Climate Impact from Aviation NO_x Emissions and Comparison of Emission Targets with the Objectives of the Paris Agreement

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** WG Lead ECATS
ECATS International Association

DLR

Overview

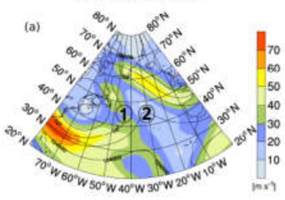
- Weather relatedTransport and chemistry of aviation NO_x-emissions

- Open issues in calculating aviation RF-NO_x
  - Methane temporal mismatch
  - Contribution and perturbation methods

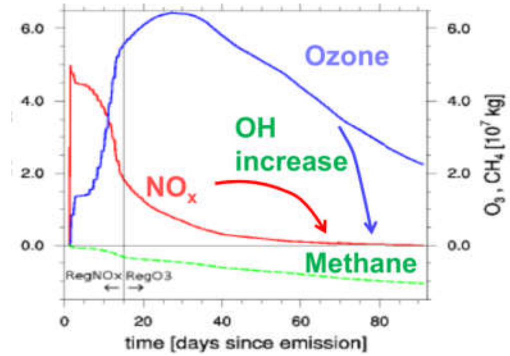
- Flightpath 2050 and the Paris Agreement

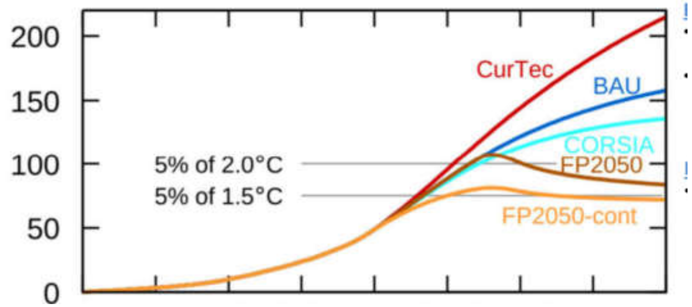
- Conclusion

Weather



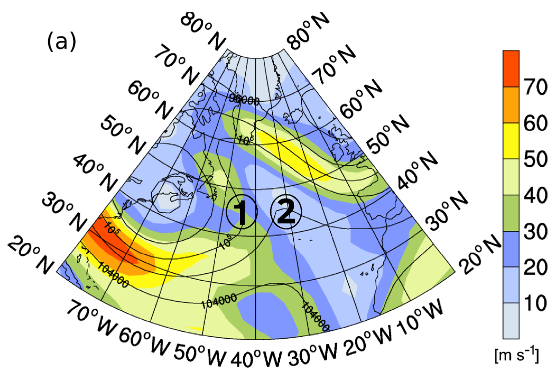
Aviation NOx - RF





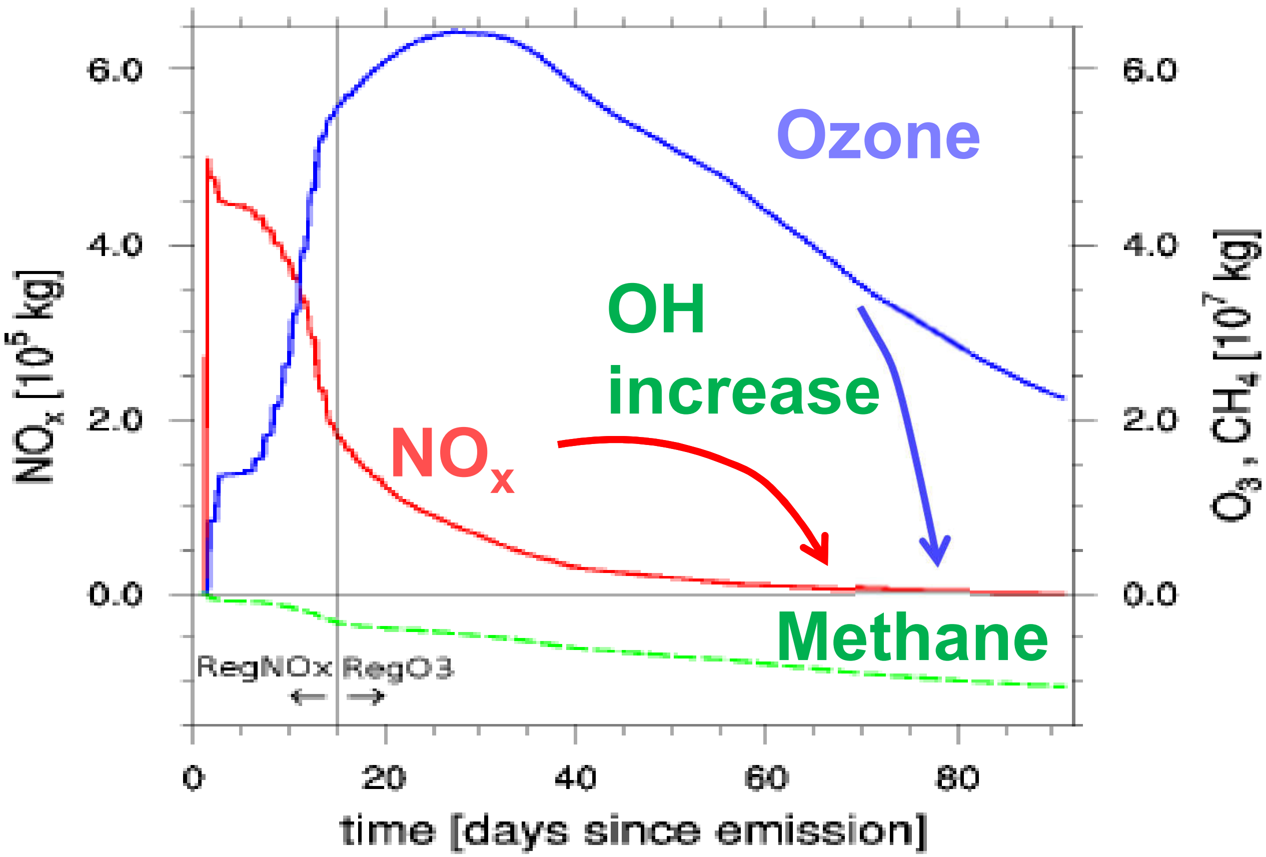
What is the relation between weather and aviation NO_x climate impact?

Weather



Aviation NOx - RF

Well established relation between NO_x-ozone-methane (typical situation)



Different time scales for NO_x, ozone, and methane

Grewe et al. (2017a)

(e.g. Fuglestvedt et al 1999)

$O_3 + H_2O \rightarrow 2\ OH$

$NO + HO_2 \rightarrow NO_2 + OH$

Methane Loss

$CH_4 + OH \rightarrow CH_3 + H_2O$

Less Background Ozone Production = Primary Mode Ozone
PMO

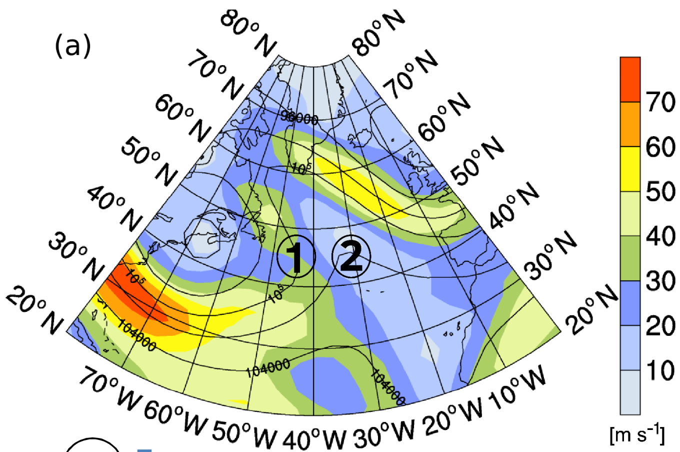
Less Stratospheric Water Vapour
SWV

The role of the emission location

Different emission locations

Different transport pathways

Different contributions to O_3 / CH_4



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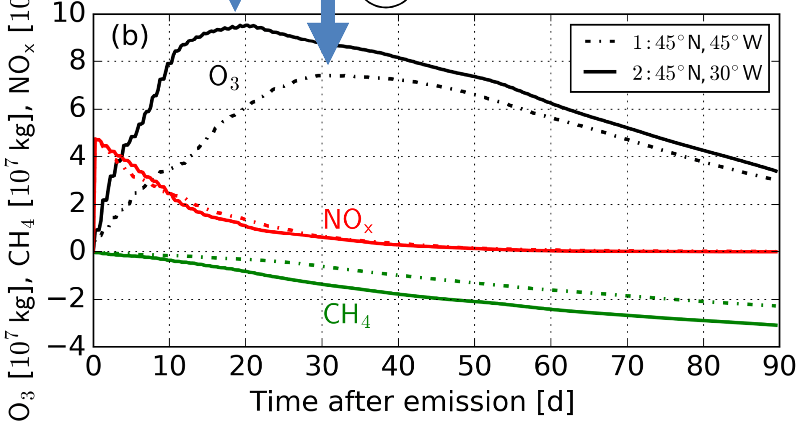
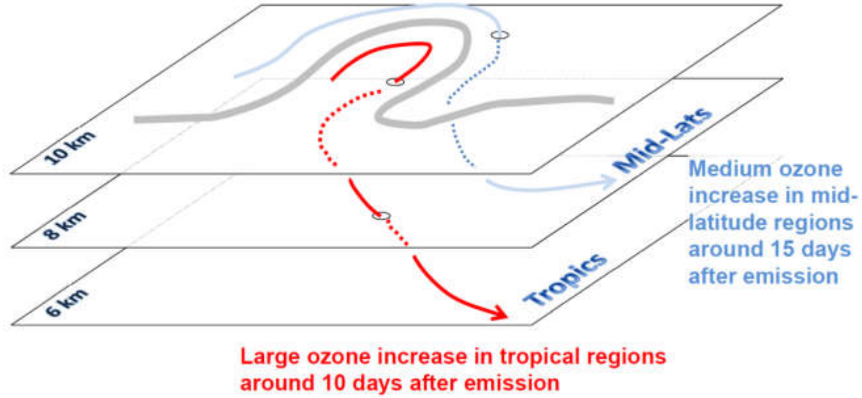
O_3-Maxiumum





Grewe et al. (2017b)

Same NO_x evolution (generally not the case)

But different O_3 and CH_4 evolution

Rosanka et al. (2020)

The role of the emission location

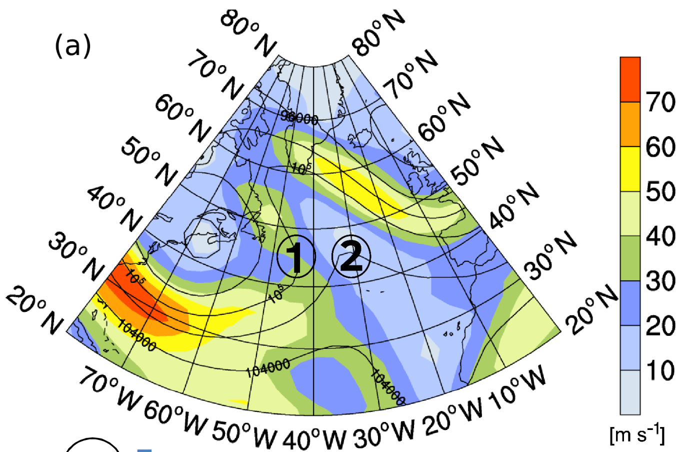
Different emission locations

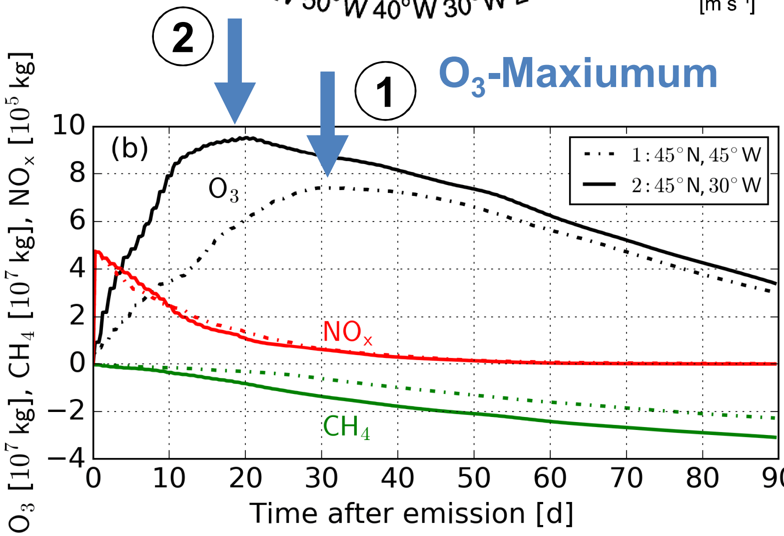
↓

Different transport pathways

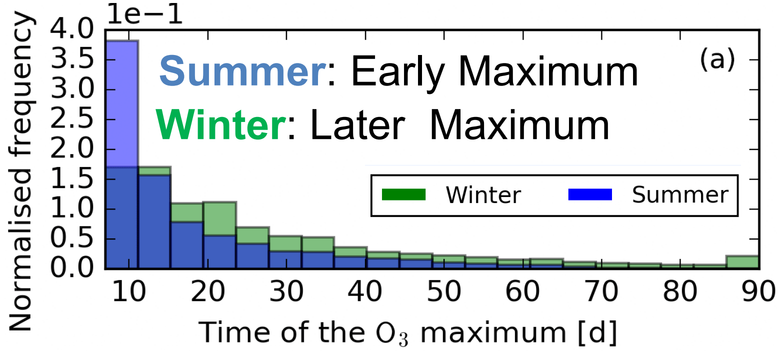
↓

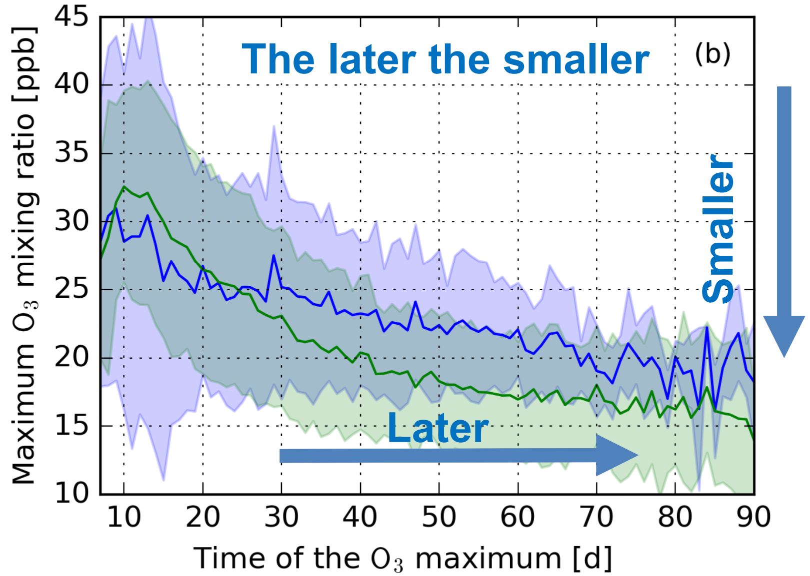
Different contributions to O_3 / CH_4





Analysis of ozone maximum for ~50,000 trajectories





Rosanka et al. (2020)

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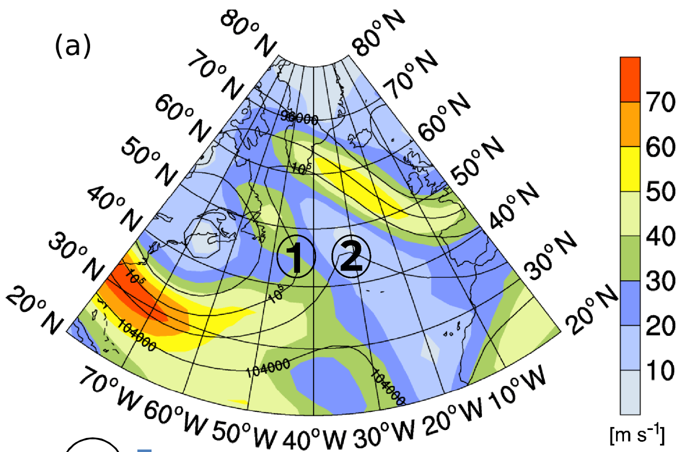

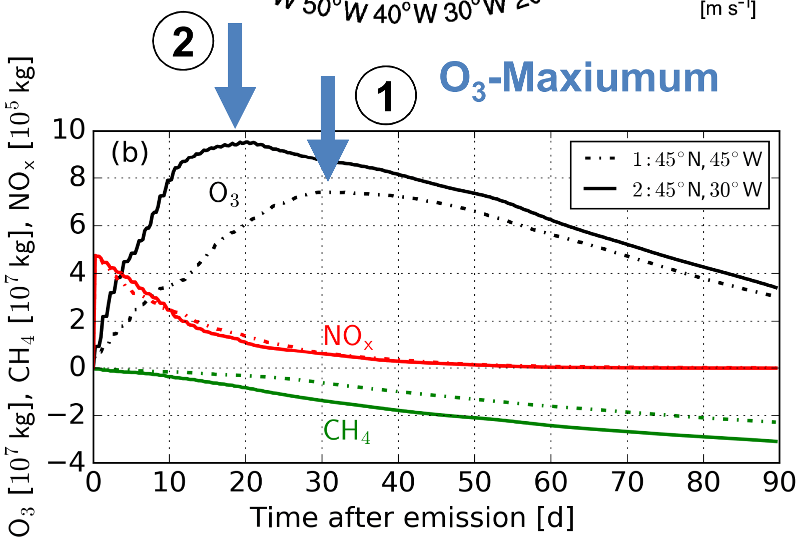

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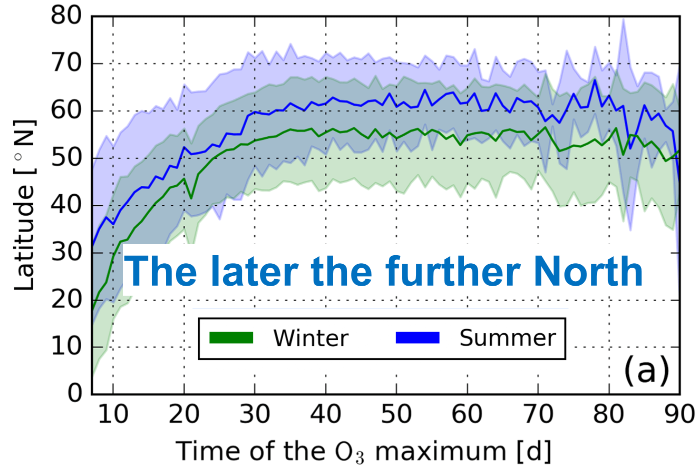

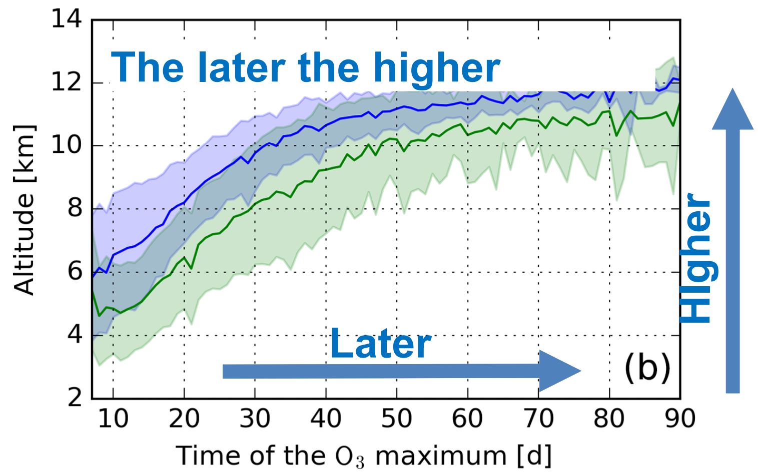

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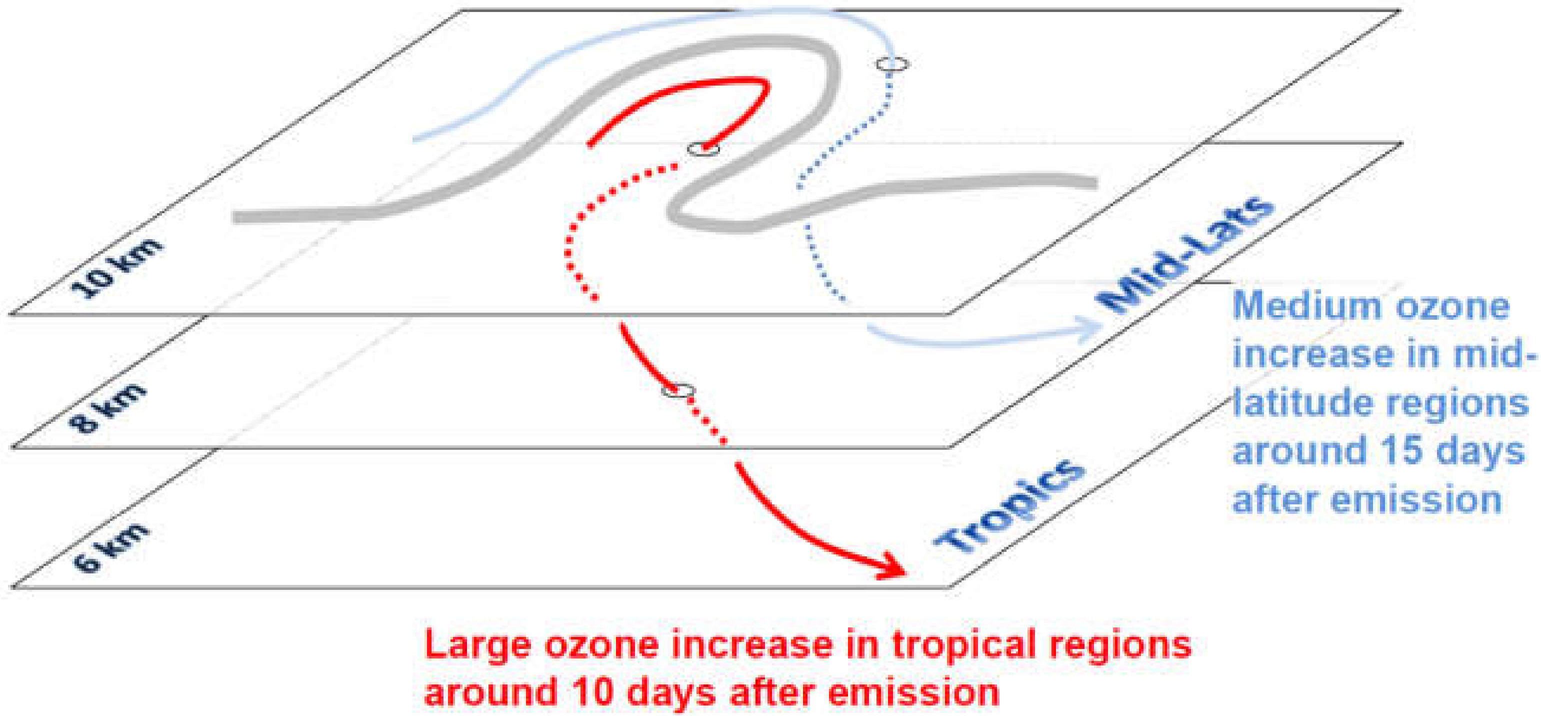
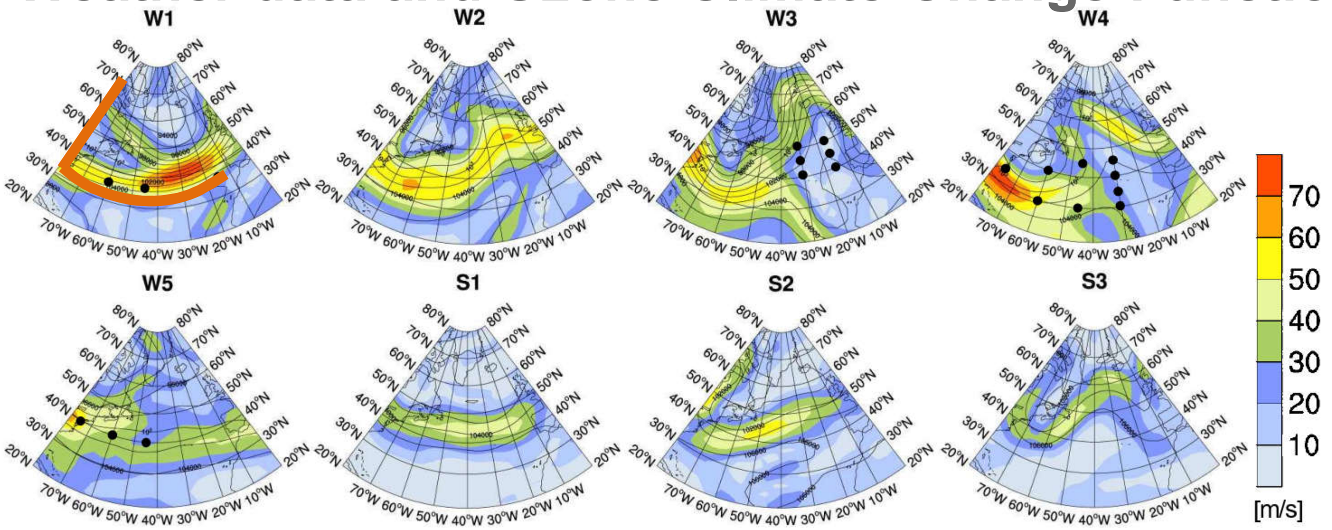
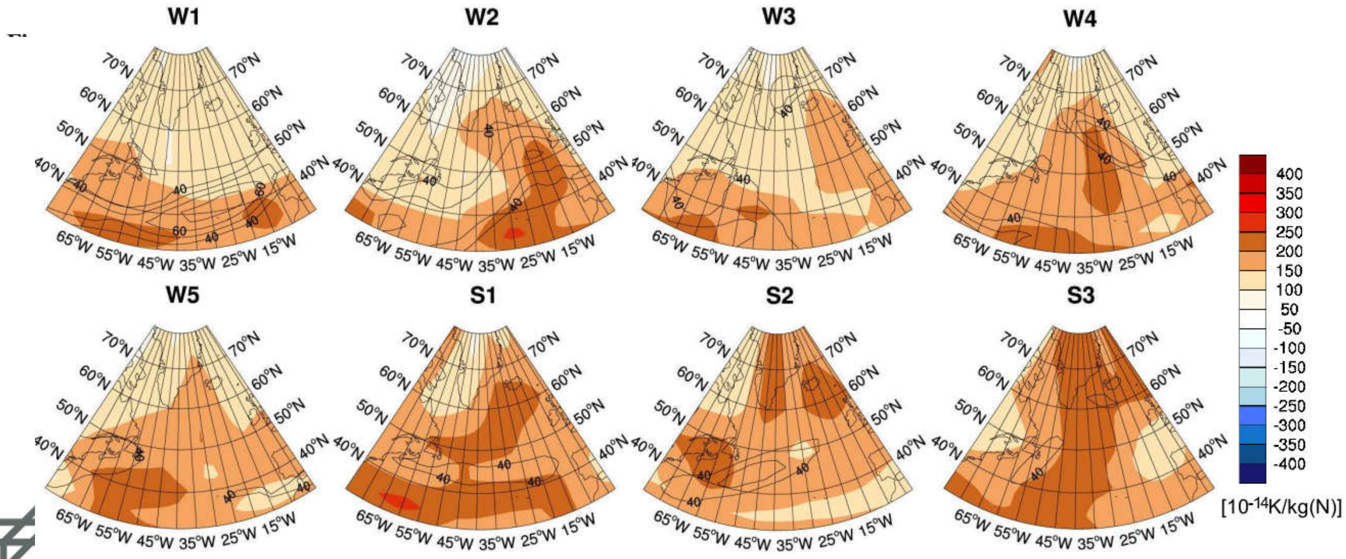


Grewe et al. (2017b)

Weather data and Ozone Climate-Change-Functions



Climatology of aviation weather situations:
Winter W1-W5
Summer S1-S3
University Reading
Irvine et al. 2013



Frömming et al. 2021

Contribution of a local NO_x emission to climate change via ozone formation

Clear relationship between weather and CCFs

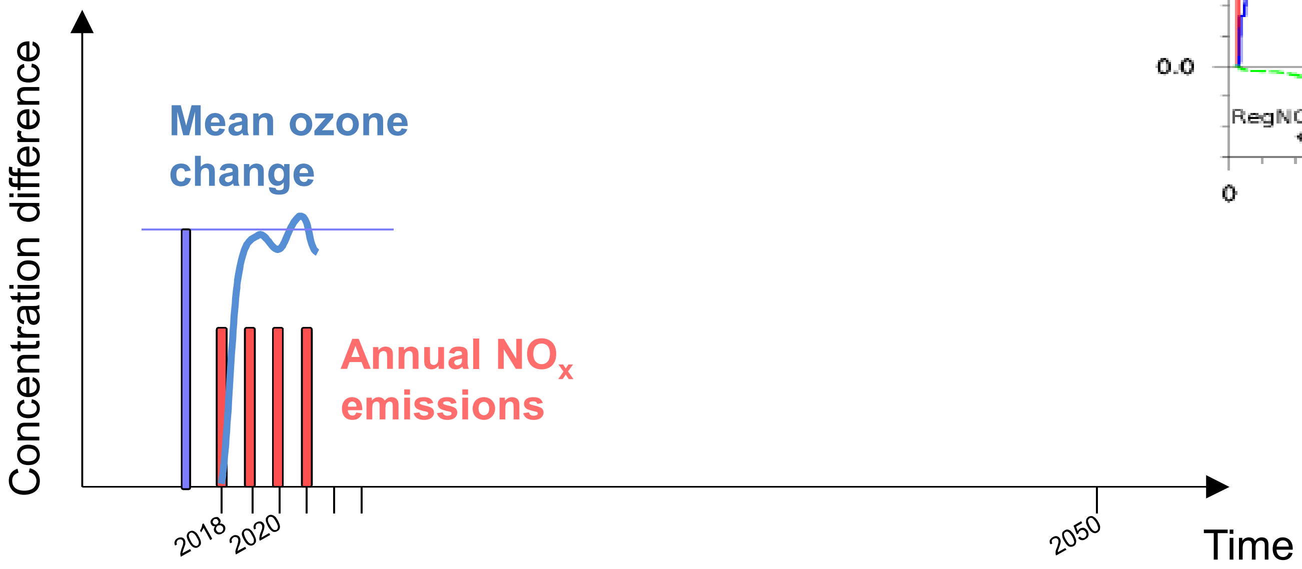
Open issues in determining the contribution of NO_x aviation emissions to climate change

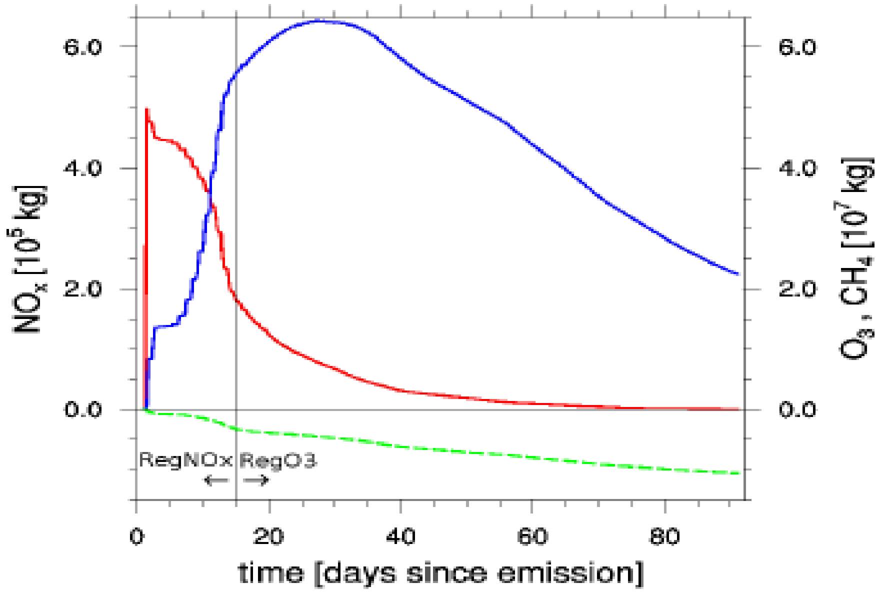
Temporal mismatch of NO_x-Ozone and NO_x-Methane RF

Contribution calculation vs. Perturbation calculation

How do we calculate O_3-RF and CH_4-RF

Comparison of a simulation with aviation emissions and without aviation emissions





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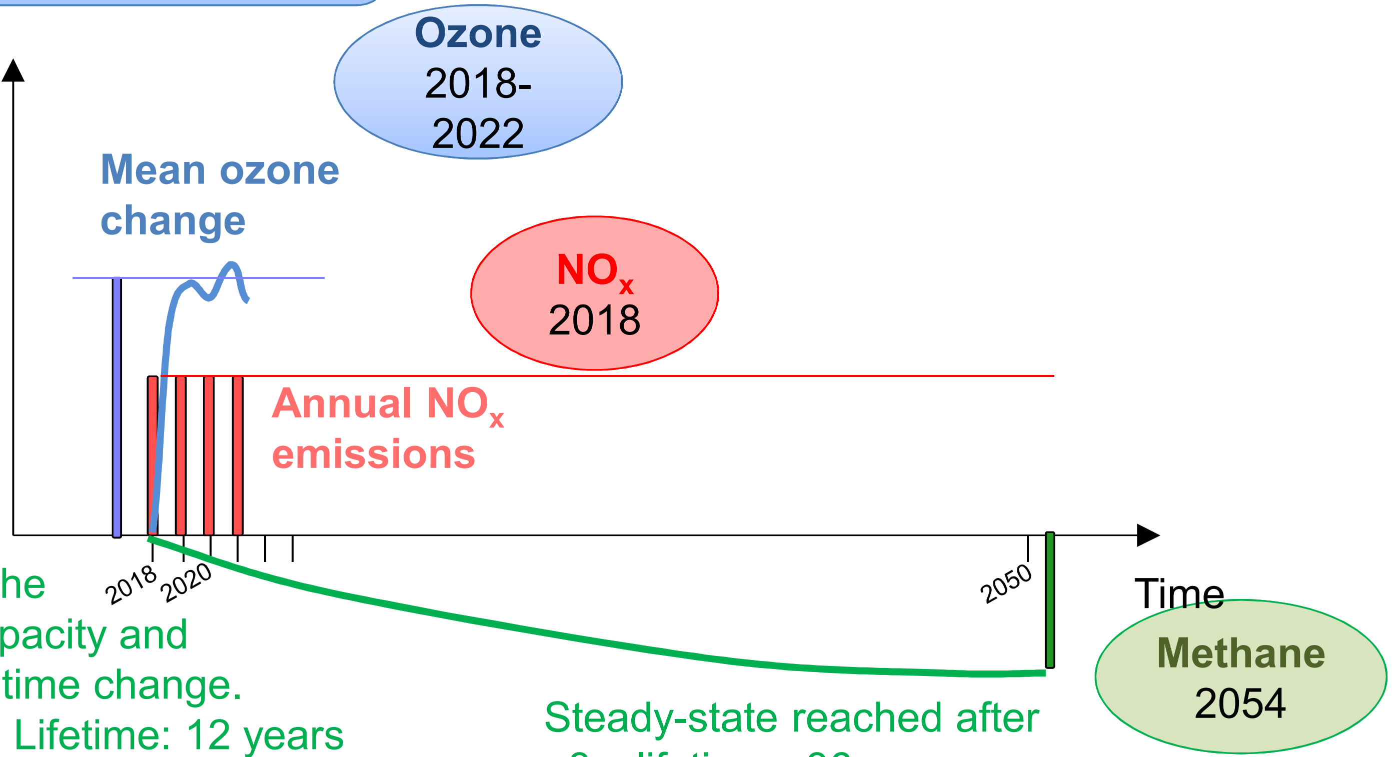
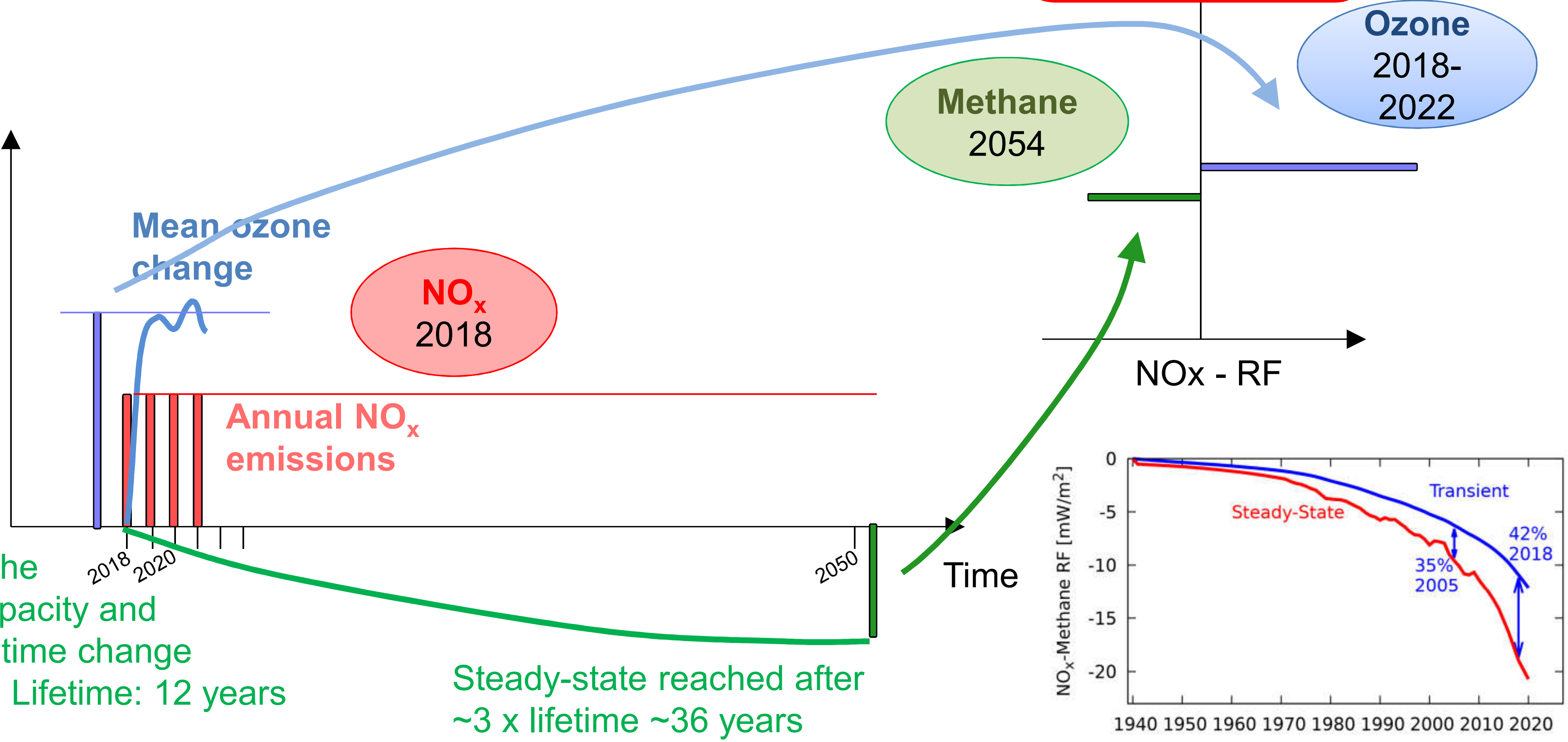


Analysis of the oxidation capacity and methane lifetime change.
Perturbation Lifetime: 12 years

Steady-state reached after ~3 x lifetime ~36 years

How do we calculate O_3-RF and CH_4-RF

Temporal Mismatch



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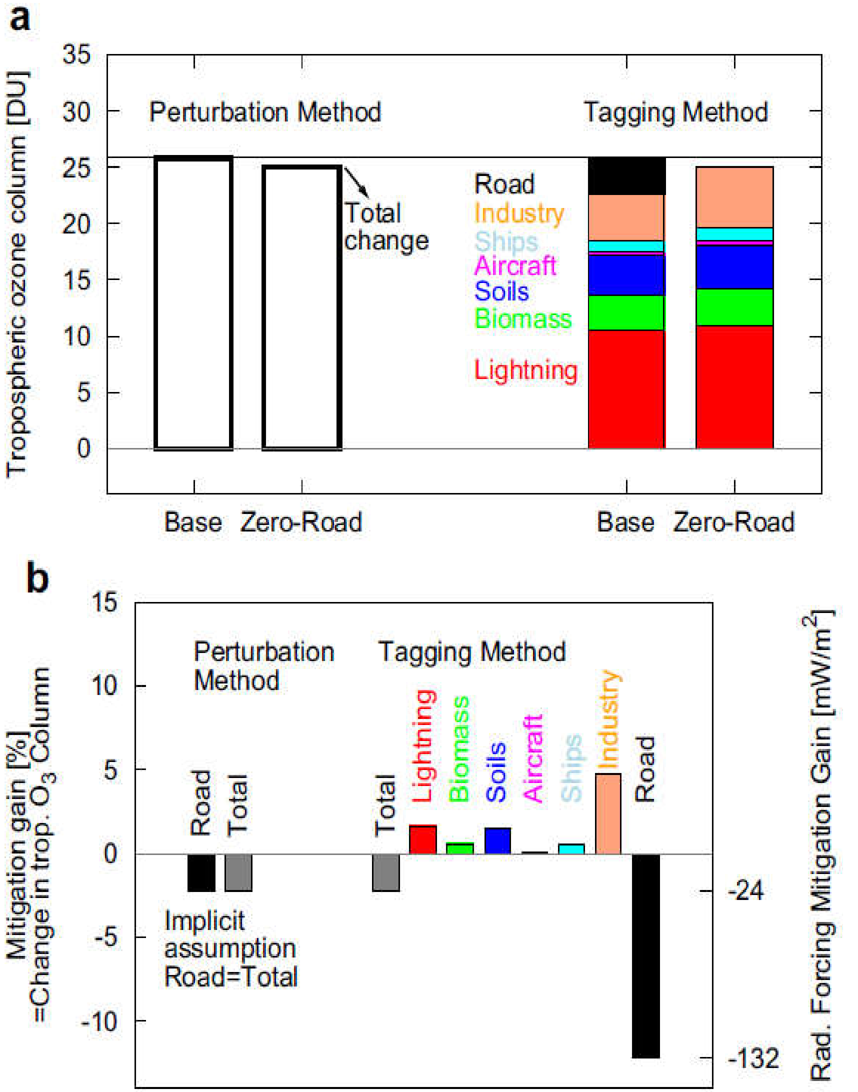
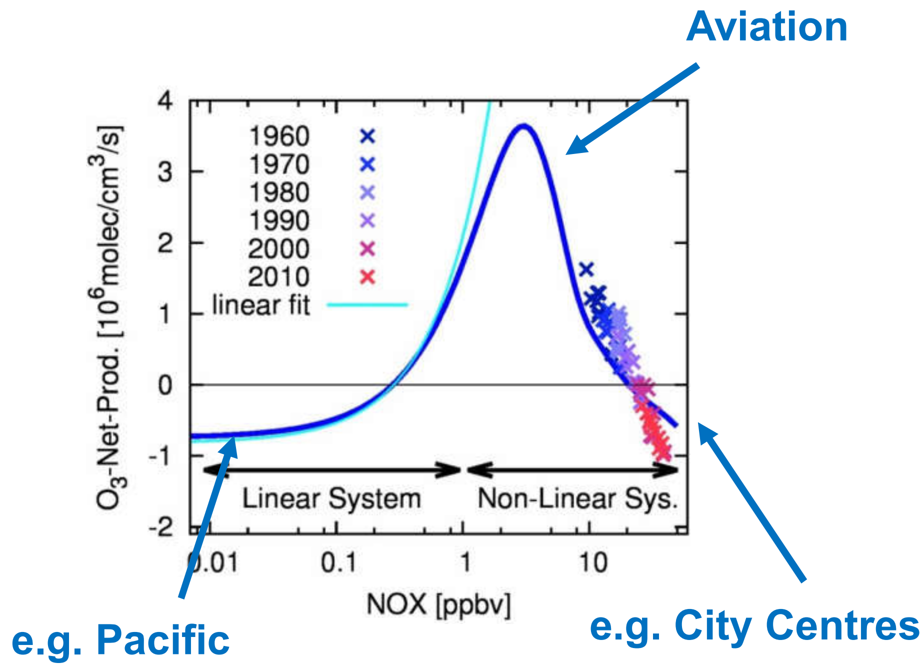
Contribution of road traffic emissions to ozone

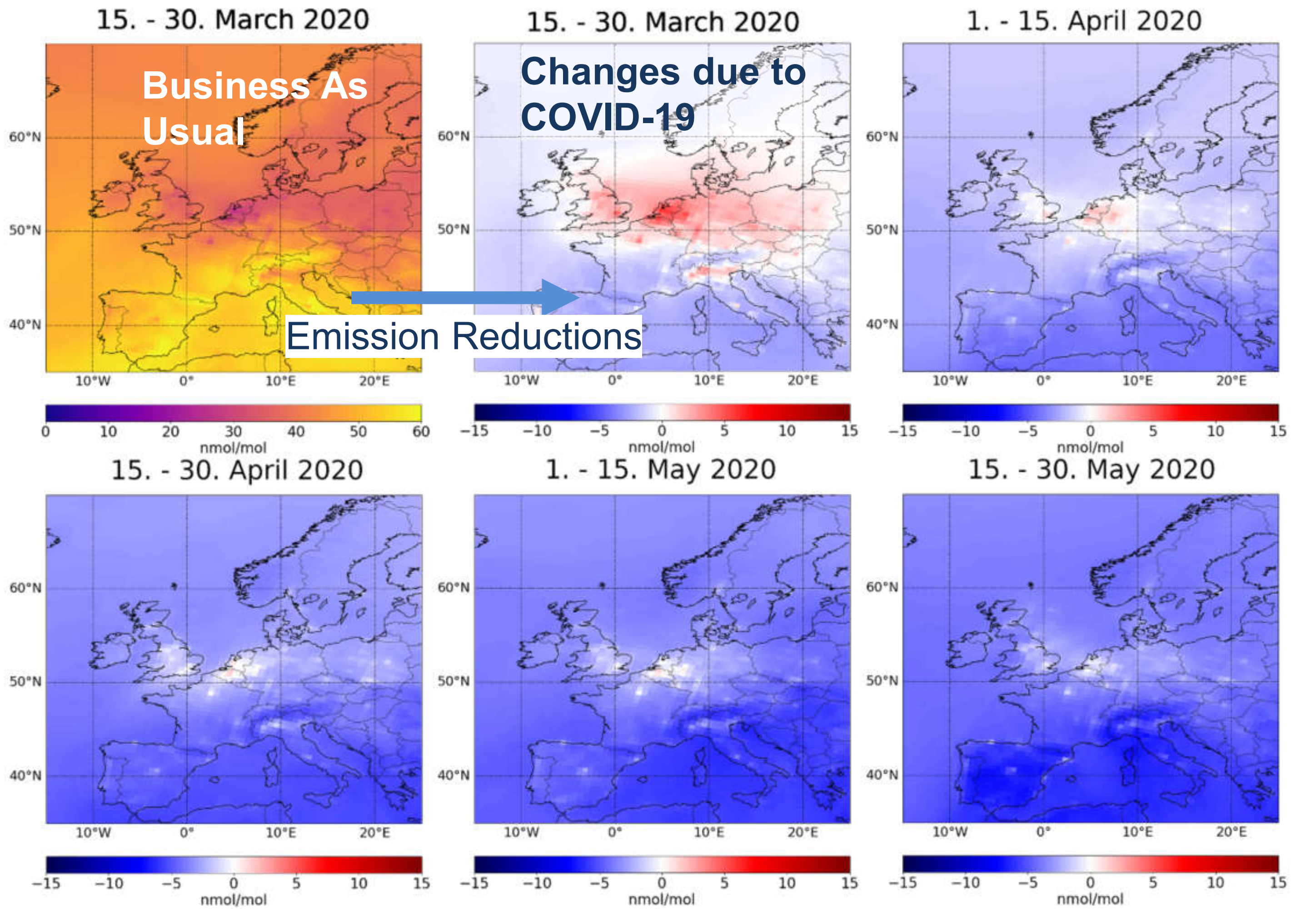


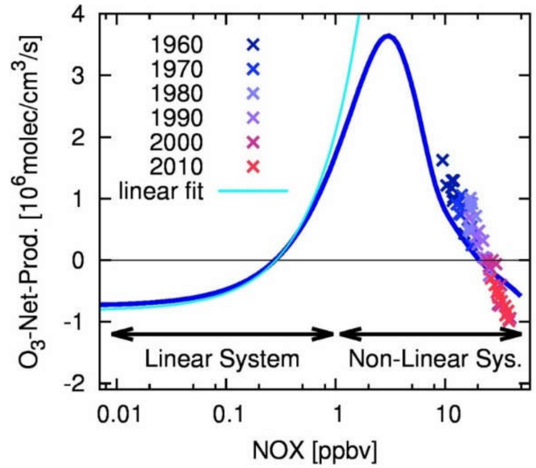
- **Ozone decreases because ozone from road traffic decreases (12%)**
- **Ozone net production rates increase ⇒ ozone from other sectors increases (-10%)**
- **Net Ozone change = 2%**



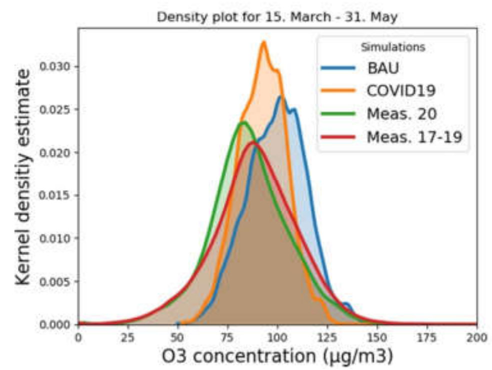
Grewe et al. (2012, 2017)

Evolution of surface ozone during COVID-19





Ozone Measurements and SimulationData



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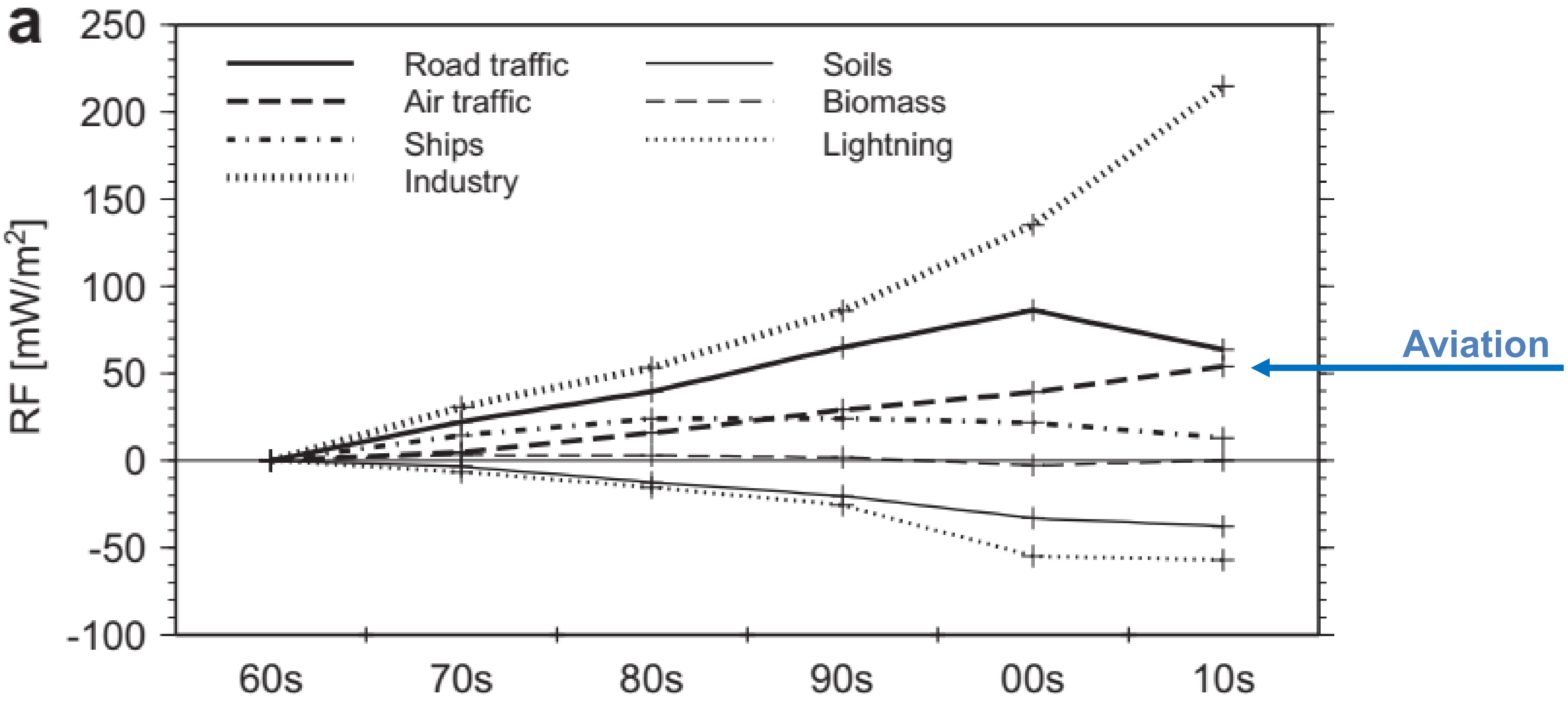
Mertens et al. 2021

Contribution of NO_x emissions to ozone Radiative Forcings



Dahlmann et al. 2011

Total Aviation NO_x Radiative Forcing

Grewe et al. 2019

Radiative forcing of Aviation NO_x emission in 2005 in mW/m^2	Lee et al. 2009	Additional processes (PMO, SWV)	Revised methane RF formula	correction of flaws	
				#1 Methane lifetime	#2 Ozone contribution method
Ozone	26.3	26.3	26.3	26.3	41.2
Methane	-12.5	-12.5	-15.4	-10.0	-10.0
PMO		-5.0	-5.0	-3.3	-3.3
SWV		-1.9	-1.9	-1.2	-1.2
Total NO_x-RF	13.8	6.9	4.0	11.8	26.7

Lee et al 2021 **Factor 2 difference due to diagnostics**

Total NO_x-ERF 2018	17.5	→	50?

Towards a roadmap: Evaluating the climate impact of aviation emission scenarios towards the Paris Agreement

Short Name	Long Name	Description
CurTec	Current Technology	Current (2012) technology is used as-is and no further political measures are implemented = "What happens if nothing happens" = "NoAction"
BAU	Business as usual	Business as usual increase in fuel efficiency without any specific aims to reduce the climate impact of aviation
CORSIA	Carbon-Offsetting Scheme	As BAU, a with carbon neutral growth from 2020 onwards
FP2050	Flight-Path 2050	As BAU, but including technology advancements, which are introduced according to Flightpath 2050
FP2050-cont	Flight-Path 2050, continuous implementation	As FP2050, but technology advancements are introduced earlier and a smooth transition is realised

Grewe et al. 2021

Summary

- Largest contribution to aviation climate impact: CO_2, NO_x and contrails
- NO_x impacts varies with altitude and also within weather situations
- Open issues in determining the contribution of NO_x aviation emissions to climate change: temporal mismatch / contribution analysis
- Flightpath 2050 goals are likely stabilizing climate impact from aviation
- However available technologies (ECATS scenario) are probably not meeting the goals. Will stronger electrification and “green” LH2 + climate friendly operations help?

Thank you for your attention

References wrt. DLR results

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- Rosanka, S., Frömming, C, and Grewe, V., The impact of weather pattern and related transport processes on aviation's contribution to ozone and methane concentrations from NOx emissions, Atmos. Chem. Phys. 20, 12347-12361, https://doi.org/10.5194/acp-20-12347-2020, 2020.
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