Summary of current (and future) work on methane as an ozone precursor

Including results from TFHTAP, CCAC, EC-JRC, TFMM/CAMS, MSC-W, and CIAM

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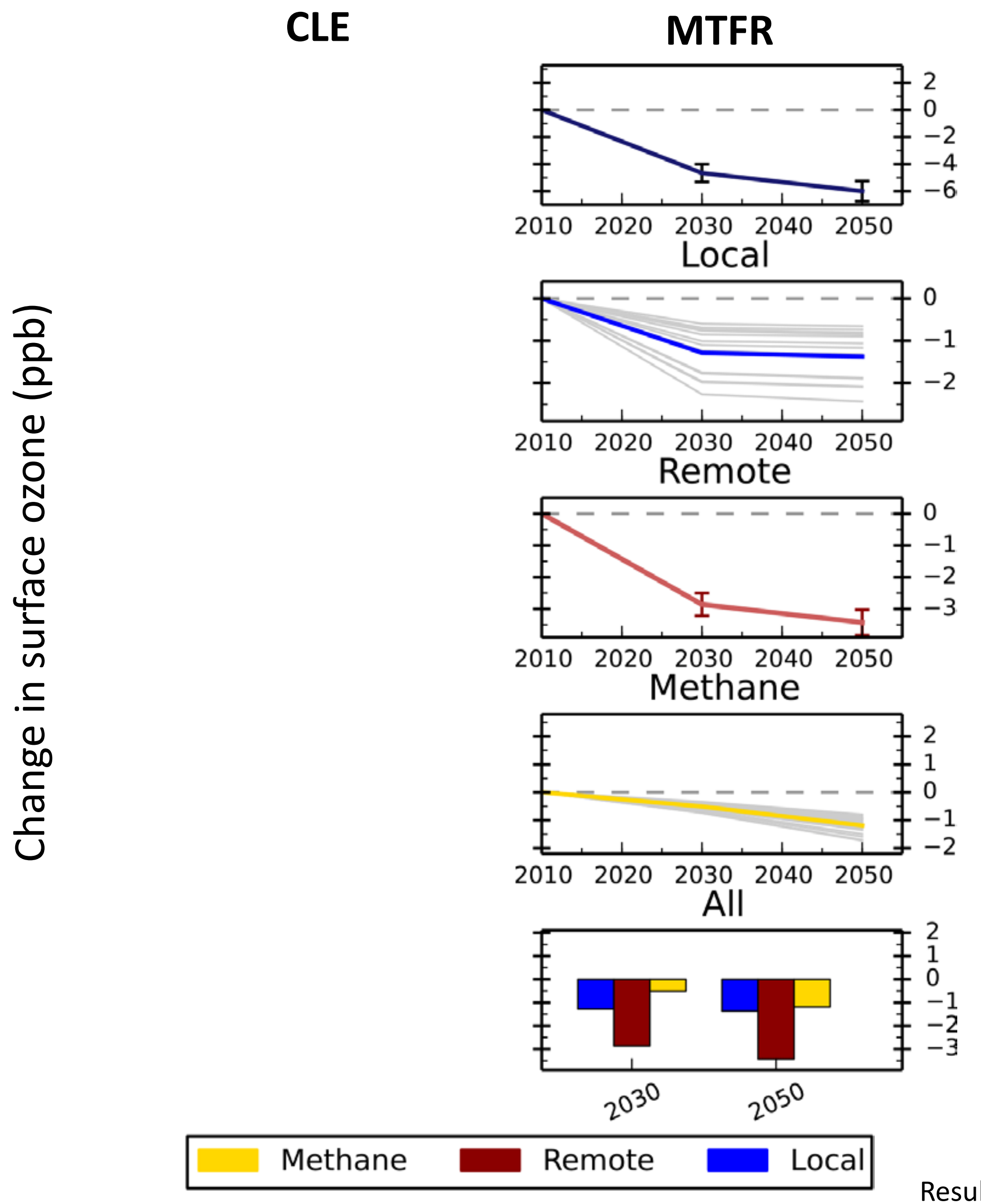
53rd meeting of the Task Force on Integrated Assessment Modelling
April 16, 2024, Paris

Introduction

- A large body of work over the past ~20 years has shown the importance of methane as an ozone precursor
- Recent work from within and outside the Convention on the relevance of methane for achieving the Convention's goals is difficult to synthesise:
  - Different emission scenarios
  - Different modelling approaches
  - Different base years
  - Different impact metrics
  - Etc…
- This presentation identifies common messages from the five most relevant studies since 2018
  - TFHTAP, CCAC, EC-JRC, TFMM/CAMS, MSC-W, and CIAM
- Key questions:
  - What is the impact of methane on ground-level ozone in the UNECE region compared with the impact of NOx and NMVOC?
  - How big is the potential of methane emission reductions in the UNECE region to reduce ground-level ozone compared with methane emission reductions in the rest of the world?
  - What future work is needed to quantify the influence of all ozone precursors and inform the negotiations on the potential revision of the Gothenburg Protocol?
  - What additional scenarios would be useful to perform this work?

TFHTAP contribution to the review of the Gothenburg Protocol (2021)



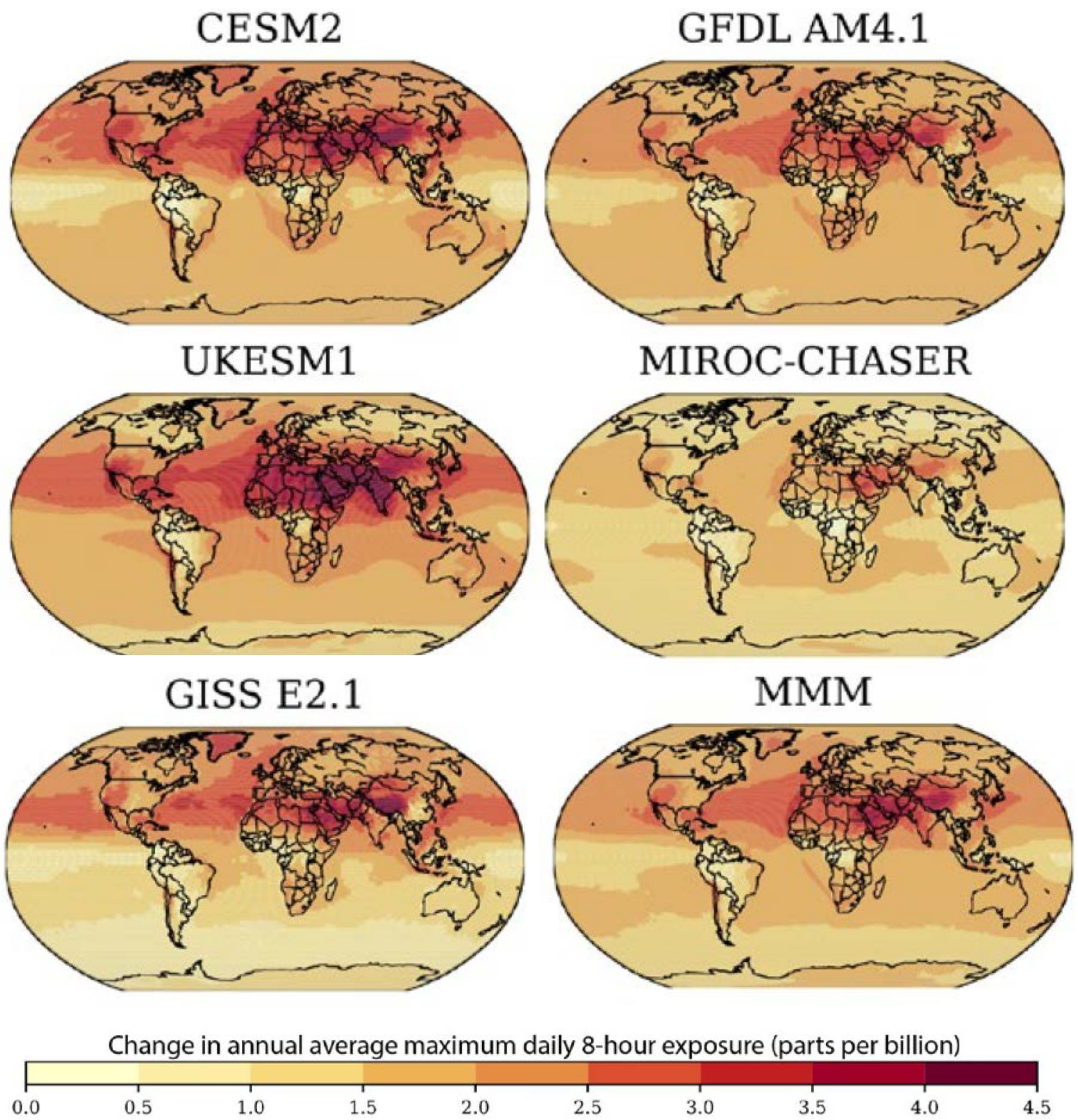
- Annual average surface ozone in Europe
- Ensemble of 14 global chemical transport models

- ECLIPSE 5a scenarios
  - CLE: global increase in methane offsets effects of European NOx/NMVOC controls on surface ozone
  - MTFR: large reductions in surface ozone due to combined effects of methane, local NOx/NMVOC and remote NOx/NMVOC
- What if: MTFR for NOx/NMVOC but CLE for methane?
  - Possibly a 30-50% smaller reduction in 2050 ozone for Europe

- Significant inter-model spread
  - Range in the methane response is similar to the magnitude of the response
  - This shows the importance of using a large ensemble of models

Results from Turnock et al. (2018) https://doi.org/10.5194/acp-18-8953-2018

UNEP/CCAC Global Methane Assessment (2021)



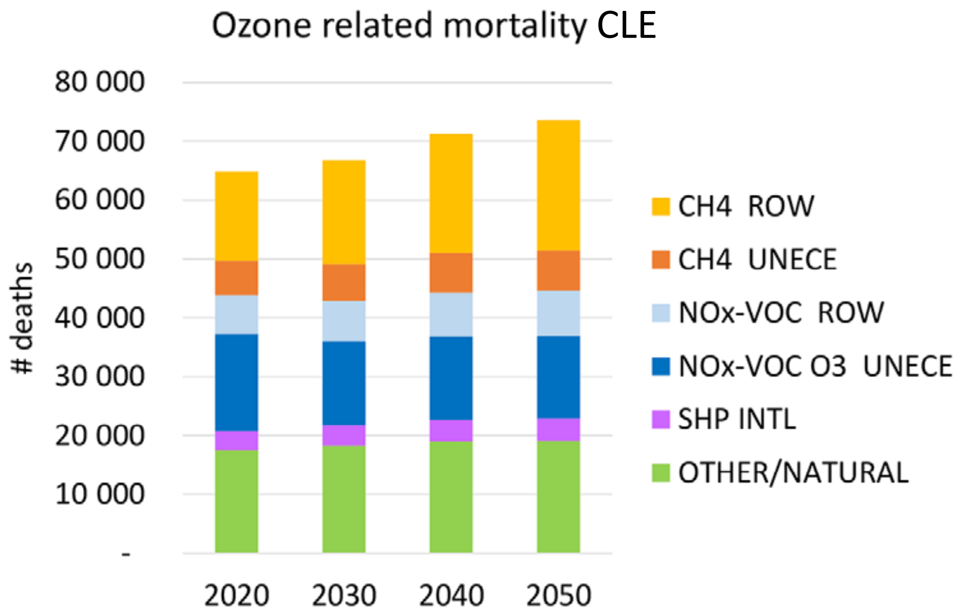
- Annual average global MDA8
- Ensemble of 5 global chemistry-climate models

- 50% reduction in global anthropogenic methane emissions
    - Corresponds to a 30% reduction in methane concentration
- NOx/NMVOC held constant at 2015 levels
- Ozone response in Europe (Germany): 3-6 ug/m3

- Range in the ozone response due to model spread
    - This shows the importance of using a large ensemble of models

Based on Fig. 3.2 of https://www.ccacoalition.org/resources/global-methane-assessment-full-report

Results from the European Commission JRC (2023)

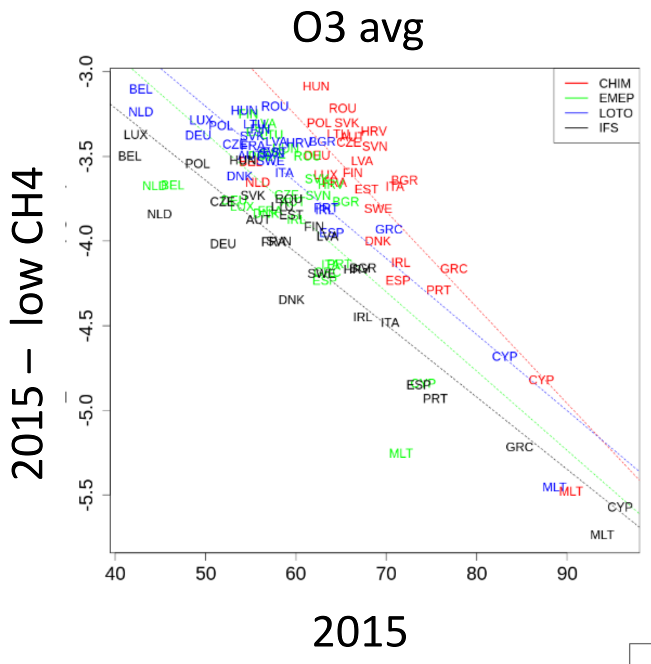


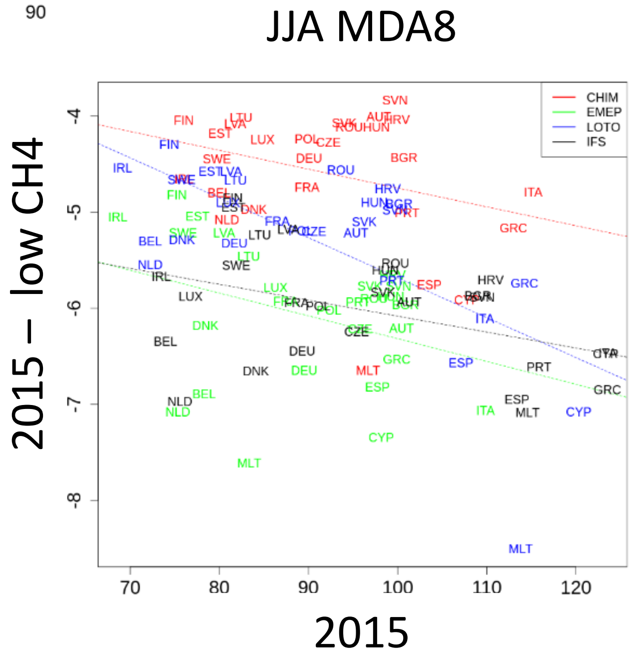
Ozone related mortality MFR - CLE

- Ozone related mortality in UNECE (incl. N.Am.)
- Results from TM5-FASST
  - Single model (TM5): no assessment of model spread
- ECLIPSE 6b scenarios
  - CLE: ozone-related mortality increases due to ROW methane
  - MFR: large reductions in ozone-related mortality due to combined effects of methane, local NOx/NMVOC and remote NOx/NMVOC
- Role of methane:
  - About half of the difference in ozone related mortality between CLE and MFR is attributed to methane
  - The UNECE (incl. N.Am.) contribution to the required methane reductions is small

Based on Figs. 4 and 9 of Belis and van Dingenen (2023) https://doi.org/10.5194/acp-23-8225-2023

Results from TFMM/CAMS71 (2023)

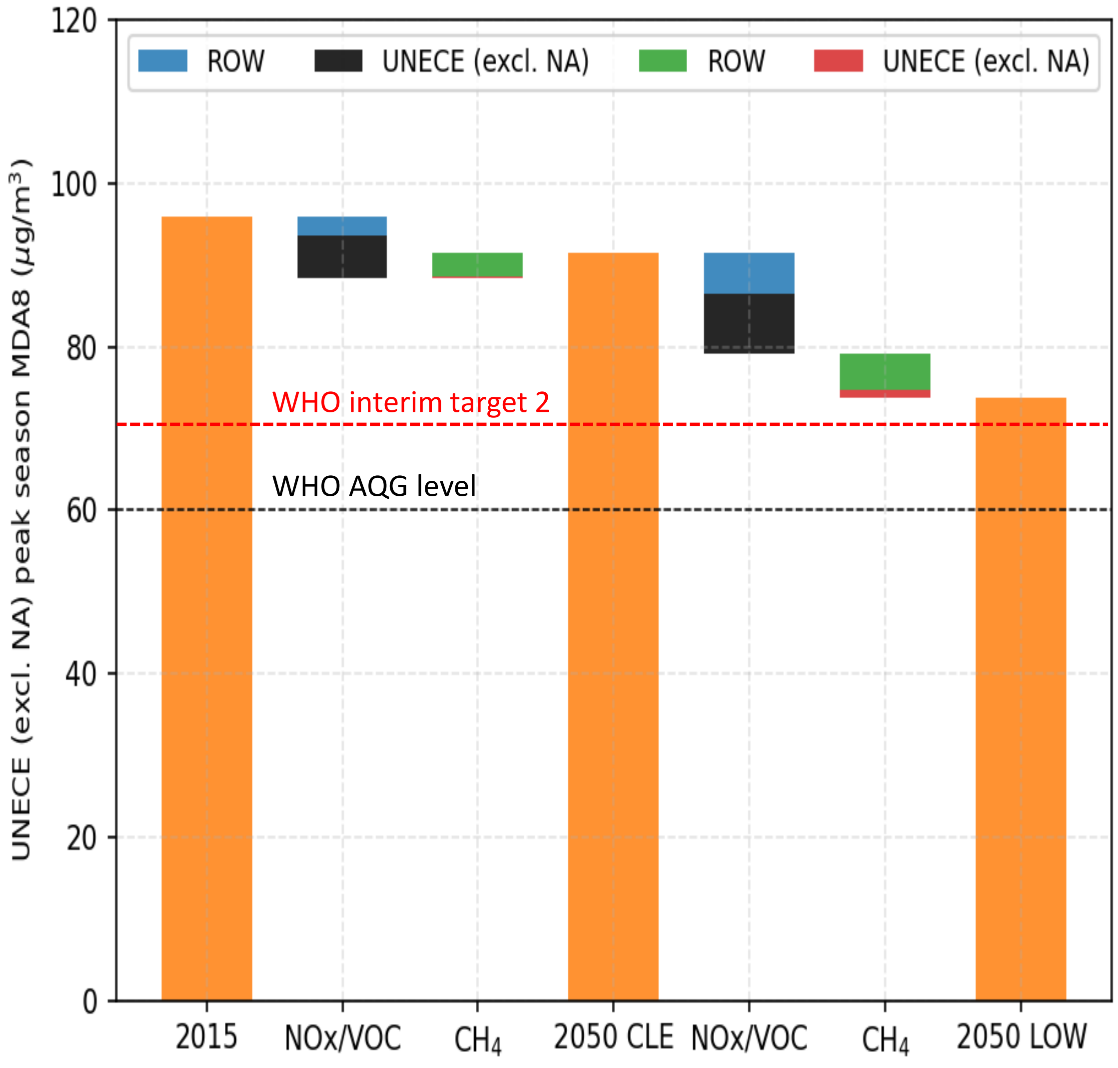




- Setup
  - Ensemble of 3 regional chemical transport models
  - Boundary conditions from a single global model
  - CH4: scenarios: -30% conc. 2050 compared to 2015
  - O3 annual avg and peaks (summer average MDA8)
- Results
  - 30% of the difference between CLE and MFR in 2050 is due to CH_4, the rest is NOX/VOC (not shown here)
  - The impact of CH4 is larger for ozone peaks than for ozone average in absolute terms, but similar in percentages
- Discussion
  - The model spread is more important for ozone peaks than annual average, emphasizing the need for multi-model approach
  - The overall conclusions are converging: the impact derived from global models for annual mean could apply for ozone peaks

Results from A. Colette, as presented to TFHTAP on 20.04.2023,
https://policy.atmosphere.copernicus.eu/reports/CAMS2_71_2021SC1-1_D4.1.1-2022P2_AQProjections_202211_v1.1.pdf

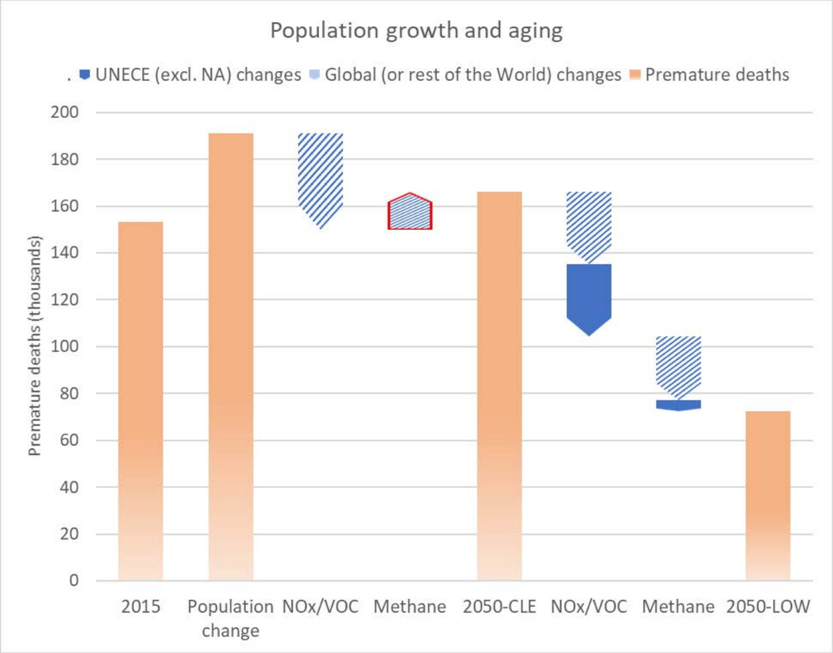
New work from MSC-W (2023)

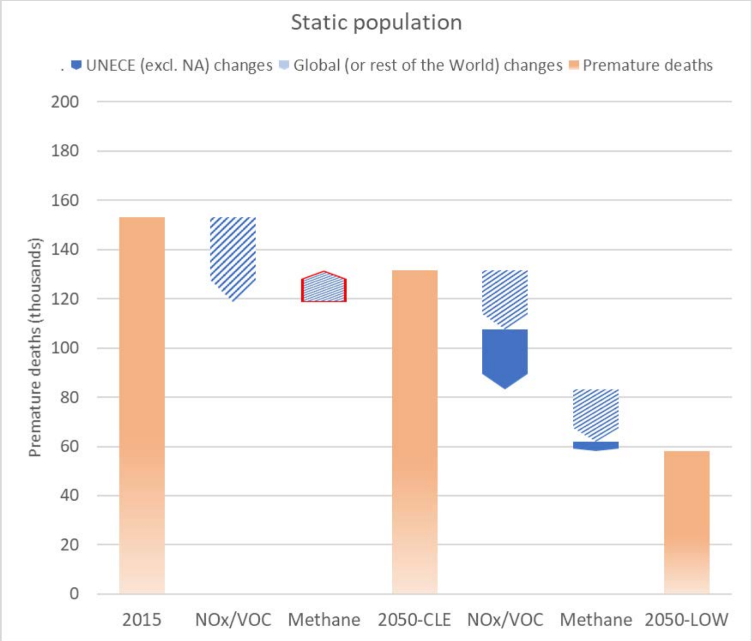


Results from H. Fagerli (personal communication)

- EMEP model run by MSC-W
  - Single model: no assessment of model spread
- New scenarios from GAINS
  - CLE: global increase in methane offsets effects of NOx/NMVOC controls on surface ozone
  - LOW: large reductions in surface ozone due to combined effects of methane, local NOx/NMVOC and remote NOx/NMVOC
- Peak season WHO ozone guideline not attained under any scenario
  - Deep reductions in all precursors required to approach the interim target value
  - UNECE NOx/NMVOC reductions have the largest effect
- Effect of methane:
  - WHO AQG are more difficult to reach without large global methane reductions
  - The UNECE (excl. N.Am.) contribution to the required methane reductions is small

Health impact assessment from GAINS (2023)





- Based on results from MSC-W
- Premature deaths in the UNECE (excl. N.Am.)
- Population changes increase ozone-related mortality in all scenarios
  - Also increases the benefit of 2050 LOW compared with 2050 CLE
- Benefit of 2050 LOW compared with 2050 CLE
  - Largest single contribution: UNECE (excl. N.Am.) NOx/NMVOC
  - Non-UNECE sources (incl. methane) outweigh UNECE sources
  - Methane reductions contribute about 1/3rd
  - UNECE part of the methane contribution is small
- Global cooperation needed to reach this ozone target

Ozone - impact of future emission policy

Action on methane would only be part of the solution; NOx/VOC emission reductions would still be very important to reduce surface O_3

- **Baseline**
  - Average ozone concentrations in Europe will **increase** by 2-5% between 2015 and 2050. Peak season MDA8 will be **reduced** around 5-10%. In both cases, CH_4 emission increase in the baseline scenario hampers the reductions expected from NOx/VOC declines

- **From 2015 baseline to 2050 LOW** (including global 50% CH_4 emission reduction) would:
  - **Reduce** average ozone concentrations by around 15% and peak season MDA8 by around 25%
  - About 20% of the annual mean ozone reduction is driven by reductions in CH_4, compared to only 12% for peak season MDA8
  - For ozone mean, transcontinental non-CH_4 sources dominate over European sources, whilst for peak season MDA8 European non-CH_4 sources dominate

- **The difference between the 2050 CLE and 2050 LOW** scenarios can be attributed to roughly ⅓ from reduction in global methane emissions, ⅓ from reduction in European precursor emissions and ⅓ from reduction of precursor emissions outside Europe, both for ozone mean and peak season MDA8

- CIAM estimates that methane emissions can be reduced (in the UNECE region) by almost 70% between 2015 and 2050, when **dietary change** and livestock reductions are included (2050 LOW scenario)

2050 LOW scenario - Ambitious global action on air pollution and methane, including non-technical measures

Based on TFHTAP/TFMM/MSC-W/CIAM work

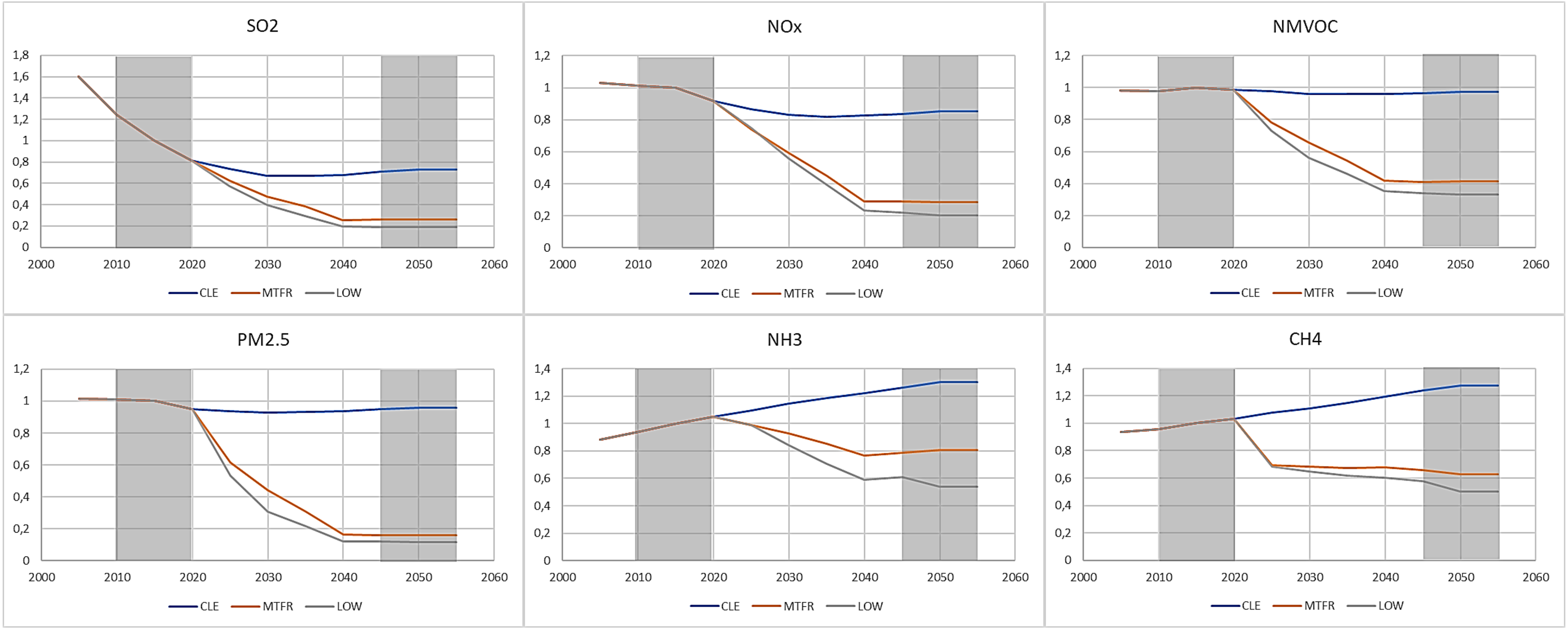
Future work

- A new round of model assessments using the current GAINS scenarios:
  - CLE, MTFR, (LOW)
- Additional scenarios:
  - HILO: A scenario representing high ambition on NOx/NMVOC but low ambition on methane
    - Methane from CLE and other pollutants from MTFR
  - We might also like to consider scenarios with regionally differentiated ambition on NOx/NMVOC/CH4
- Requirements for future quantitative assessments of methane as an ozone precursor:
  - An ensemble of global and regional models, including the EMEP model
  - Consistent experimental setup and output metrics, including impacts
- Relevant items from the 2024-2025 draft workplan
  - 1.1.1.7, 1.1.3.1, 1.1.3.2, 1.1.3.4, 1.1.4.2

Relevant items from the 2024-2025 draft workplan

1.1.1.7	On basis of recent evidence, long-term trends and uncertainty in future projections, provide insight into robustness of modelled long-term O_3 projections in relation to CH_4 mitigation	Synthesis of O_3 mitigation options	TFMM, MSC-W, TFHTAP	EMEP budget
1.1.2.1	Investigate practicalities and processes required for including CH_4 in annual emissions inventory reporting	Status report (2024)	TFEIP, CEIP	Additional resources required
1.1.3.1	Contribute to Gothenburg Protocol revision as mandated by Executive Body	Pending decision by Executive Body in December 2023	TFIAM, CIAM, TFMM, MSC-W, CCC, TFHTAP, CCE	EMEP budget and recommended contributions
1.1.3.2	Support policy process with scenario analyses	Calculation and analysis of scenarios	CIAM, MSC-W, TFHTAP, TFIAM	
1.1.3.4	Integrate knowledge from science bodies in integrated assessment framework and support policy process with scenario analyses	Specification of "optimized scenarios", "optimized and equity scenario", "ozone precursor scenarios", "health in cities scenarios"	CIAM, MSC-W, TFHTAP, TFIAM	Additional resources required
1.1.4.2	Organize new global and regional model simulations of historical trends and future scenarios for Gothenburg Protocol pollutants	Initial findings assessment (2025)	TFHTAP, TFMM	Parties' in-kind contributions
1.2.3	Regular coordination with task forces and expert groups on CH_4, O_3, N	Meeting notes	TFIAM, TFHTAP, TF-Health, TFRN, FICAP	

GAINS LRTAP future scenarios
(total global anthropogenic emissions)



Data from Zig Klimont

Which scenarios?

- Direct assessment of scenarios with an ensemble of global chemistry-climate models is computationally expensive
- Top priority scenarios:
  - CLE and MTFR
  - “HILO”: methane from CLE and other pollutants from MTFR (representing high ambition on “Gothenburg pollutants” and low ambition on methane)
- Additional scenarios for direct assessment (resources permitting):
  - LOW
  - CLE and MTFR with present-day climate (calculation of the climate change impact on future air quality)
- Any number of further scenarios can be rapidly assessed using an *ensemble emulator*

Chemistry-climate simulations

- Transient simulations (2010-2055) with an ensemble (5-10 models) of comprehensive global chemistry-climate models
  - How does air quality evolve in the future under the GAINS scenarios?
  - What is the effect of inaction on methane?
  - What is the future ”climate penalty”?
  - What is the inter-model uncertainty?
  - How well does our scenario emulator work? (see next slide)

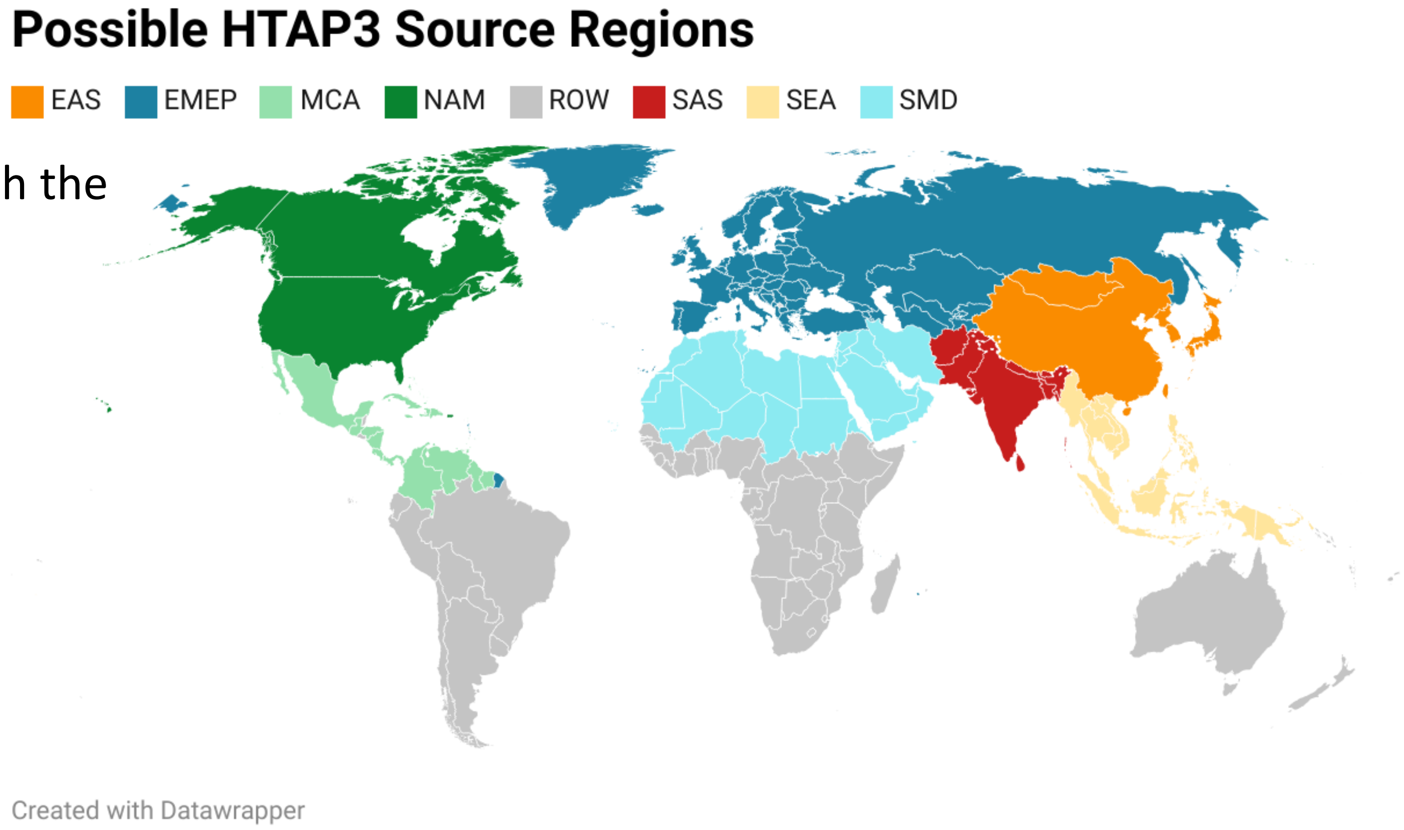
- Focus on calculation of policy-relevant impact metrics
  - Human health
  - Impacts on vegetation

Chemical transport model simulations

- Simulations with an ensemble of 10-15 global CTMs (2015 meteorology)
  - Set of ~25 emission perturbation runs (GAINS 2050 CLE emissions)
    - Source-receptor relationships (with uncertainty estimates)
      - Emulator development

- Rapid assessment of the GAINS scenarios with the ensemble emulator

- Policy-relevant impact metrics



HTAP3: Current set of requested CTM perturbation runs

Highest Priority	1
Next Priority	
Lower Priority	

Priorities for HTAP3 Simulations		**2015 meteorology / 2050 emissions**
Base (CLE 2050 emissions)	BASE (CLE 2050)	1
Global Perturbations		
Increase CH4 Conc	CH4INC	
Decrease CH4 Conc	CH4DEC	1
Decrease CH4 Conc and all anthro emissions	CH4ALL	1
Decrease CH4 Conc and anthro NOx emissions	CH4NOX	
Decrease All anthro emissions	GLOALL	1
Decrease NOX	GLONOX	1
Decrease VOC	GLOVOC	1
Decrease CO	GLOCO	1
Global Scenario Runs		
CLE 2015 emissions	CLE2015	1
MTFR (2050)	MTFR	
HILO (2050)	HILO	
LOW (2050)	LOW	

Regional Emissions Perturbation (2015 meteorology, 2050 CLE emissions)		All	NOX	VOC	CO	SO2	NH3	PM
N America	NAM	1	1	1				
EMEP Domain	EMEP	1	1	1				
EMEP West	EMEPW							
EMEP East	EMEPE							
East Asia	EAS	1	1	1				
South Asia	SAS	1	1	1				
South and East Mediterranean	SMD	1	1	1				
Middle East	MDE							
North Africa	NAF							
SE Asia	SEA							
Mex/C America/Caribbean	MCA							
Rest of World (SAM+SAF+PAN)	ROW							
South America	SAM							
Southern Africa	SAF							
Aust/NZ/Pacific	PAN							
Shipping	SHIP	1						
Aviation	AVI							

Timing

- HTAP online Task Force meeting April 22-25: finalization of experimental specification
- Final set of scenarios expected by June 2024
- Model simulations expected to begin in July 2024
- Some early model results expected by Spring 2025 (HTAP Task Force Meeting)
- Preliminary analysis by September 2025 (EMEP-WGE Steering Body meeting)
- Remaining model results and further analysis by Spring 2026 (WGSR)
- Final report by September 2026 (EMEP-WGE Steering Body meeting)

Open questions on scenarios

- Will the scenarios for the GP revision process be ready by June 2024?
- Will they contain the same basic set (CLE, MTFR, LOW)?
- Are there any additional scenarios of interest?
- Do we have a common base year? 2015?
- Will the scenarios still branch at 2020?