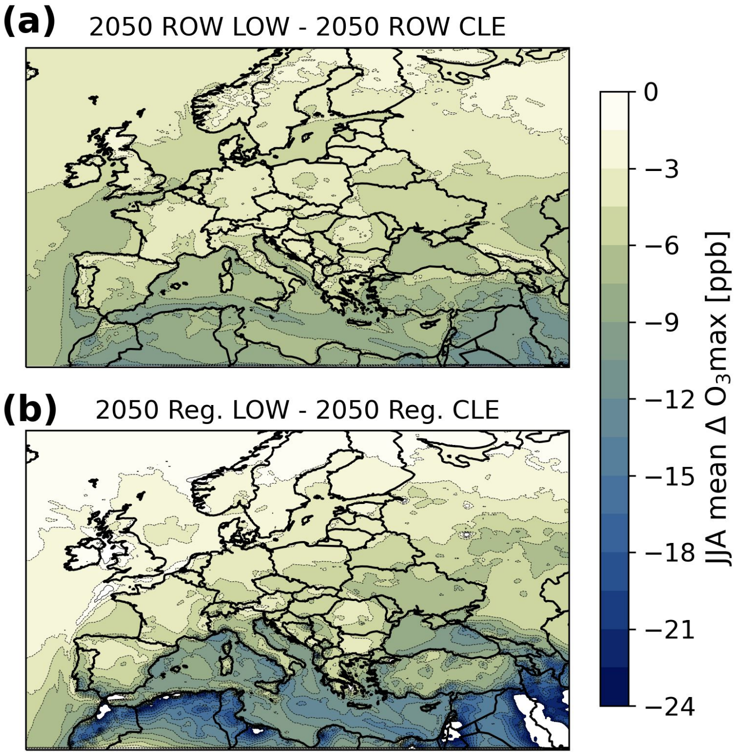
Norwegian Meteorological Institute

European and non-European mitigation by 2050

Regional (Reg) EMEP domain with nested (Nest) BCs from LOW & CLE global runs for 2050

(a) {LowNest,BaseReg} - {BaseNest,BaseReg}

(b) {LowNest,LowReg} - {LowNest,BaseReg}

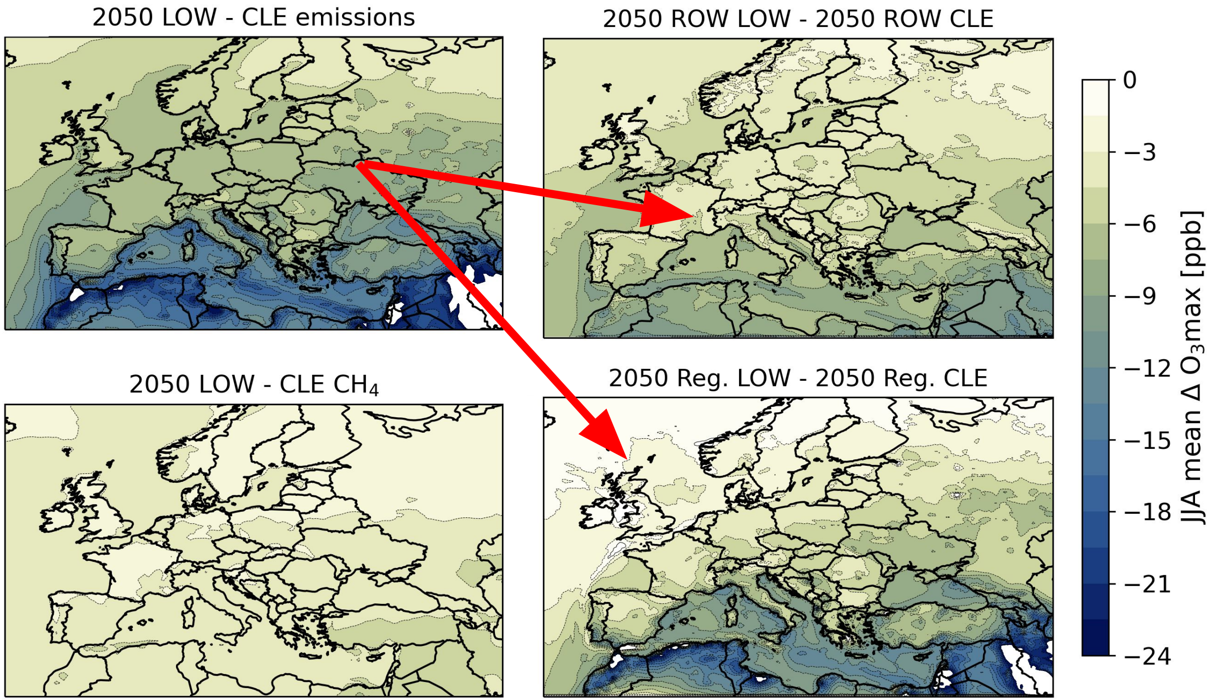


Norwegian Meteorological Institute

Relative O_3max (JJA) impacts

Compared to 2050 CLE, effect of CH_4 mitigation on JJA O_3 max of the same magnitude as LOW ROW and LOW Europe

Comparing to present day (2015), global LOW is much more important and CH_4 less important

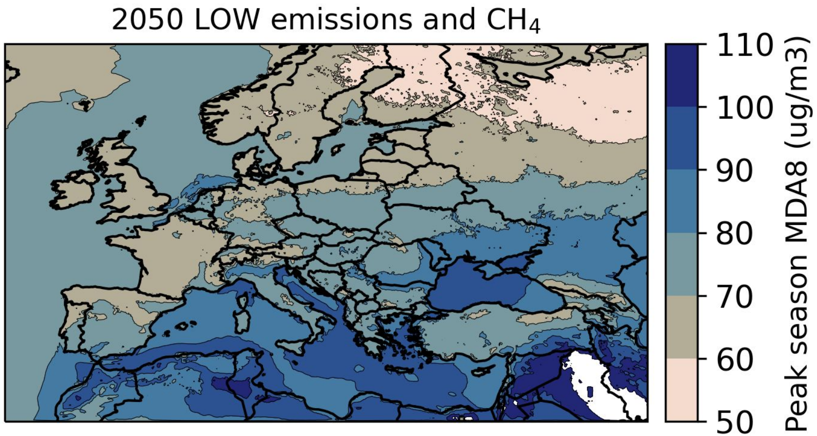


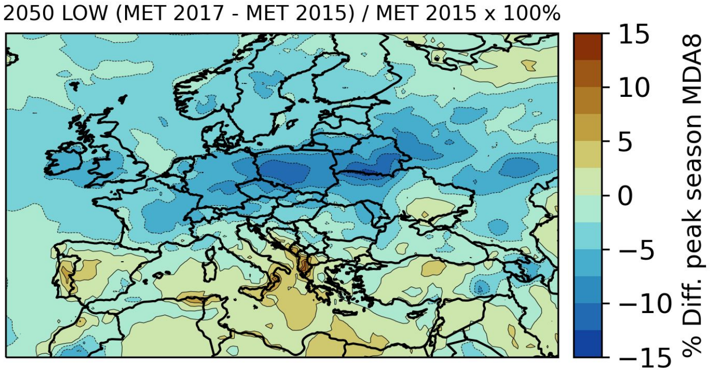
Norwegian Meteorological Institute

Peak season MDA8 in 2050 LOW

Regional model with LOW emissions + LOW BCs and LOW CH_4 (1431 ppb)

WHO guidelines not met in the 2050 LOW scenario





Meteorological year?

Norwegian Meteorological Institute

Conclusion

50% *CH_4 emission reduction* relative to 2015 reduces background CH_4 by 22% (~400 ppb) by 2050 relative to 2015 (1834 ppb), but by 35% (~800 ppb) relative to 2050 CLE (2215 ppb)

Results for 2050 European surface O_3

- Relative to present day, the impact of CH_4 is small compared to the impact of emission reductions
- JJA O_3max reductions between CLE and LOW are ~⅓ due to CH_4 and ~⅓ due to both ROW and regional non-CH_4 emission reductions

Policy on CH_4 is important for further reducing projected surface O_3 concentrations

Challenges

- Natural CH_4 emissions are uncertain (100-300 Tg/yr), as are anthropogenic CH_4 emission projections
- Feasibility of the CLE scenario
- Inter-model variability in CH_4 response
- Impact of meteorological year → Climate change?

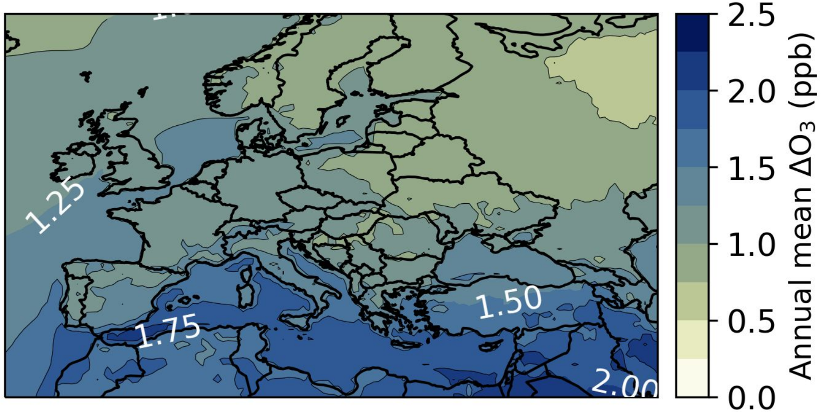
Norwegian Meteorological Institute

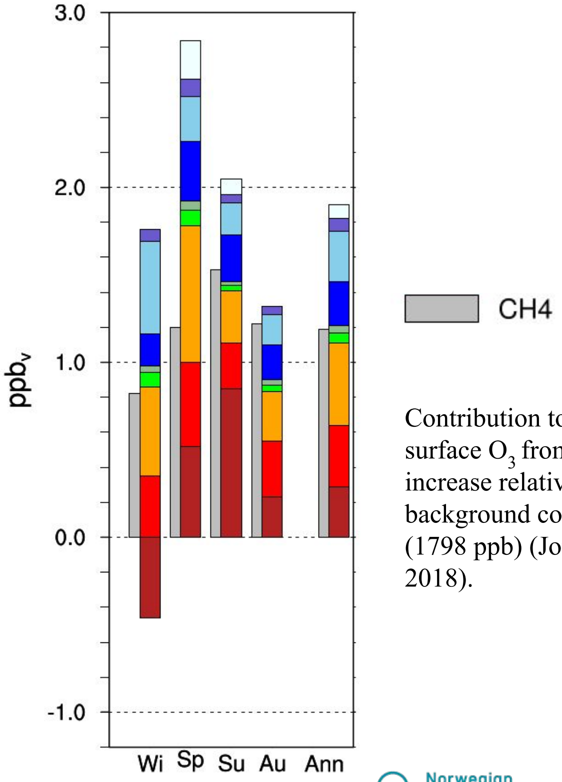
Extra slides

Comparison to earlier work

Jonson *et al.* (2018) reported annual mean 1.2 ppb surface O_3 increase over Europe with 20% CH_4 increase (~400 ppb)

→ consistent with the current model setup shown below {2015 baseline CH_4 x 1.2 - 2015 baseline}



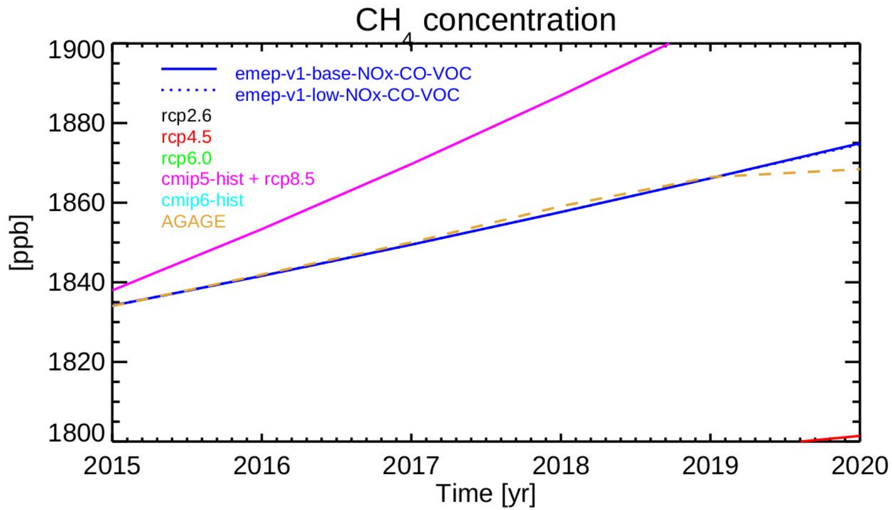


(a) EMEP_rv48

Contribution to European surface O_3 from a 20% CH_4 increase relative to 2010 background concentrations (1798 ppb) (Jonson *et al.*, 2018).

Box-model

- Box-model background CH_4 concentrations for CLE and LOW emission scenarios
- Natural $CH_4 \approx 240$ Tg/yr by tuning to observed 2015-2019 global average



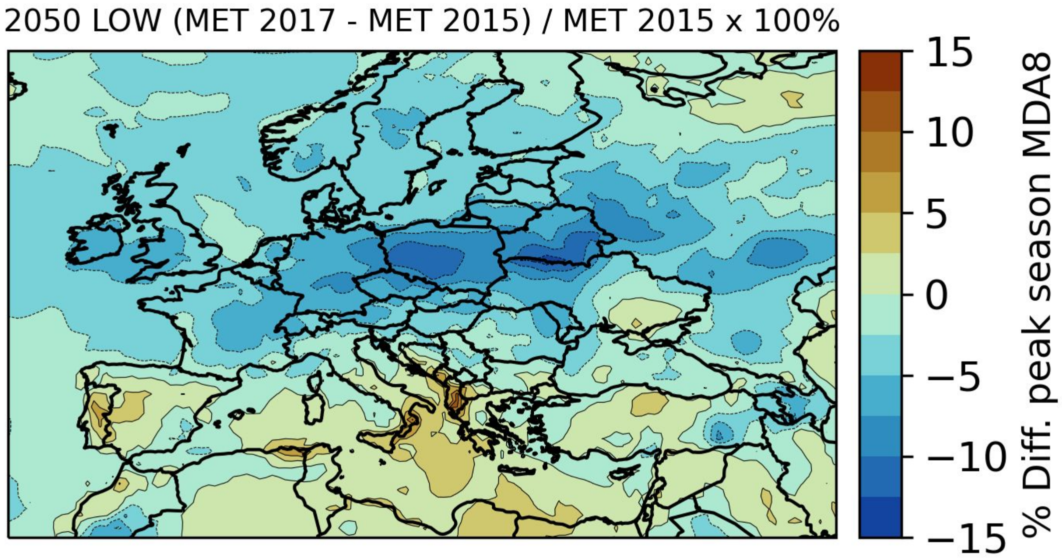
$$\frac{1}{\tau_{CH_4}} = \frac{1}{\tau_{OH}} + \frac{1}{\tau_{strat}} + \frac{1}{\tau_{soil}} + \frac{1}{\tau_{trop-Cl}}$$

$$\frac{\mathrm{d}\,B}{\mathrm{d}t} = -\frac{1}{\tau_{CH_4}} B + E$$

Norwegian Meteorological Institute

Impact meteorology on peak season MDA8

2050 LOW scenario shows considerable peak season MDA8 variability between different meteorological years

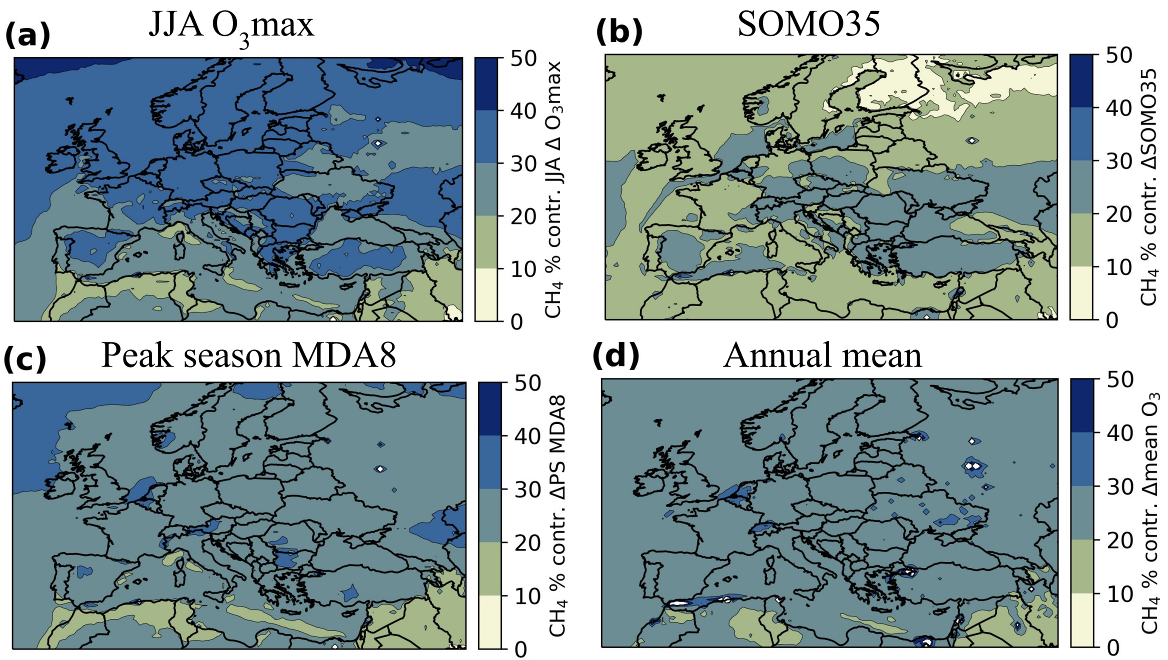


Norwegian Meteorological Institute

Relative impact CH_4 on O_3 reductions compared to 2050 CLE

Percentage total O_3 reductions due to CH_4 for different O_3 metrics

a. JJA O_3max
b. SOMO35
c. Peak season MDA8
d. Annual mean



Generally between 20-40% contribution from CH_4, highest for JJA O_3max

Norwegian Meteorological Institute