CLINSH fleet scenario impacts on air quality in multiple European urban areas

CLINSH
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Final conference – 25th Nov 2021
Vlaadingen - NL

Dr. Martin Ramacher
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Helmholtz-Zentrum hereon

Motivation

a global health threat

Air pollution is now considered to be the world’s largest environmental health threat, accounting for

7 million deaths

around the world every year.

WHO 2020

EEA estimates for premature deaths in Europe 2019 due to:

$PM_{2.5}$ - 373000

NO_2 - 47700

O_3 – 9070

EEA 2021

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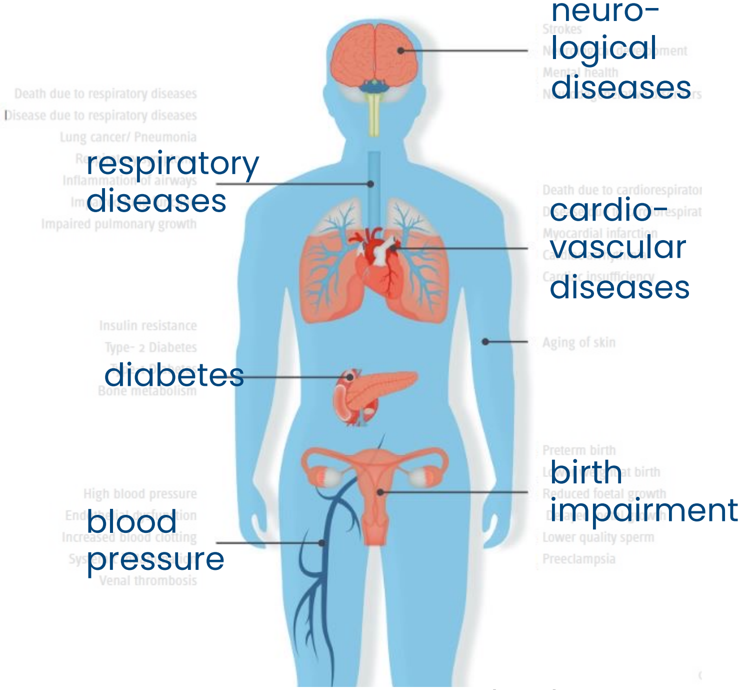
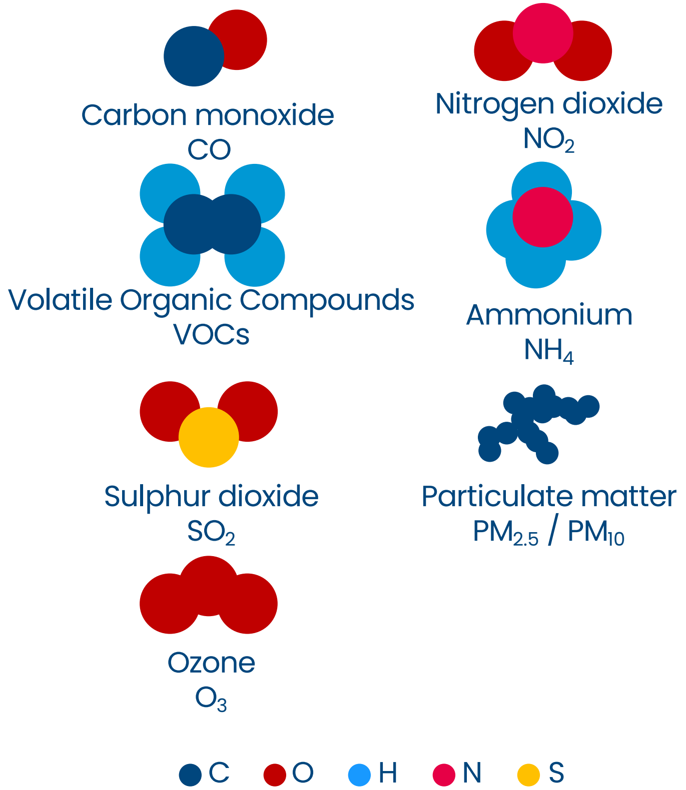
Air pollution – health effects, pollutants, sources

Health effects

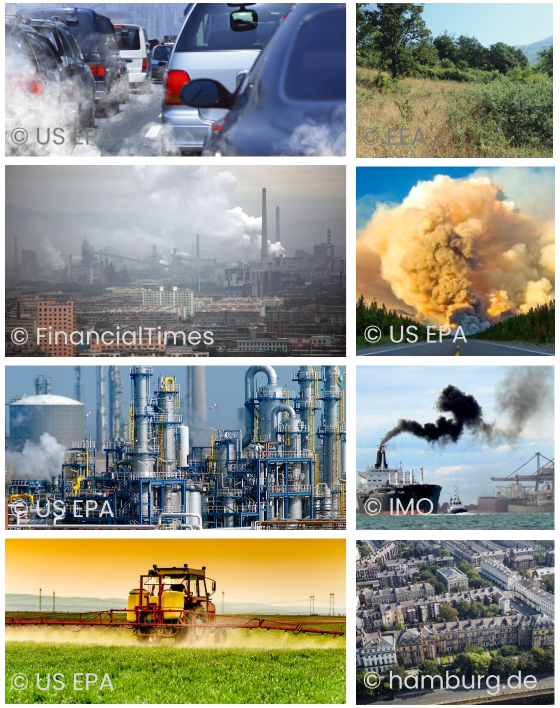


adapted after: Thurston et al. (2017)

Pollutants

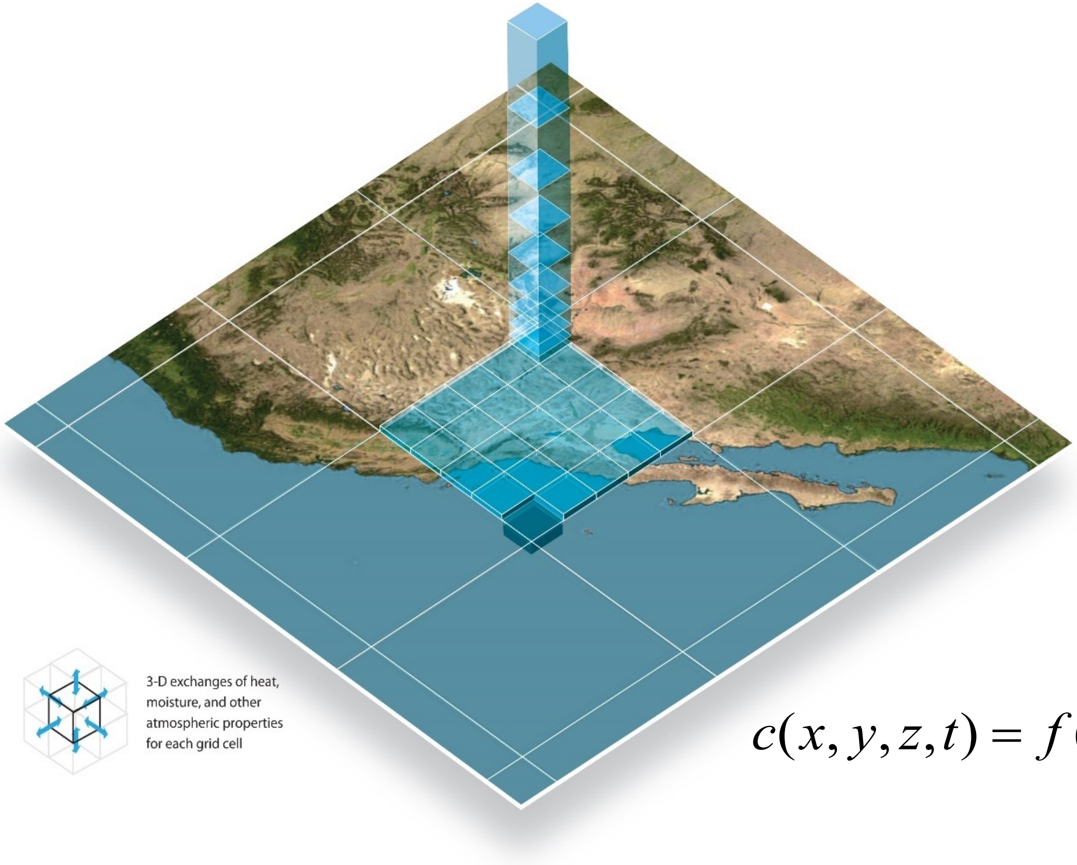


Emission sources



Air pollution – from emissions to exposure

Emission sources



$$c(x, y, z, t) = f(ADV, E, DEP, K)$$

Chemistry Transport Models are realistic numerical models for the description of air pollutant transport on different temporal and spatial scales.

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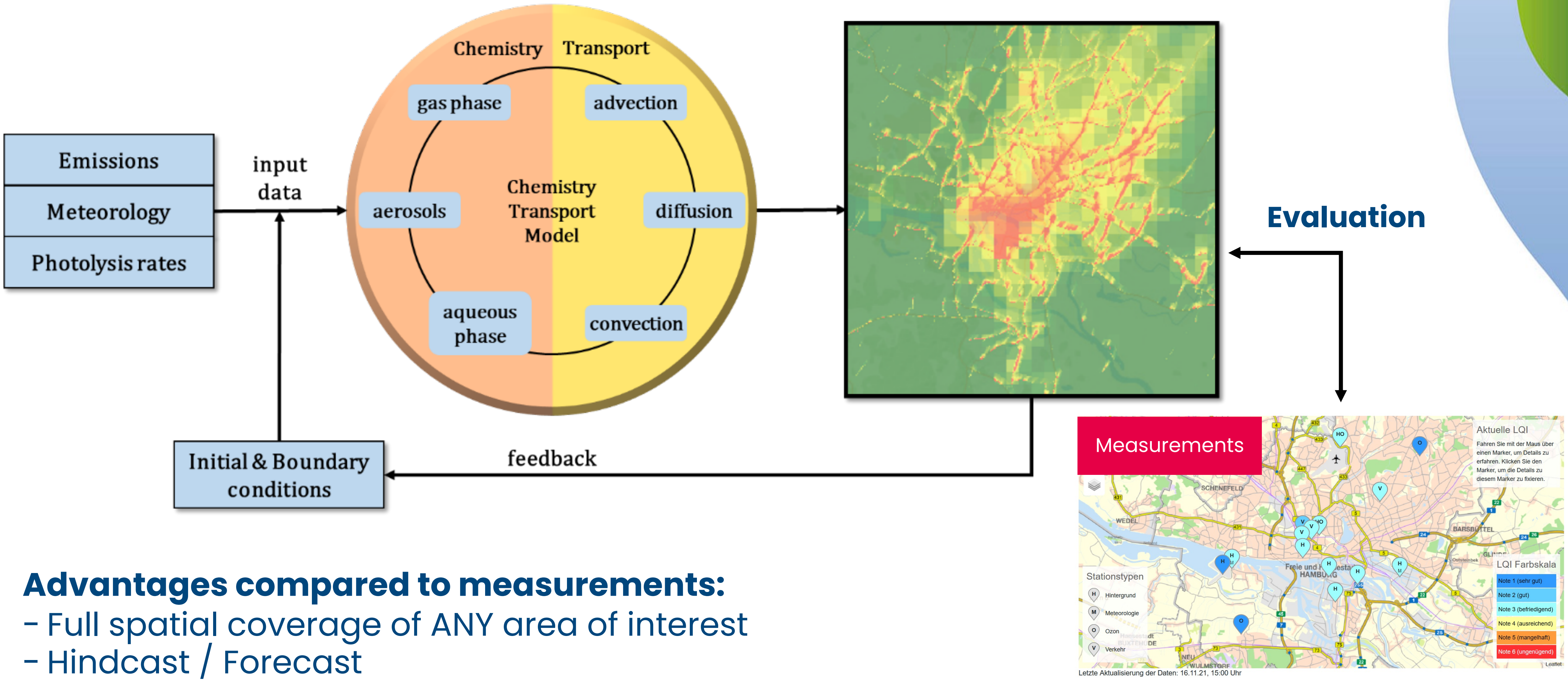
Chemistry Transport Modeling (CTM)



Advantages compared to measurements:

- Full spatial coverage of ANY area of interest
- Hindcast / Forecast
- Scenario simulations

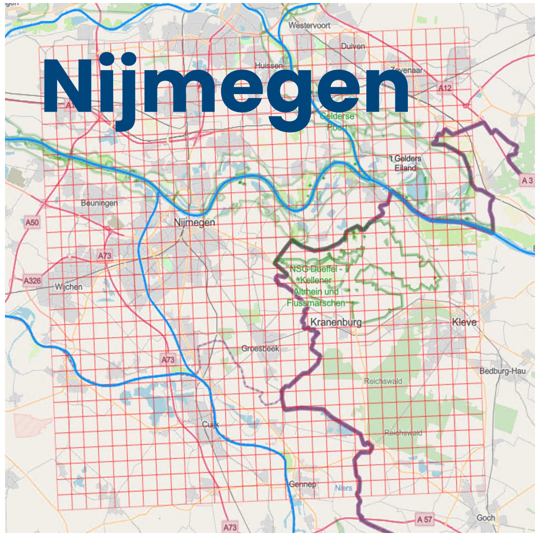
Application of CTM in CLINSH

Domain extent – 50 x 50 km^2

Eulerian grid resolution – 1 x 1 km^2

Near field sub grid resolution – 100 x 100 m^2

Projection – UTM Zone 31 N

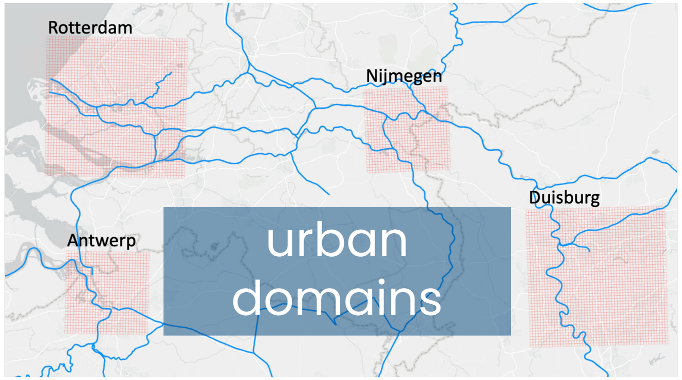


Domain extent – 30 x 30 km^2

Eulerian grid resolution – 1 x 1 km^2

Near field sub grid resolution – 100 x 100 m^2

Projection – UTM Zone 32 N



Domain extent – 30 x 30 km^2

Eulerian grid resolution – 1 x 1 km^2

Near field sub grid resolution – 100 x 100 m^2

Projection – UTM Zone 31 N

Domain extent – 50 x 50 km^2

Eulerian grid resolution – 1 x 1 km^2

Near field sub grid resolution – 100 x 100 m

Projection – UTM Zone 32 N

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Land-based emissions input

Emission sources

Necessary information about emission sources:

- Spatial (where?)
- Temporal (when?)

Possible data sources for emission inventories:

- municipalities, authorities
- urban, regional, global databases

<u>CLINSH approach</u>

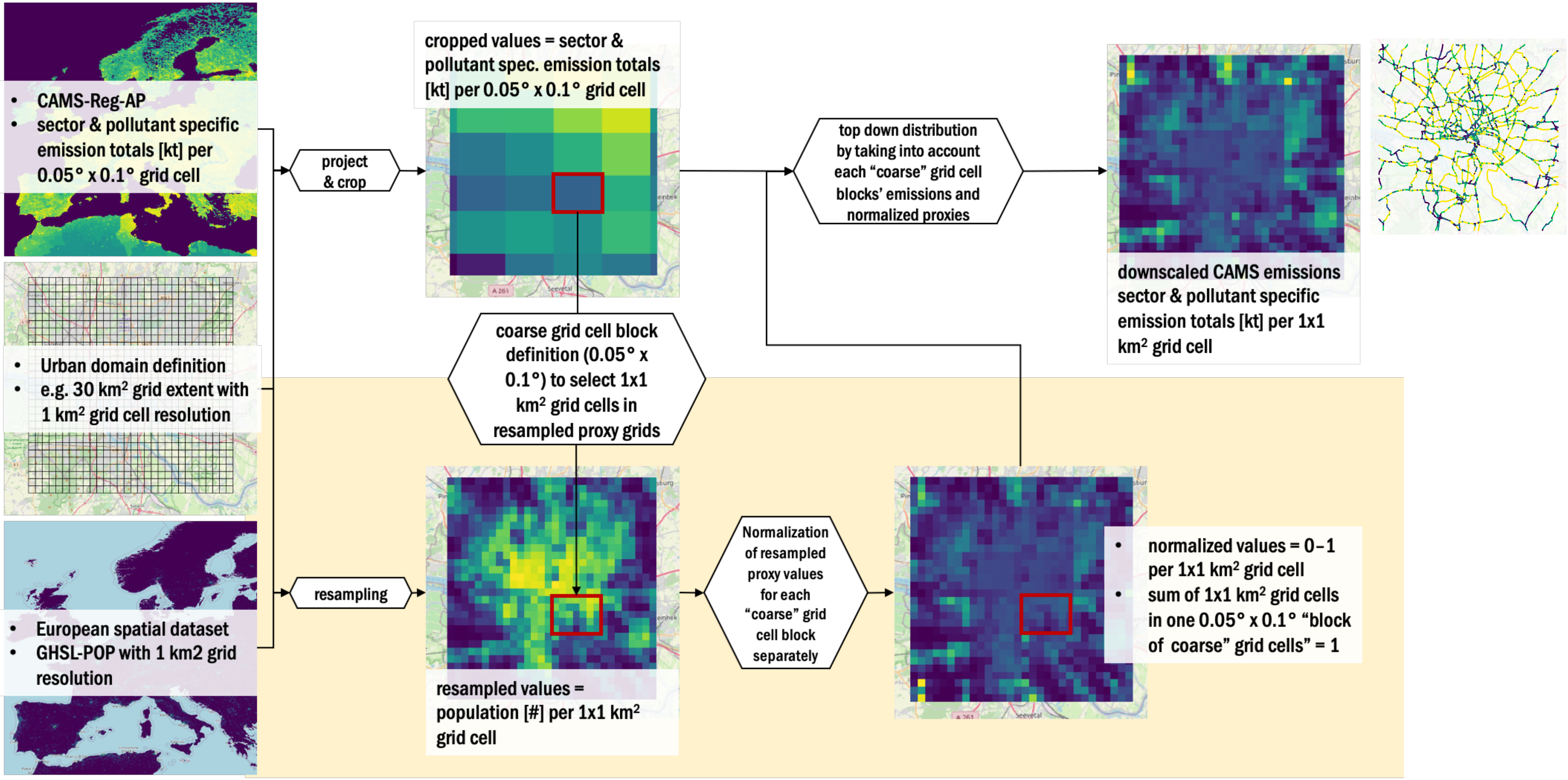
Apply database inventories to achieve comparability!

Advantage: consistent application to all urban domains = direct comparibilty

Disadvantage: less accurate emissions compared to emissions inventories from authorities

→ results should not be used for air quality reporting!

Land-based emission input – the URBEM framework (Ramacher et al. 2021)



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Land-based & sea-going ship emissions input

	Rotterdam		Nijmegen		Antwerp		Western Rhein-Ruhr area	
	NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}
other [kt/a]	41.3	3.64	4.39	0.78	32.50	2.69	57.22	10.29

Table 5: Annual total emissions in kt/a for all urban domains as derived from downscaling and distributing CAMS-Reg-AP and E-PRTR emission inventories for the year 2016.

SNAP	source type	Rotterdam [kt/a]		Nijmegen [kt/a]		Antwerp [kt/a]		Western Rhine-Ruhr area [kt/a]	
		NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}
SNAP1	psrc	6.73	0.18	0.37	-	5.63	0.12	13.39	
SNAP1	asrc	-	0.03	0.64	0.03	0.15	0.04	0.02	0.66
SNAP2	asrc	1.75	0.12	0.48	0.08	0.70	0.53	2.11	0.42
SNAP3	psrc	0.57	0.06	-	-	0.34	-	11.89	2.63
SNAP3	asrc	3.27	0.93	0.11	0.16	4.82	0.77	0.71	2.18
SNAP4	psrc	1.98	-	-	-	5.22	-	1.51	
SNAP4	asrc	-	0.25	0.03	0.04	-	0.19	1.64	1.20
SNAP5	asrc	0.01	-	-	-	0.03	0.01	0.02	0.00
SNAP6	psrc	1.72	0.07	-	-	0.82	-	2.42	
SNAP6	asrc	-	0.09	0.04	0.04	-	0.04	-	0.50
SNAP7	lsrc	14.70	1.37	2.36	0.22	6.68	0.59	21.42	2.22
SNAP8*	asrc	17.33*	0.99*	2.80*	0.16*	12.75*	0.77*	1.09*	0.06*
SNAP10	asrc	1.89	0.24	0.36	0.21	0.41	0.18	2.09	0.48

Ship emission scenarios in CTM simulations

	Rotterdam		Nijmegen		Antwerp		Western Rhein-Ruhr area	
	NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}	NO_x	PM_{10}
other [kt/a]	41.3	3.64	4.39	0.78	32.50	2.69	57.22	10.29
ships [kt/a]	2.68	0.09	1.32	0.04	0.97	0.03	2.05	0.06
share [%]	6.49	2.48	30.11	5.13	2.97	1.12	3.58	0.58

S2020b

Identification of inland shipping emissions on air quality:

2020 baseline = S2020b
2035 baseline = S2035b
2035 CLINSH = S2035c

kept constant: meteorology, boundaries, land-based emissions

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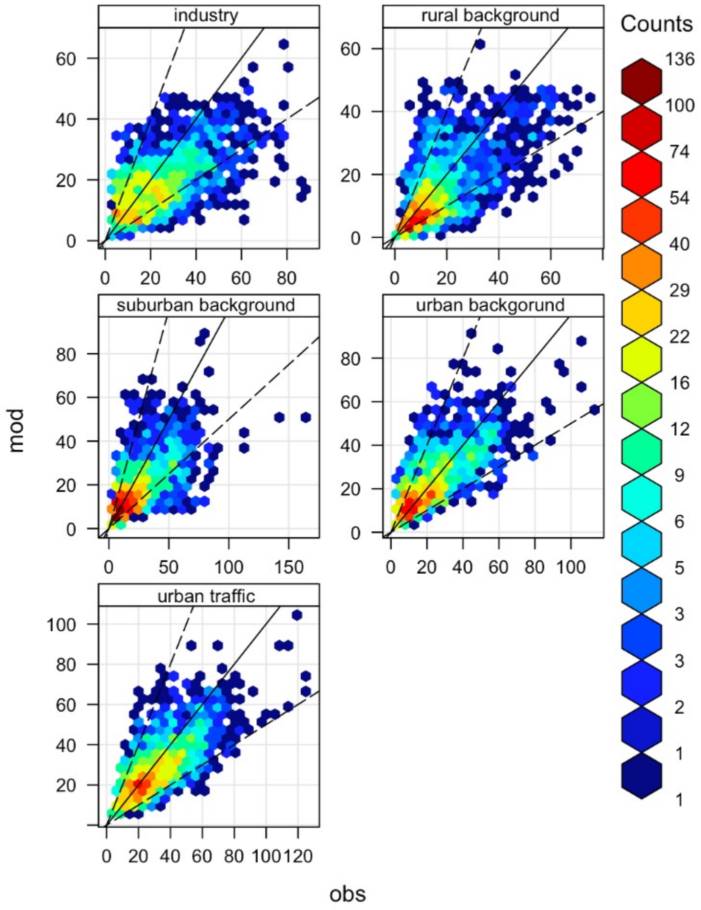
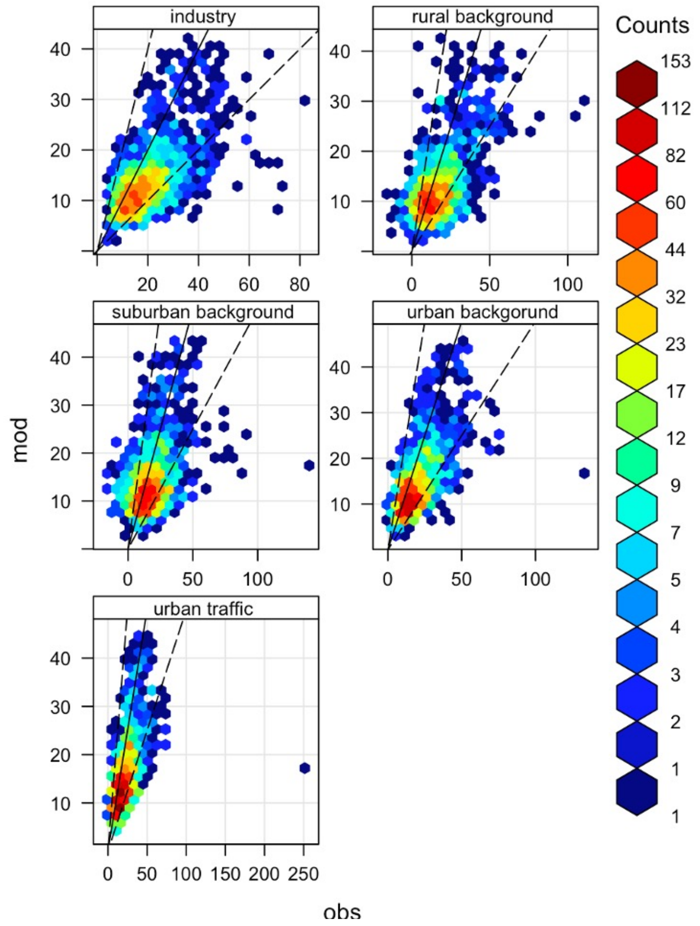
Evaluation of CTM results (S2020b)

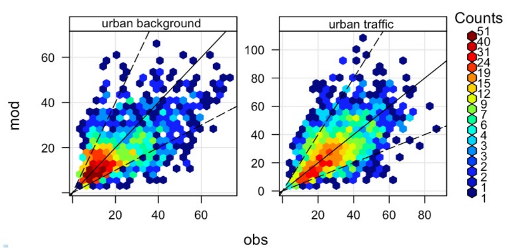
Rotterdam NO_2 hourly



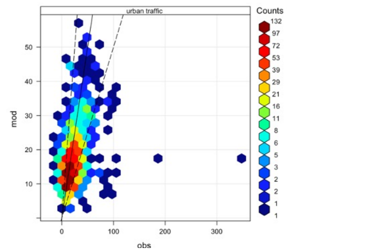
Rotterdam PM_{10} hourly



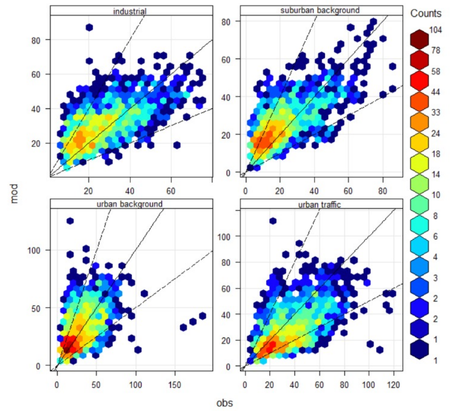
Nijmegen NO_2 hourly



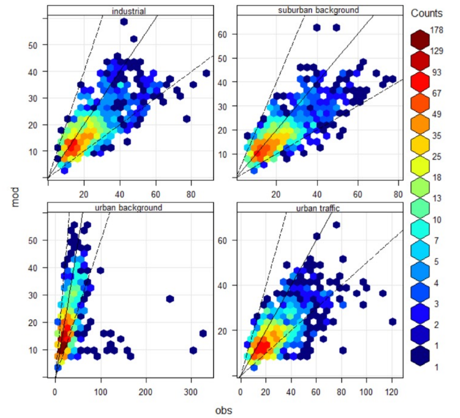
Nijmegen PM_{10} hourly



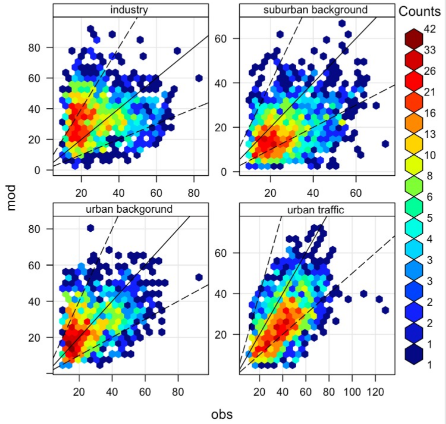
Antwerp NO_2 hourly



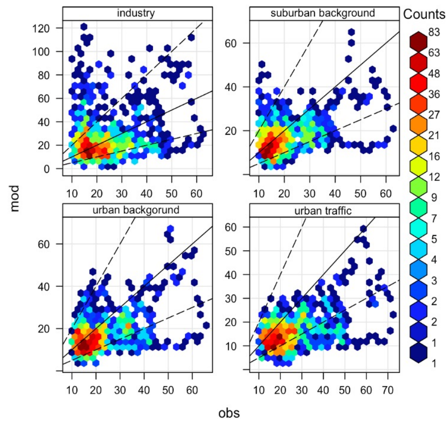
Antwerp PM_{10} hourly



Western Rhine-Ruhr area NO_2 hourly



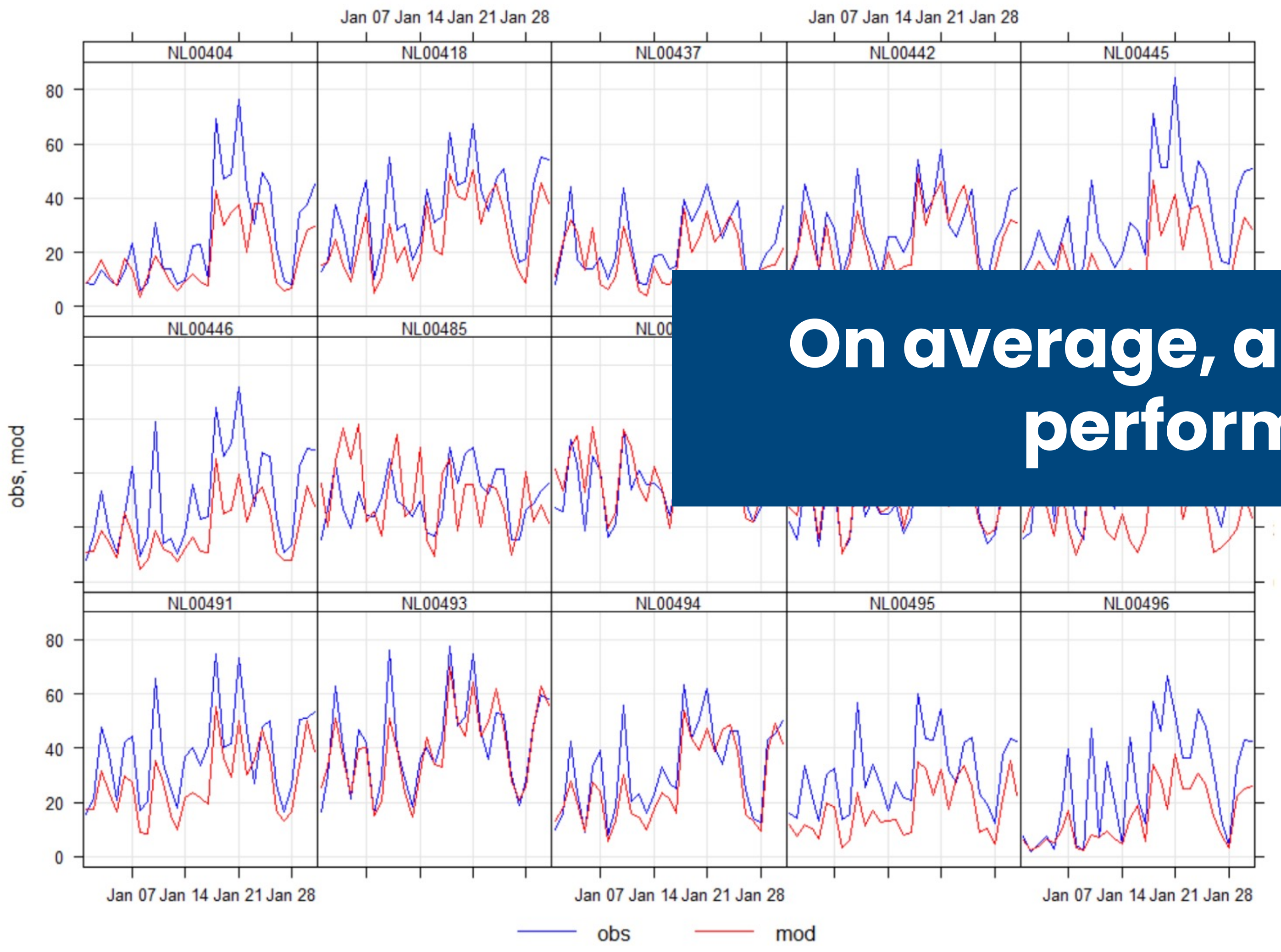
Western Rhine-Ruhr area PM_{10} hourly



For all cities available in the B4 report

Evaluation of CTM results (S2020b)

Rotterdam January 2019 NO_2 daily time series [µg/m³]



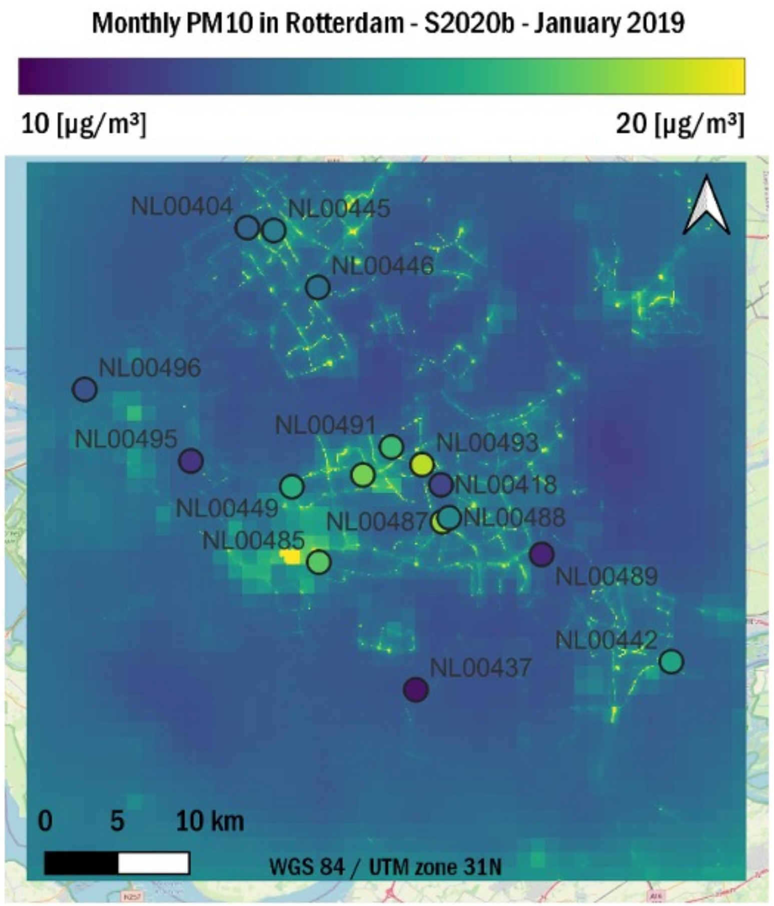
area	type	month	n	FAC2	MB	NM
Rotterdam						
n.a.	industry	January	2229	0.59	-8.29	-0.2
n.a.	industry	July	2193	0.54	-3.00	-0.1
rural	background	January	743	0.79	-4.74	-0.2
rural	background	July	739	0.69	-0.28	-0.0
suburban	background	January	718	0.69	-12.19	-0.3
suburban	background	July	741	0.80	1.12	0.07
urban	background	January	3694	0.83	-5.42	-0.1
urban	background	July	3691	0.66	5.94	0.34
urban	traffic	January	3719	0.74	-8.58	-0.2
urban	traffic	July	4454	0.70	1.87	0.07
Nijmegen						
urban	background	January	731	0.85	-7.88	-0.2
			721	0.77	3.14	0.23
			695	0.90	-2.09	-0.0
			738	0.79	5.25	0.20
Antwerp						
			5815	0.80	-1.38	-0.0
			6363	0.62	8.52	0.41
suburban	background	January	2770	0.79	-0.78	-0.0
suburban	background	July	2600	0.52	8.89	0.63
urban	background	January	1310	0.82	-5.39	-0.1
urban	background	July	1432	0.70	8.38	0.41
urban	traffic	January	1420	0.72	-12.26	-0.2
urban	traffic	July	1442	0.68	-1.35	-0.0
Western Rhine-Ruhr area						
n.a.	industry	January	2484	0.67	-0.52	-0.0
n.a.	industry	July	2213	0.58	9.48	0.37
suburban	background	January	2505	0.55	-11.31	-0.3
suburban	background	July	2122	0.51	-5.49	-0.2
urban	background	January	3634	0.68	-4.61	-0.1
urban	background	July	3032	0.61	2.60	0.10
urban	traffic	January	5586	0.60	-17.29	-0.4
urban	traffic	July	5677	0.67	-10.25	-0.2

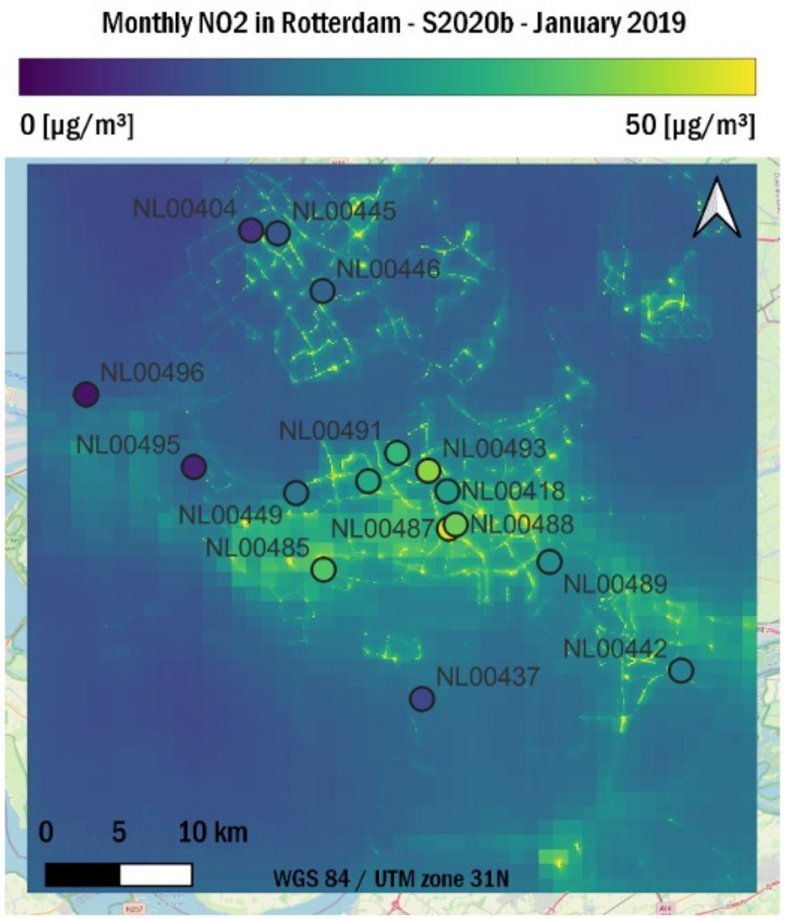
On average, a satisfactory performance

For all cities available in the B4 report

Results

Air quality in S2020b – all sources – Rotterdam - January





For all cities available in the B4 report

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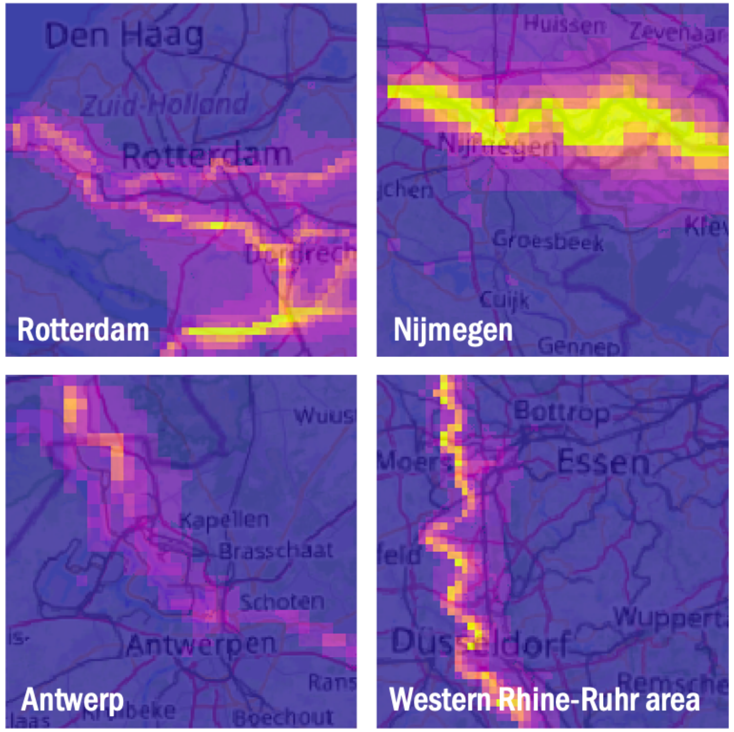
Results

pollutant		WHO2021
PM_{10} [µg/m³]	annual	15
NO_2 [µg/m³]	annual	10

Impact of inland shipping in S2020b

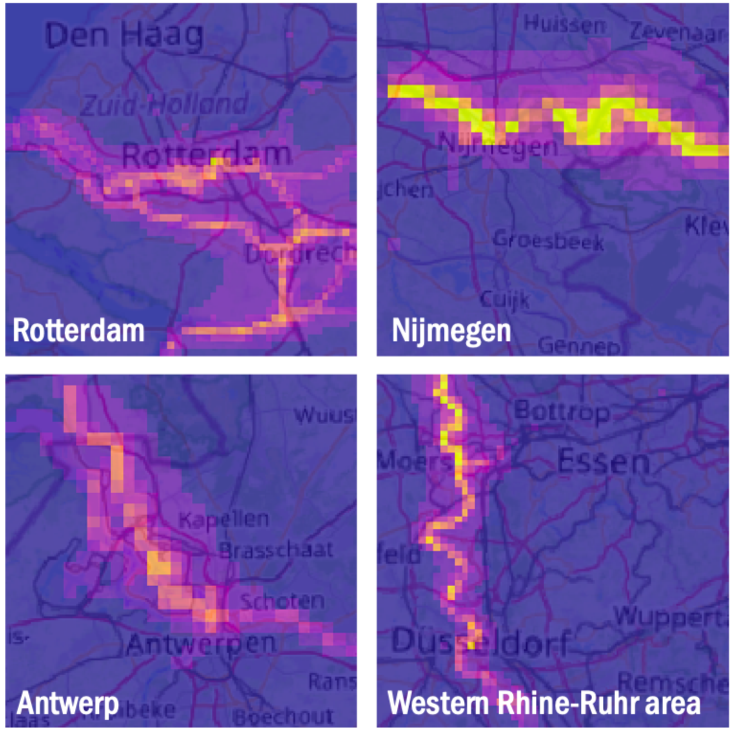


S2020b - NO_2 inland shipping contribution

[µg/m³]

<= 0,4
0,4 - 0,8
0,8 - 1,2
1,2 - 1,6
1,6 - 2,0
2,0 - 2,4
2,4 - 2,8
2,8 - 3,2
3,2 - 3,6
> 3,6

domain	Mean [µg/m³]	Max [µg/m³]
Rotterdam	0.54	4.83
Nijmegen	0.95	11.52
Antwerp	0.26	2.07
Western Rhine-Ruhr area	0.37	5.27



S2020b – PM_{10} inland shipping contribution

[µg/m³]

<= 0,0
0,0 - 0,1
0,1 - 0,1
0,1 - 0,1
0,1 - 0,1
0,1 - 0,2
0,2 - 0,2
0,2 - 0,2
0,2 - 0,3
> 0,3

domain	Mean [µg/m³]	Max [µg/m³]
Rotterdam	0,04	0,39
Nijmegen	0,05	0,83
Antwerp	0,03	0,32
Western Rhine-Ruhr area	0,03	0,41

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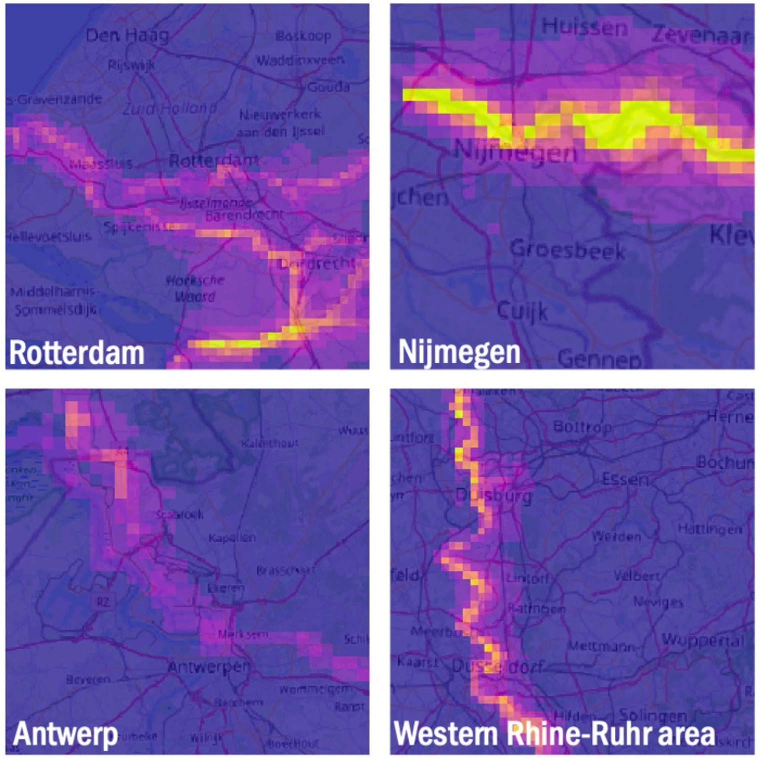
Results

pollutant		WHO2021
NO_2 [µg/m³]	annual	10

Impact of inland shipping in CLINSH scenarios 2035b and 2035c – NO_2

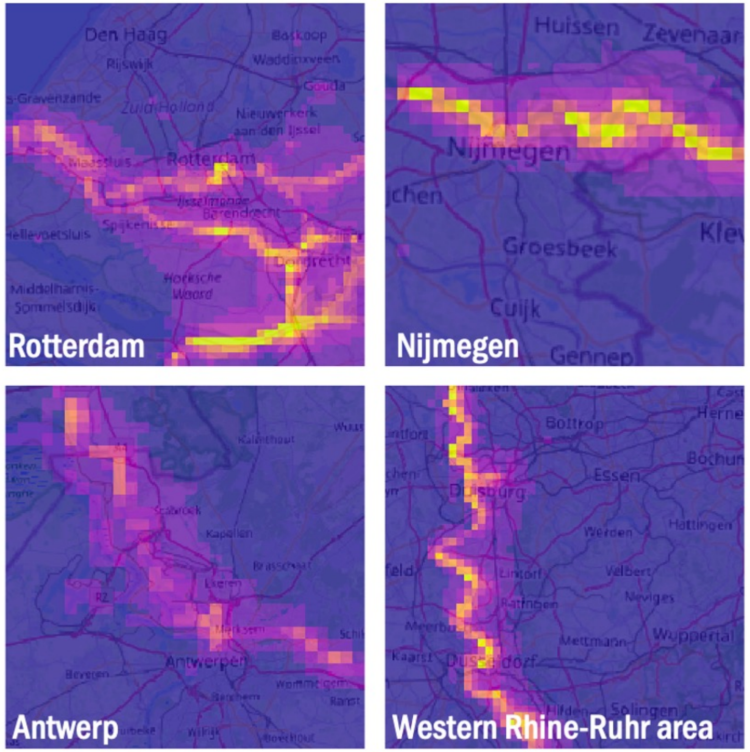


S2035b - NO_2 inland shipping contribution

[µg/m³]

- <= 0,4
- 0,4 - 0,8
- 0,8 - 1,2
- 1,2 - 1,6
- 1,6 - 2,0
- 2,0 - 2,4
- 2,4 - 2,8
- 2,8 - 3,2
- 3,2 - 3,6
- > 3,6

domain	Mean [µg/m³]	Max [µg/m³]
Rotterdam	0.41	3.74
Nijmegen	0.73	9.38
Antwerp	0.20	1.62
Western Rhine-Ruhr area	0.30	4.28



S2035c - NO_2 inland shipping contribution

[µg/m³]

- <= 0,1
- 0,1 - 0,2
- 0,2 - 0,3
- 0,3 - 0,4
- 0,4 - 0,5
- 0,5 - 0,6
- 0,6 - 0,7
- 0,7 - 0,8
- 0,8 - 0,9
- > 0,9

domain	Mean [µg/m³]	Max [µg/m³]
Rotterdam	0.15	1.29
Nijmegen	0.23	3.36
Antwerp	0.08	0.64
Western Rhine-Ruhr area	0.09	1.37

For PM_{10} available in the B4 report

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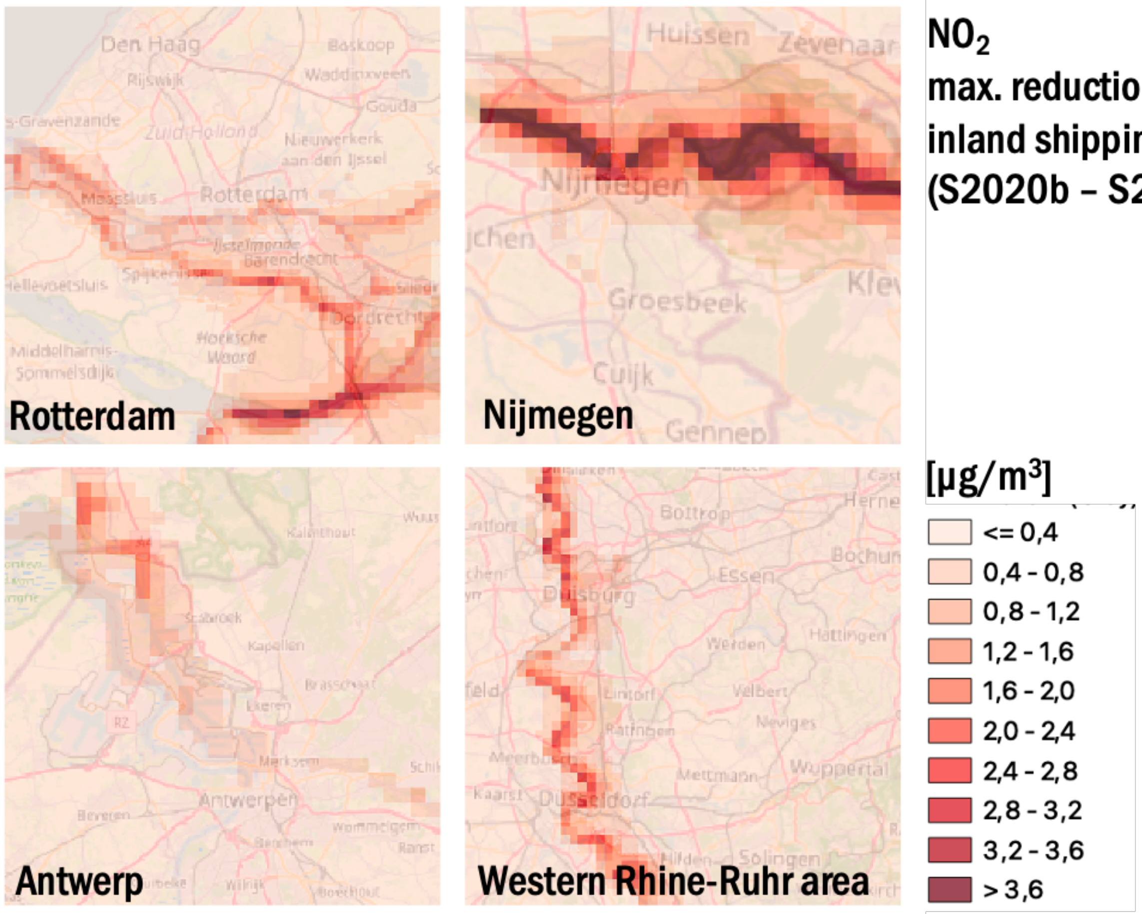
Results

Reduction potentials inland shipping CLINSH scenarios

NO_2

pollutant		WHO2021
NO_2 [µg/m³]	annual	**10**

NO_2
max. reduction of inland shipping (S2020b – S2035c)



domain	Mean red. [%] S2035b	Mean red. [%] S2035c
Rotterdam	-25	-72
Nijmegen	-23	-76
Antwerp	-22	-70
Western Rhine-Ruhr area	-20	-76

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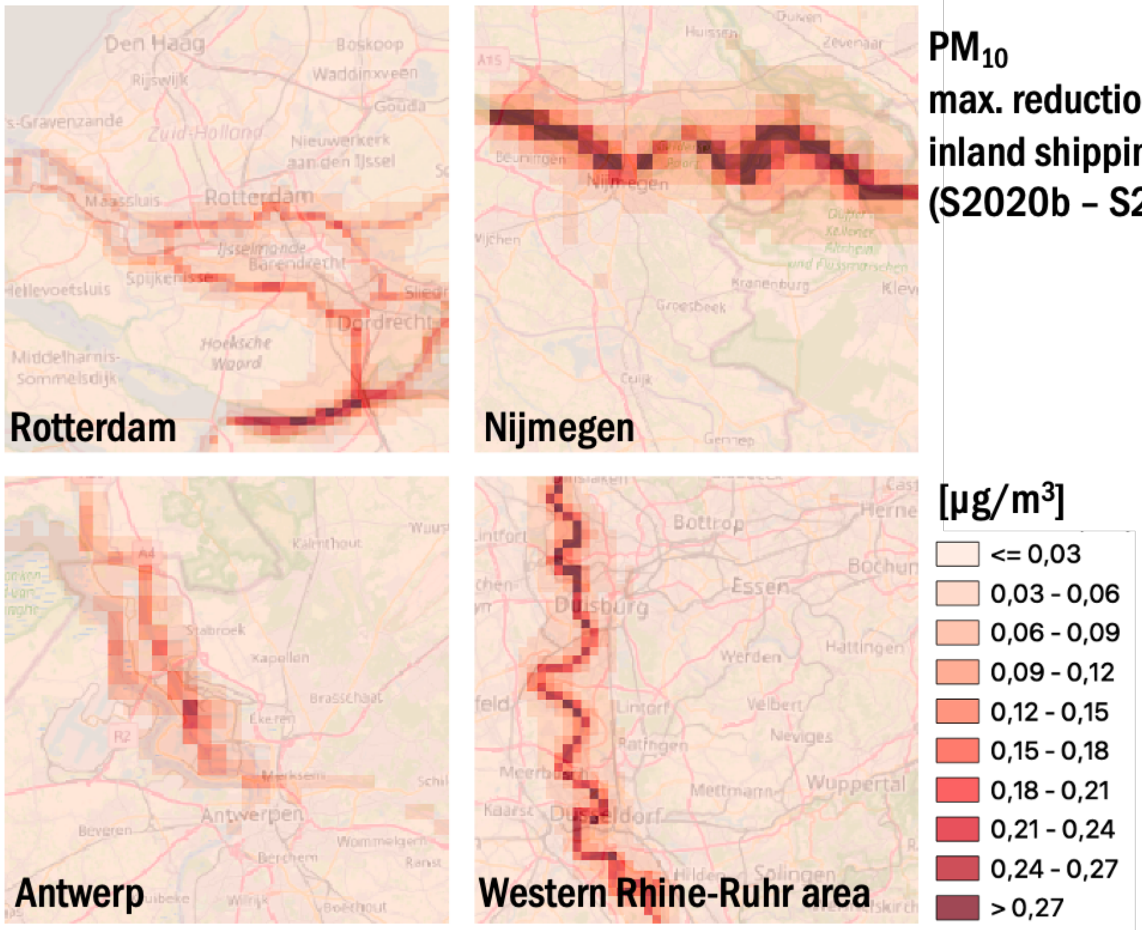
Results

Reduction potentials inland shipping CLINSH scenarios

PM_{10}

pollutant		WHO2021
PM_{10} [µg/m³]	annual	15



PM_{10}
max. reduction of inland shipping (S2020b – S2035c)

domain	Mean red. [%] S2035b	Mean red. [%] S2035c
Rotterdam	-25	-66
Nijmegen	-33	-89
Antwerp	-23	-61
Western Rhine-Ruhr area	-27	-85

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Summary

We developed a Chemistry transport modelling chain to identify the impact of inland shipping emissions:

- Based on CLINSH emission factor for inland vessels
- Applying CLINSH emission scenarios
- Applicable to any urban area in Europe
- Achieving comparable & consistent results for air quality impacts

We identified high potentials to improve the air quality by applying technologies and pathways as evaluated and promoted in the CLINSH project.

Highest reduction potentials (improvements in air quality) are achieved in the **S2035c** scenarios for all cities under investigation:

PM_{10} **61–89%** reduction potential on average
NO_2 **70–75%** reduction potential on average

Focus on NO_2, due to very low PM_{10} contributions in S2020b/S2035b/S2035c.

Thank you for your attention!

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Final conference – 25th Nov 2021
Vlaadingen - NL

Dr. Martin Ramacher
Dr. Armin Aulinger

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