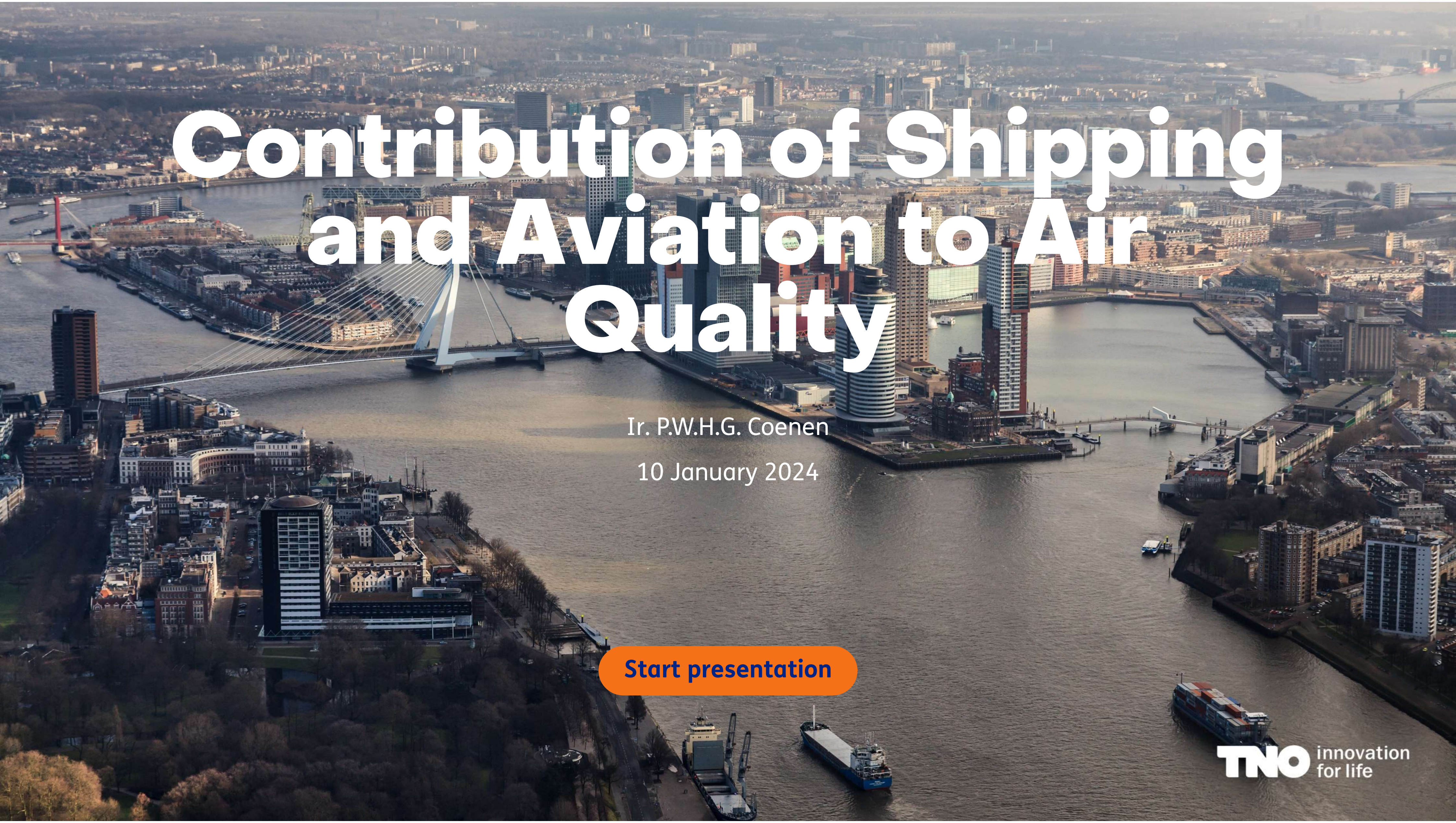


Contribution of Shipping and Aviation to Air Quality

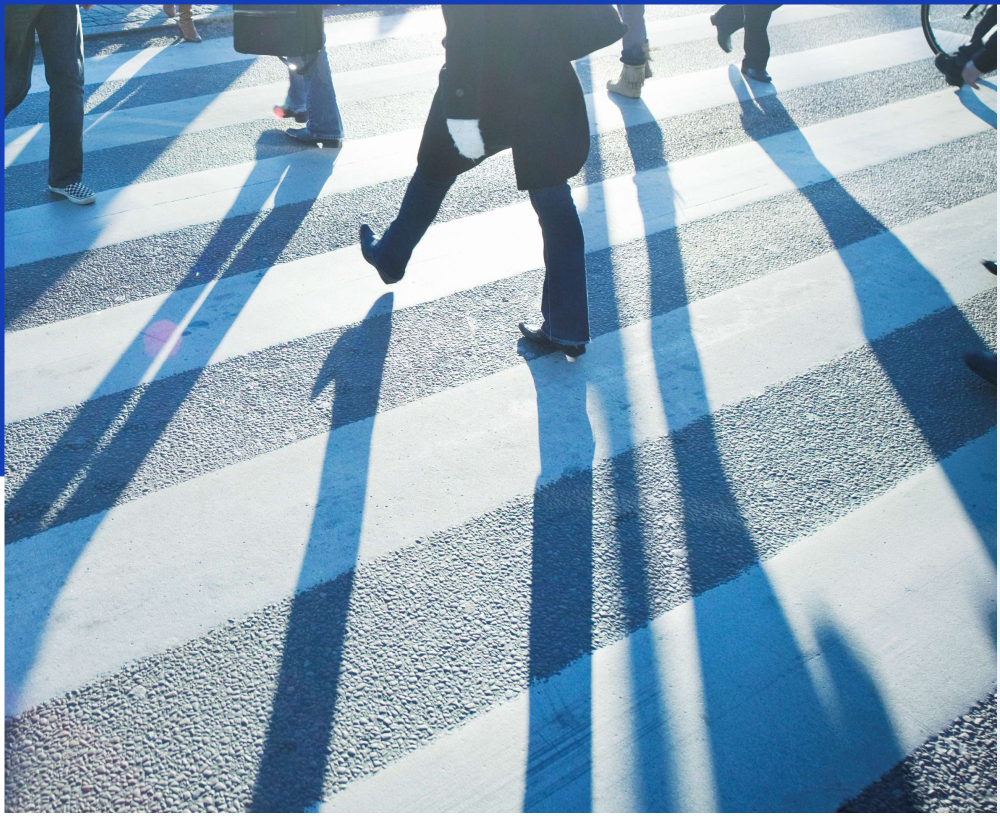
Ir. P.W.H.G. Coenen

10 January 2024

Start presentation

TNO innovation for life

Agenda



1. Introduction
2. Approach
3. Emission data
4. Results Maritime study
5. Result Aviation study
6. Overall conclusion

Introduction

Concawe commissioned TNO to determine the contribution of shipping and aviation emissions to local air quality in cities.

Why these studies:

- Emissions from major urban sources decreased over the past decades as a result of EU legislation:
  - industrial sources
  - road transport

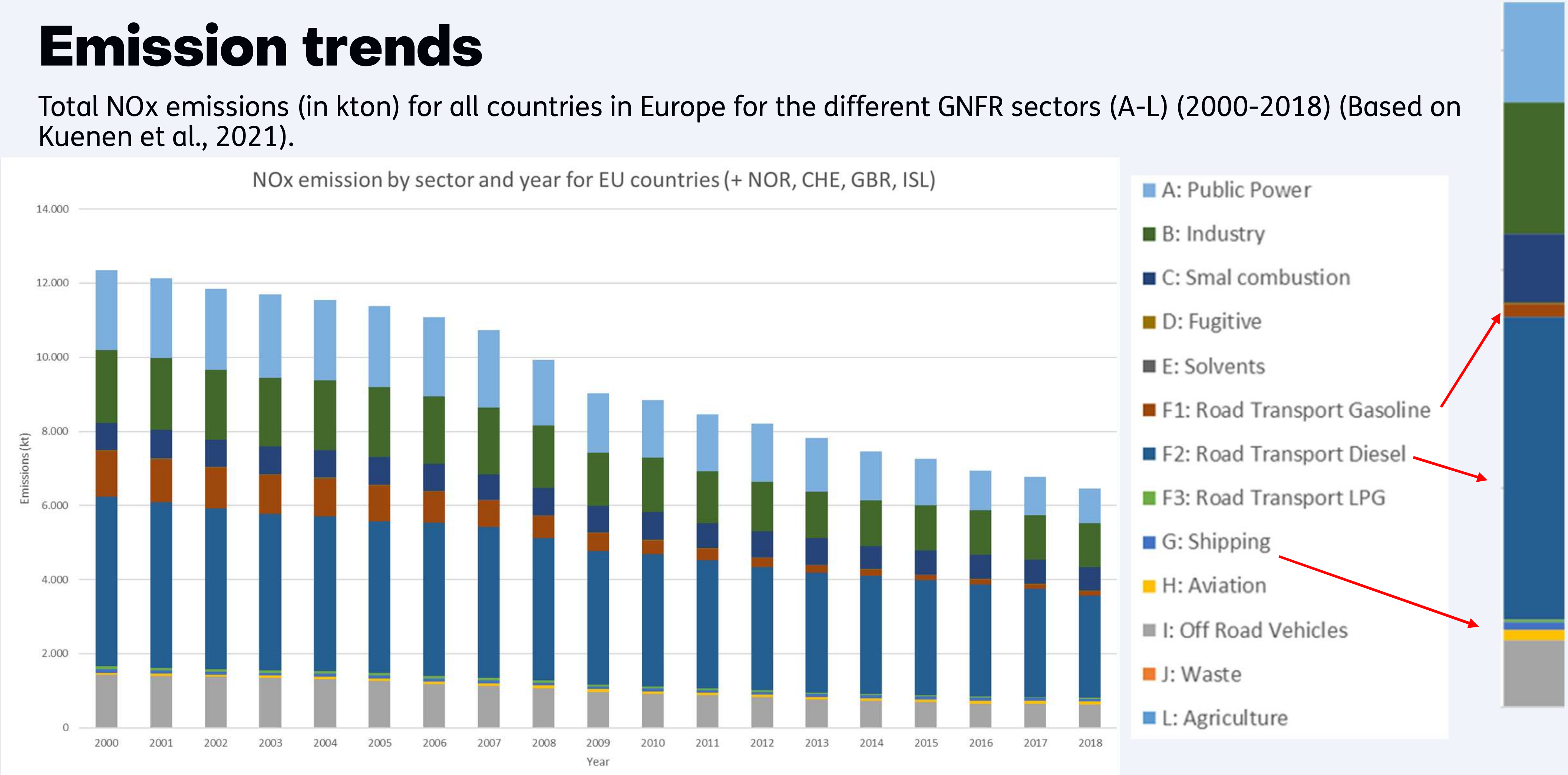
- ***Other, formerly less contributing, sources become more relevant***

Objective of the studies:

Enhance Concawe's understanding on the role of the shipping and aviation emissions in the current air quality in major cities.

Emission trends

Total NOx emissions (in kton) for all countries in Europe for the different GNFR sectors (A-L) (2000-2018) (Based on Kuenen et al., 2021).



Approach #1

Approach

Chemical transport model to calculate AQ (NO_2, SO_2, $PM_{2.5}$ and PM_{10}):

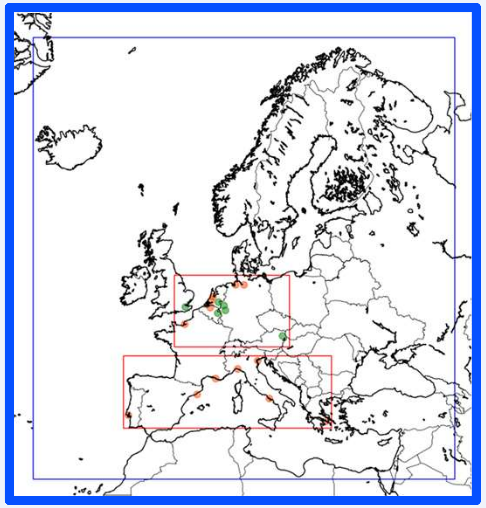
- Labelling approach (contribution of shipping and aviation and 10 other sectors are calculated)

Resolution:

- First run over Europe 25x25km
- Followed by nested runs of 6x6km (and 1x1km) runs

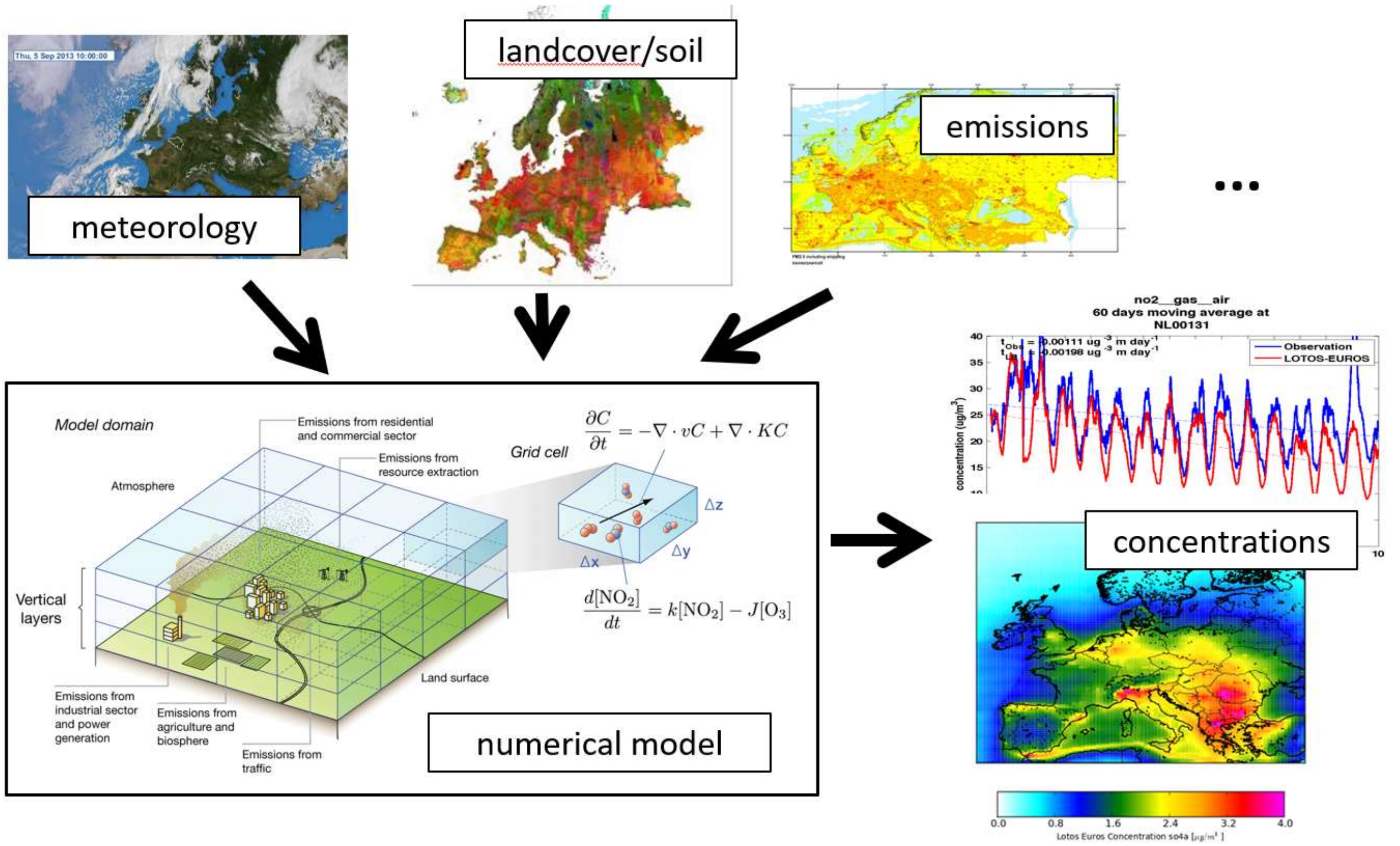
Targeted urban area's:

- Maritime study: Calculations for 13 sea ports and 6 inland ports
- Aviation study: Calculations for 6 major international airports



Approach #2

LOTOS-EUROS AQ Model



Emission data

Emission datasets used (NO_2, SO_2, $PM_{2.5}$ and PM_{10}):

(6x6 km and 1x1 km)

- CAMS-REG v5.1 inventory emission data for the year 2018 *(6x6 km)*
  - Based on National Inventories from Member States, but....
  - ➢ National shipping data are replaced by shipping emissions based on AIS data.
    (these cover al seagoing shipping, also those not reported in the official inventories)
  - ➢ Non-anthropogenic sources such as biogenic emissions and volcanos are included
- TNO GHG-co 1x1 km v1.0 (1x1km, no PM and SO_2)

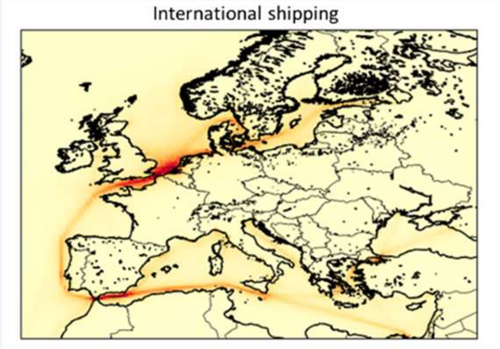
- For Germany and The Netherlands a high resolution dataset was used which consider airports as surface sources rather than point sources. (i.e., more detailed representation of airports with runways)

Theme name **Maritime study**

Maritime study

Important aspects related to the shipping emission datasets used (NO_2 in kton):

From National inventories											From CAMS_REG	
NFR category	Description	NLD	GBR	BEL	DNK	DEU	FRA	NOR	SWE	Total	Description	
1A3di(ii)	International inland waterways	16.6	N.O.‡	2.1	0.0	I.E.*	0.8	N.O.‡	N.O.‡	19.4		
											Inland shipping	65.4
1A3dii	National navigation (shipping)	9.0	88.0	4.0	11.3	23.9	10.1	29.0	8.6	183.9		
1A4ciii	Fishing: National fishing	7.0	12.0	0.1	4.2	0.4	17.4	8.1	1.7	50.9		
MEMO	International maritime navigation (bunkers)	102.8	238.8	16.2	40.0	84.0	157.6	12.2	88.0	739.6		
Sum of seagoing emissions		118.9	338.8	20.3	55.5	108.2	185.1	49.3	98.3	974.4	North Sea	429.3

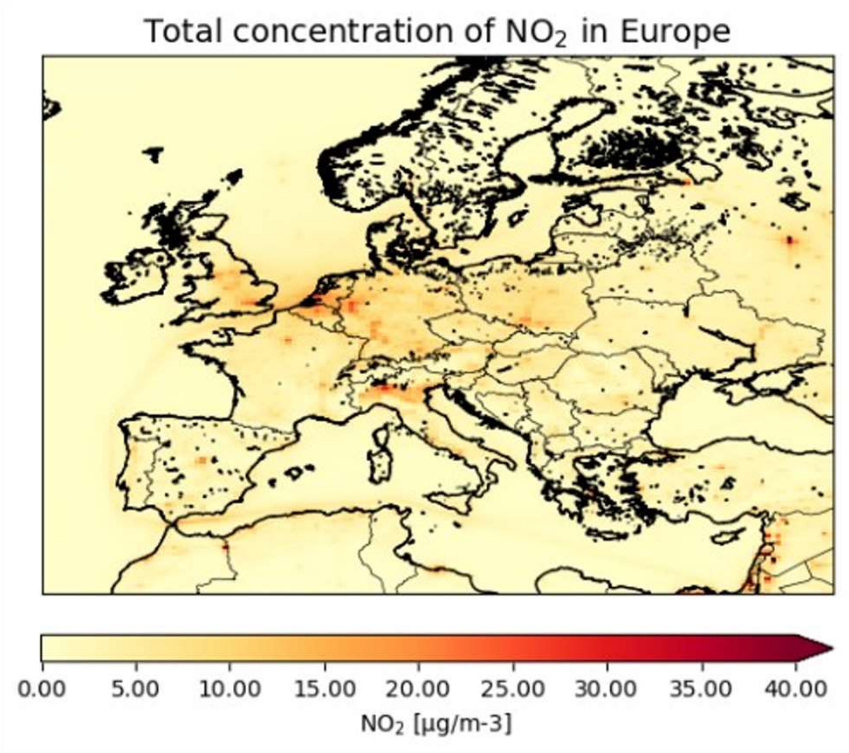


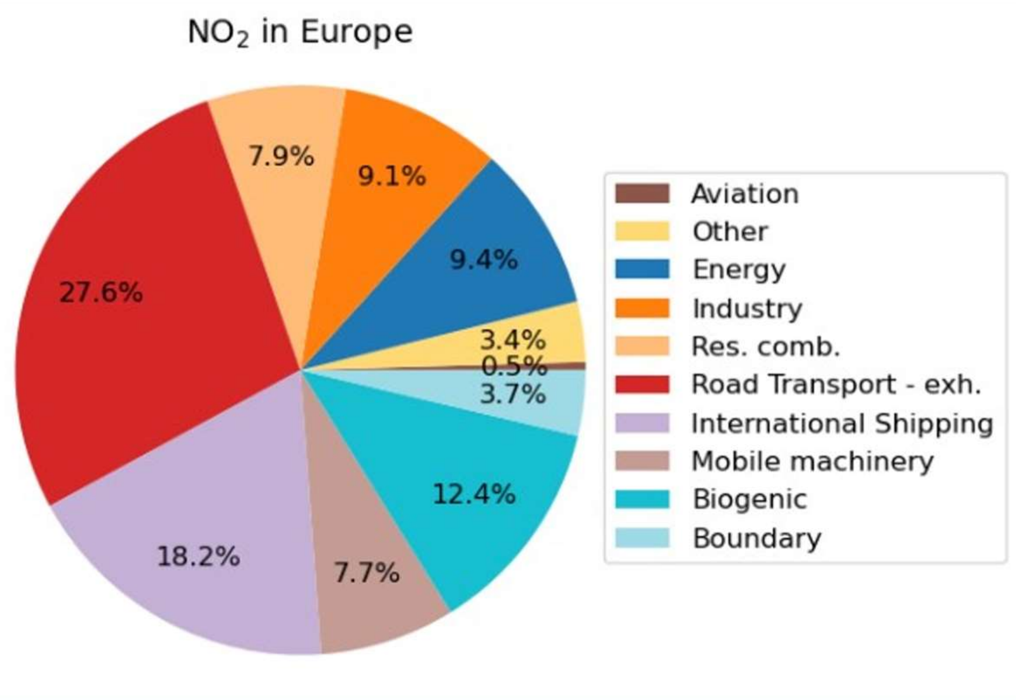
Maritime study

- Seaports:
  - Rotterdam
  - Antwerp
  - Hamburg
  - Amsterdam
  - Marseille
  - Bremenhaven
  - Barcelona
  - Le Havre
  - Genoa
  - Piraeus
  - Lisbon
  - Naples
  - Venice

- Inland ports:
  - Vienna
  - Liege
  - Duisburg
  - Nijmegen
  - Londen
  - Cologne

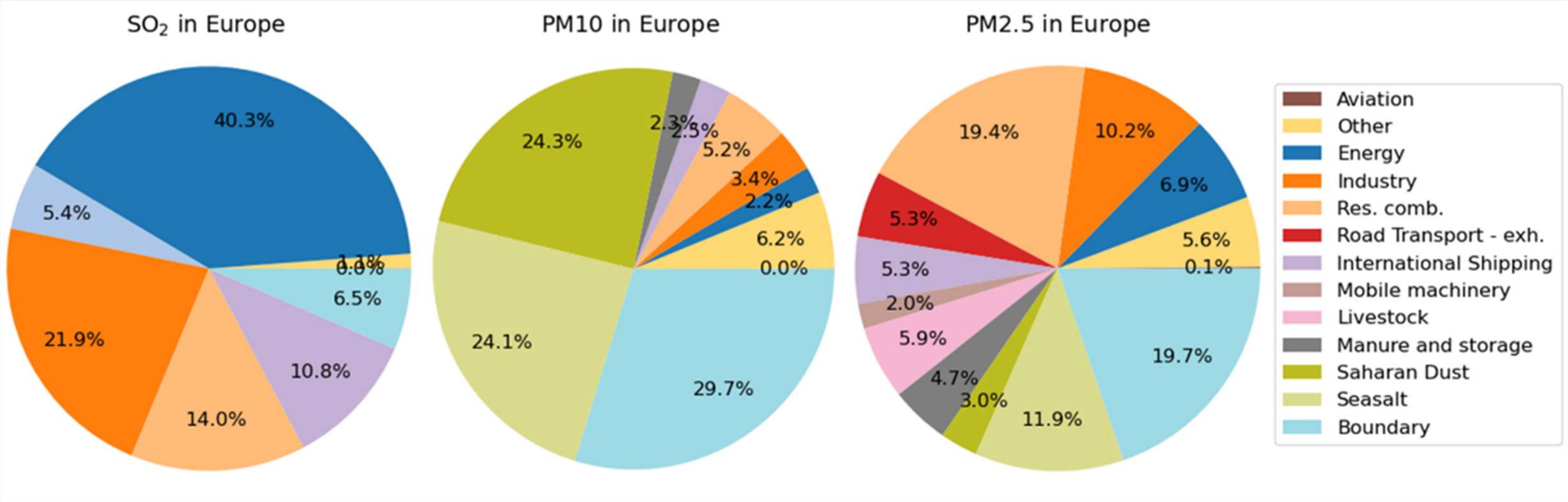
Results Maritime study (EU scale)





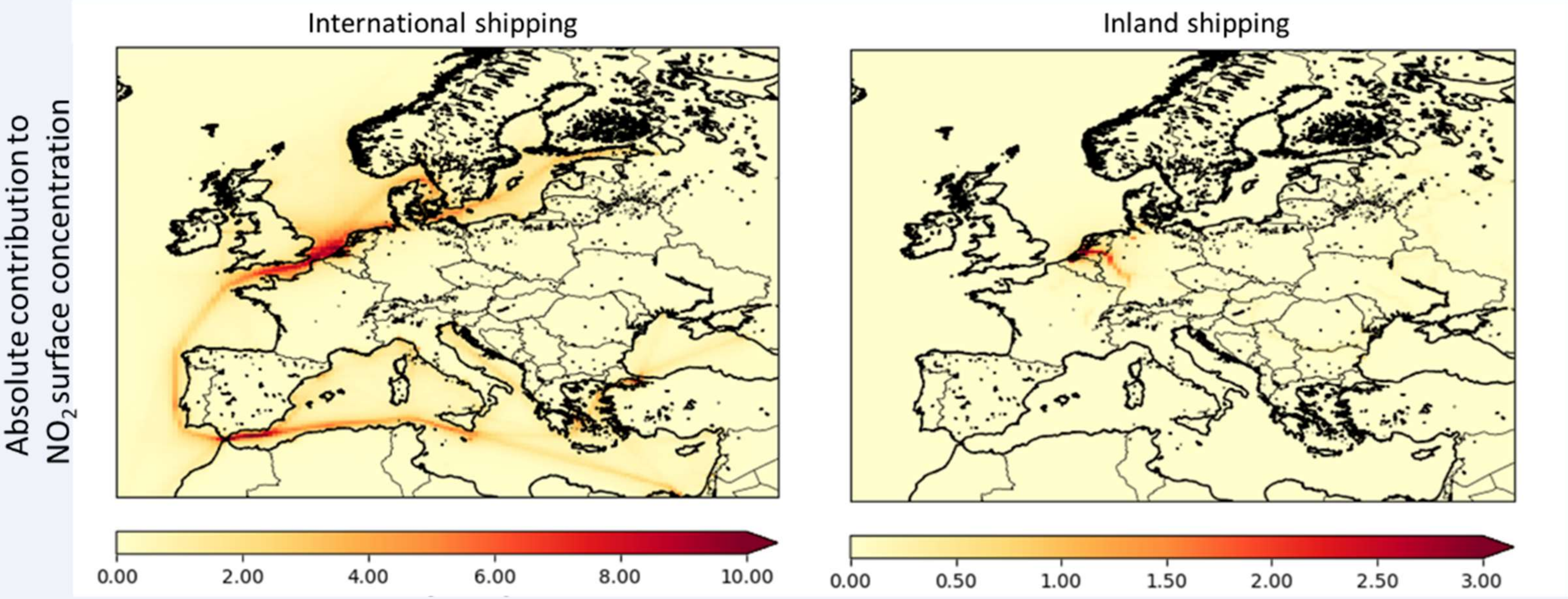
The annual average NO_2 surface concentration for 2018 in the simulation domain of the coarse (25x25km) resolution LOTOS-EUROS simulation. The relative contributions from the various sectors to the surface concentration of NO_2 for the entire simulation domain (right panel).

Results Maritime study (EU scale)

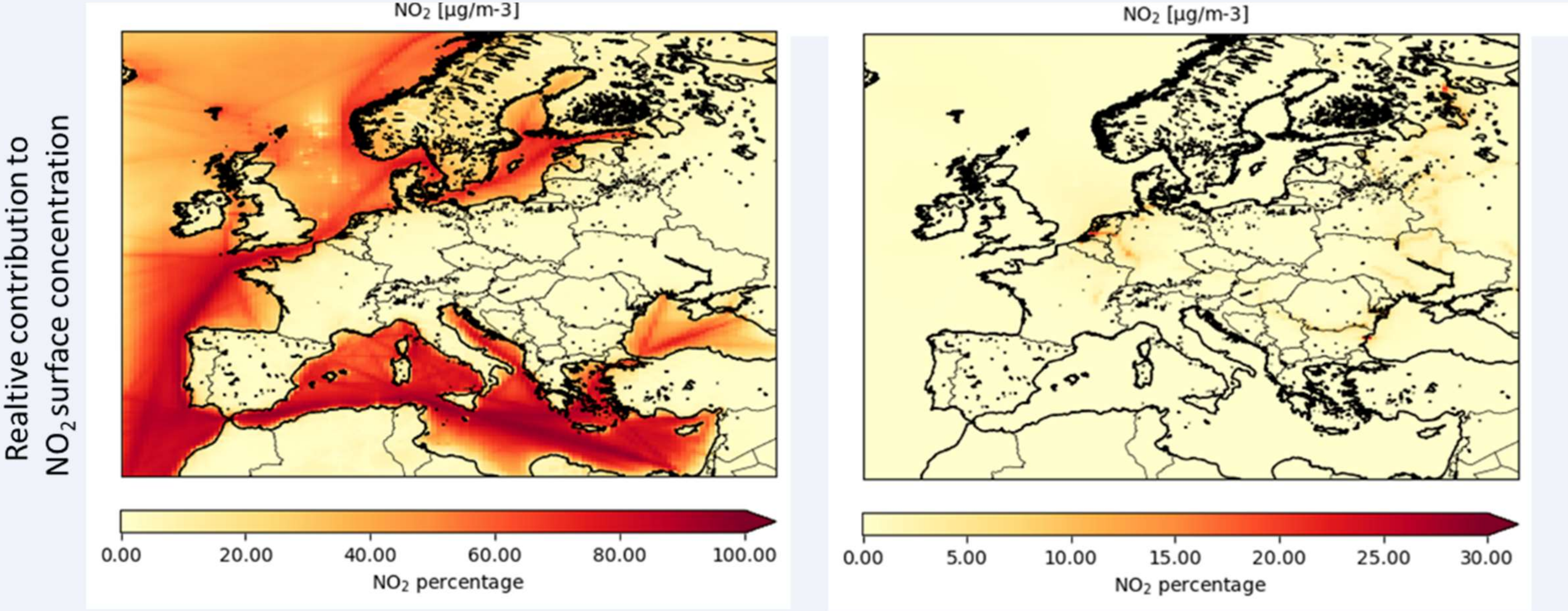


Relative contributions from the various labelled sectors to the surface concentration of SO_2, PM10 and PM2.5 for the entire simulation domain.

Results Maritime study (EU Scale)

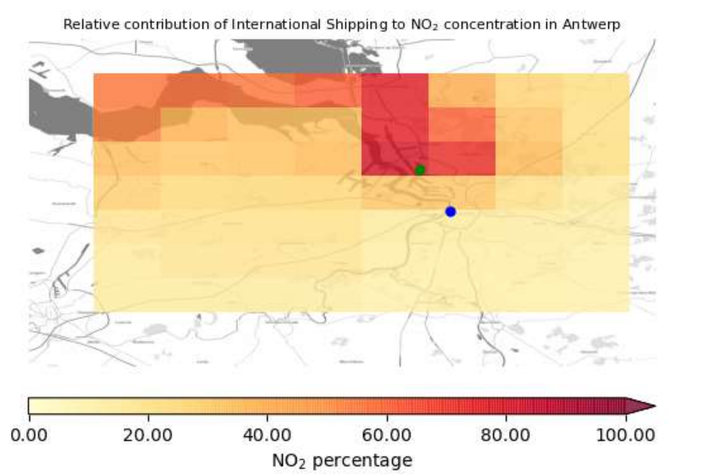


Results Maritime study (EU Scale)

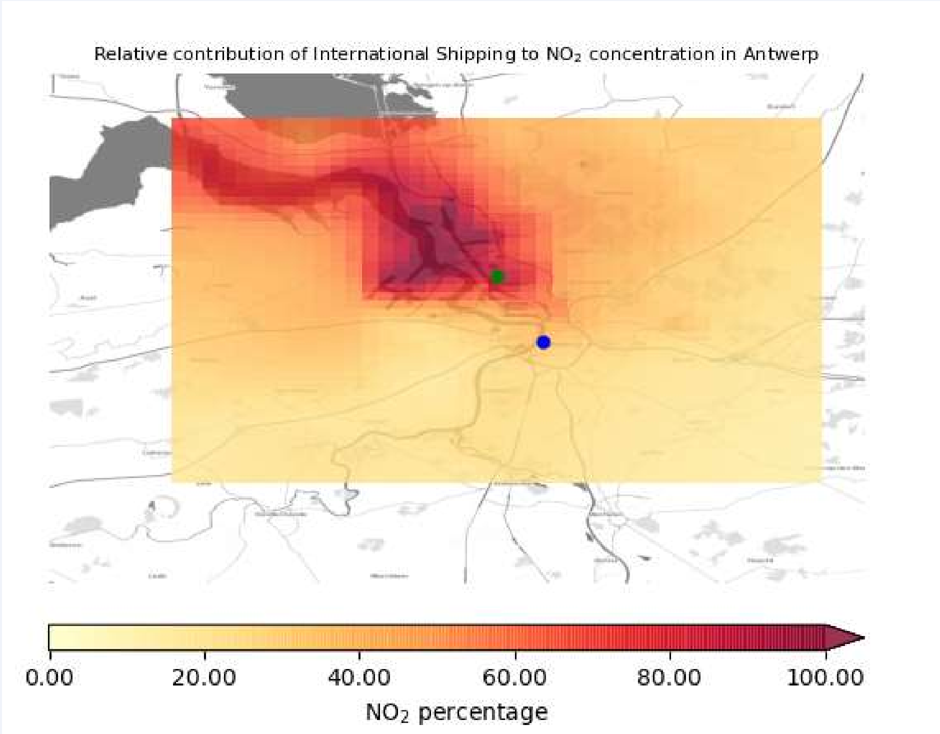


Results Maritime study (example for Antwerp)

6x6 km resolution

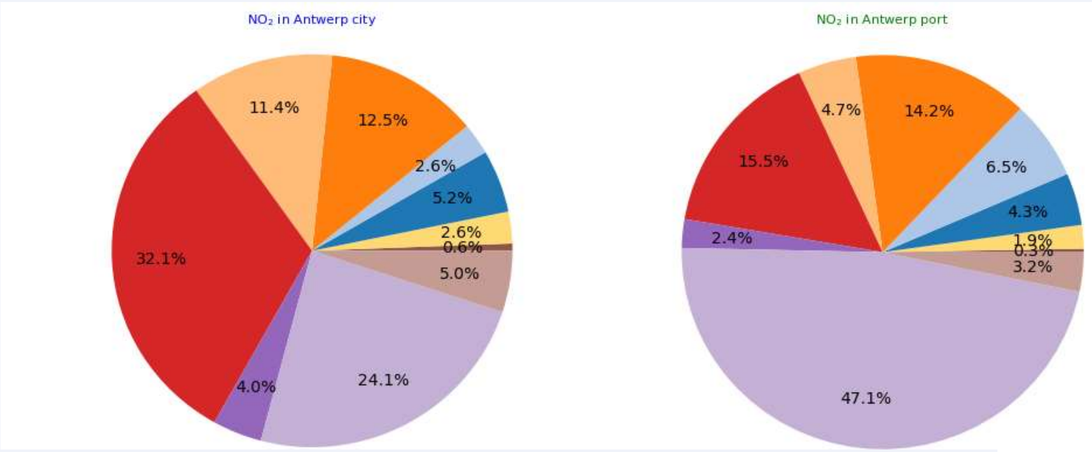


1x1 km resolution



Results Maritime study (example for Antwerp)

6x6 km resolution



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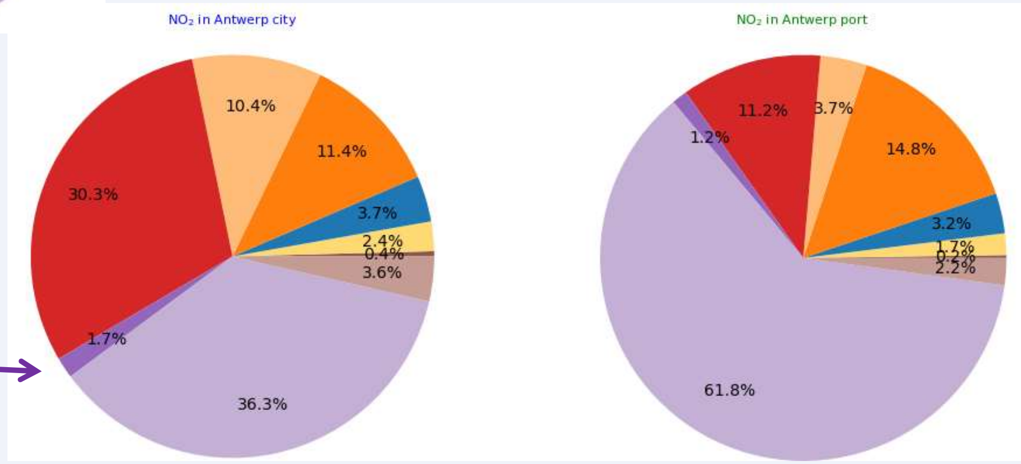


Inland shipping

Results Maritime study (Sea ports)

	Annual average NO_2 concentration [µg/m³]	Inland shipping contribution (%)	International shipping contribution (%)
	Sea Ports		
Rotterdam	28	29 (10.7)	13 (14)
Antwerp	24	4.0 (1.7)	24 (36)
Amsterdam	22	16	13
Hamburg	23	4.0 (1)	26 (39)
Bremerhaven	21	1.3	59
Marseille	14	0.0	29
Barcelona	32	0.0	20
Le Havre	14	0.3 (0.2)	51 (62)
Genoa	19	0.0	48
Piraeus	34	0.0	34
Lisbon	15	0.0	15
Naples	25	0.0	19
Venice	16	0.0	28
Average SP	22	4.2	28

The contribution of shipping (%) to the annual average concentration of NO_2 in the city centres.

Between brackets: 1x1km run

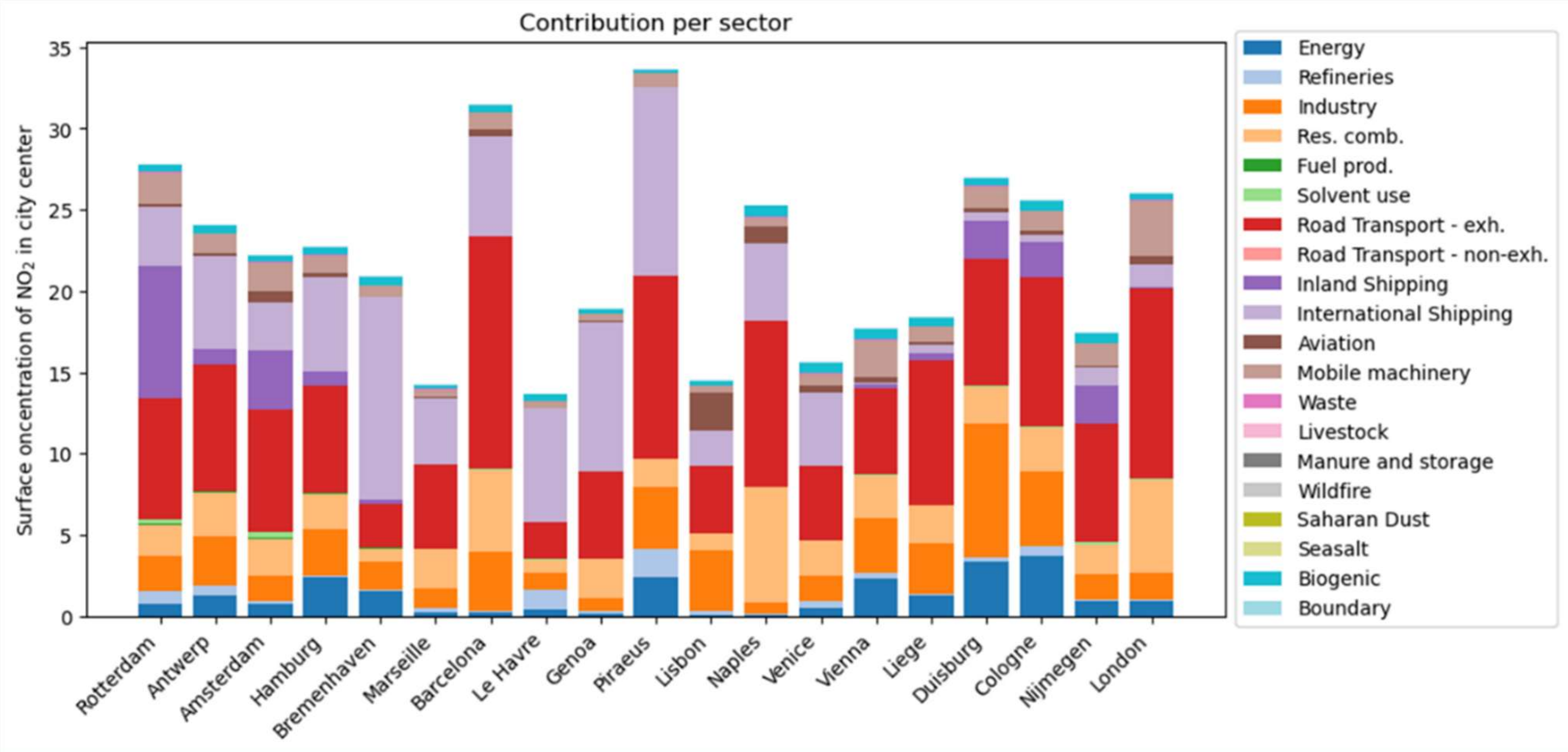
Results Maritime study (Inland Ports)

	Annual average NO_2 concentration [µg/m^3]	Inland shipping contribution (%)	International shipping contribution (%)
	Inland Ports		
Vienna	18	1.6	0.3
Liege	18	2.7	2.8
Duisburg	27	8.7	2.0
Cologne	26	8.6	1.6
Nijmegen	17	13	6.5
London	26	0.2	5.5
Average IP	22	5.8	3.1

The contribution of shipping (%) to the annual average concentration of NO_2 in the city centres.

Marine study (overall results)

The contribution per sector to the annual average concentration of NO_2 in the city centres

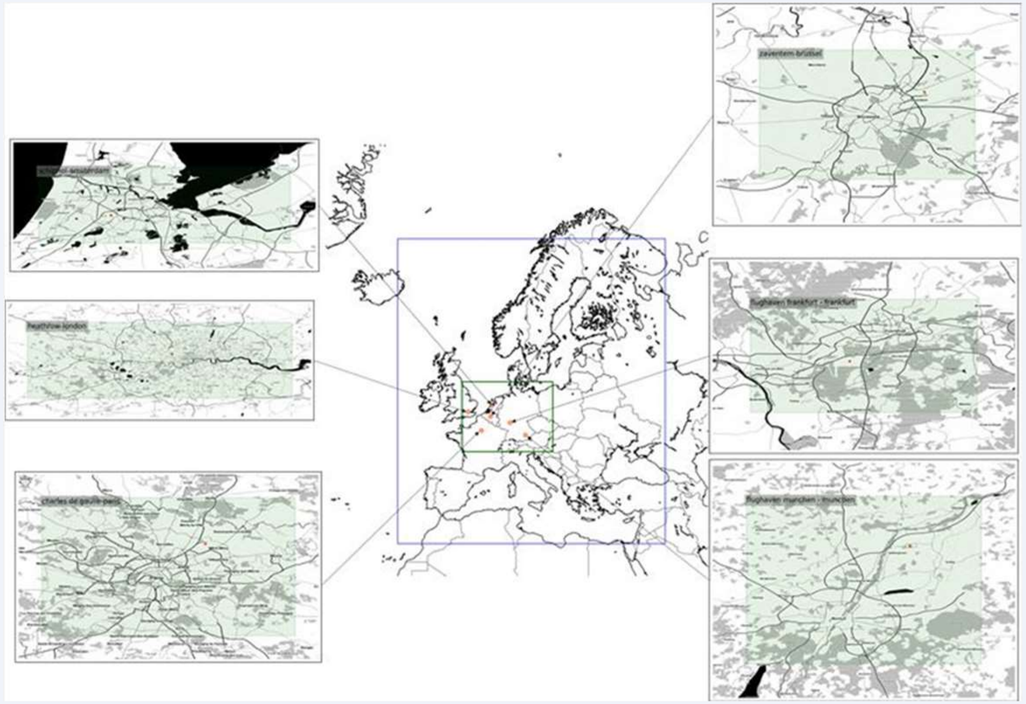


Aviation study

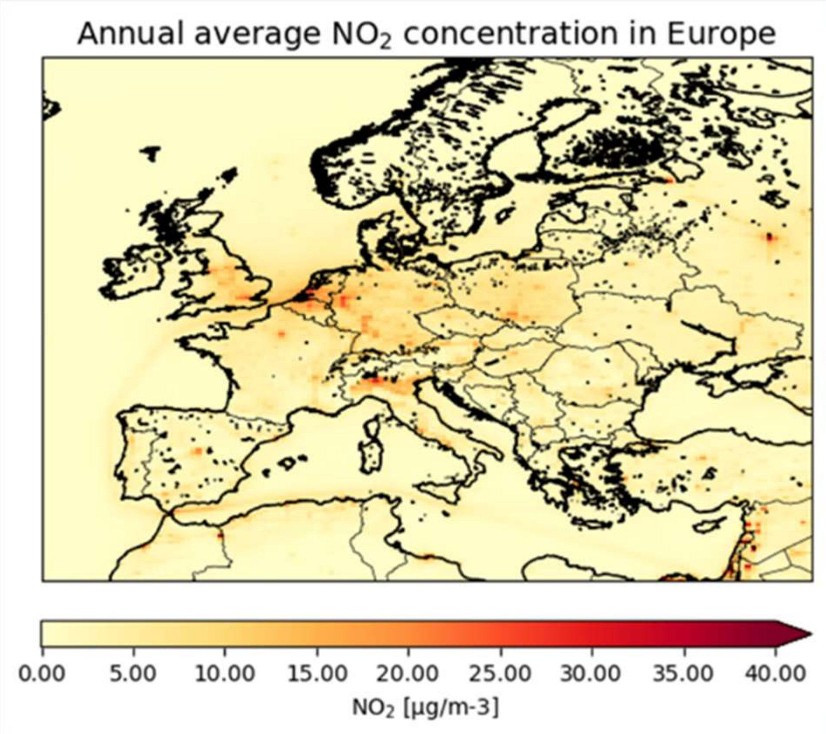
Selected Airports

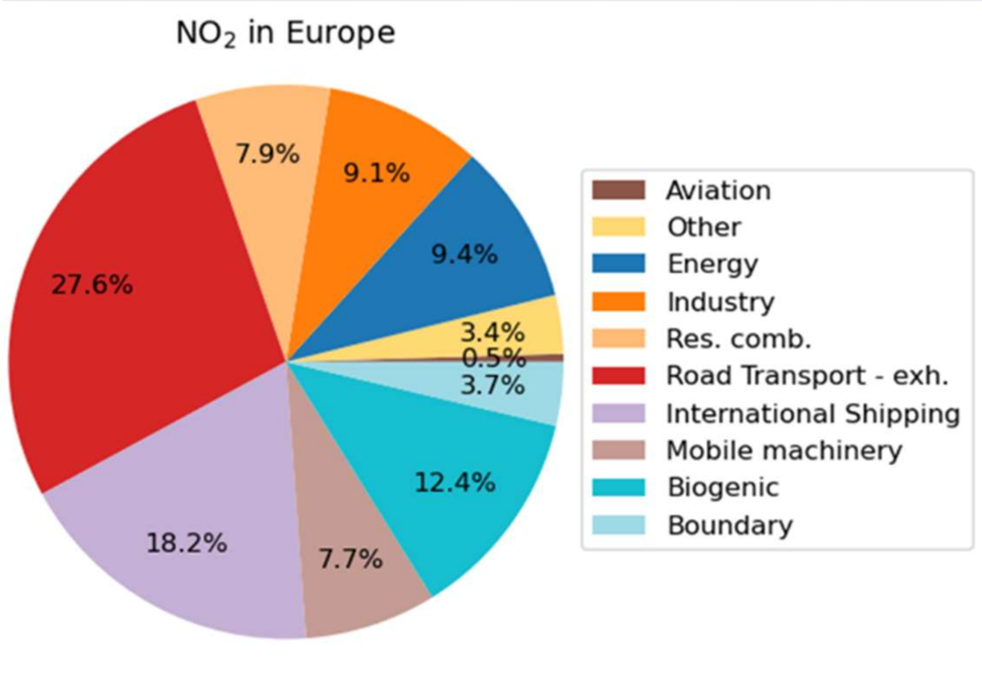
1. London (UK)
2. Paris (FR)
3. Amsterdam (NL)
4. Frankfurt am Main (GE)
5. Munich (GE)
6. Brussels (BE)

High resolution emission datasets



Results Aviation study (EU scale)

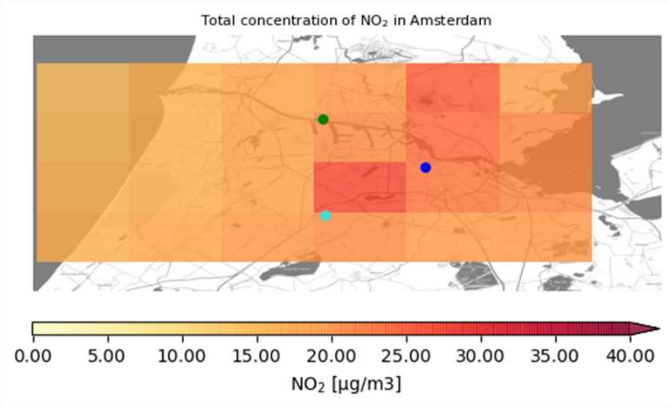




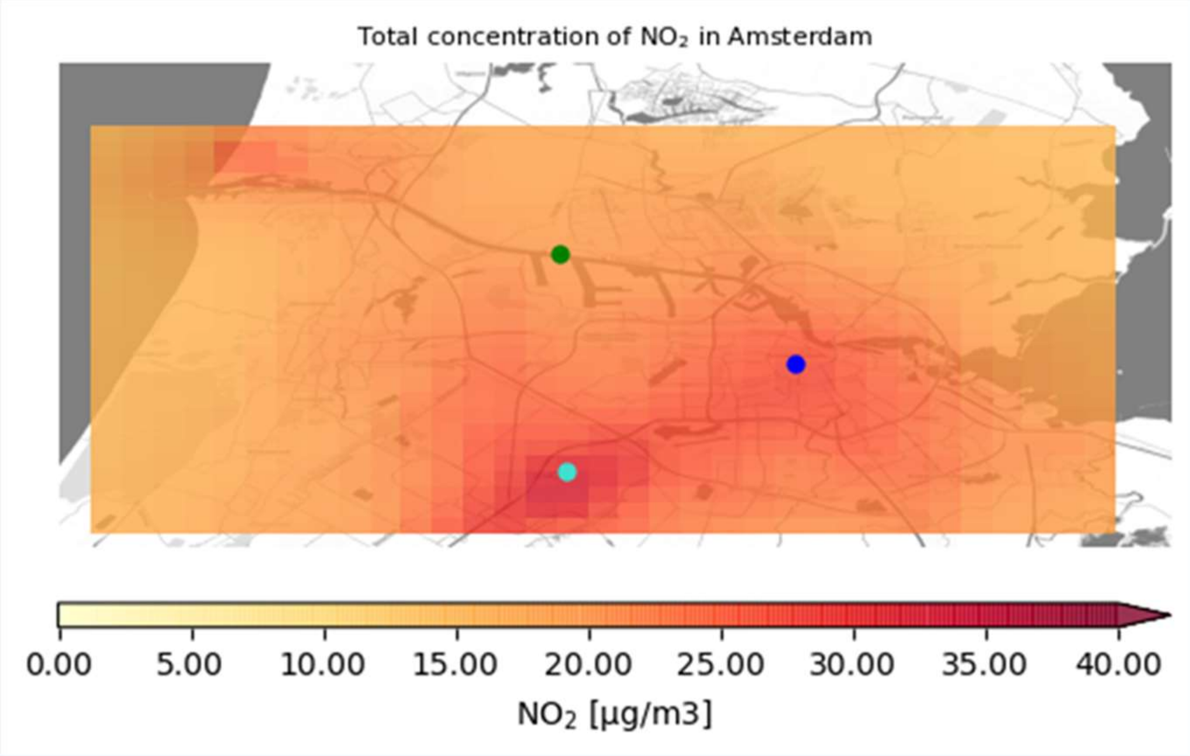
The annual average NO_2 surface concentration for 2018 in the simulation domain of the coarse (25x25km) resolution LOTOS-EUROS simulation. The relative contributions from the various sectors to the surface concentration of NO_2 for the entire simulation domain (right panel).

Results Aviation study (example Amsterdam)

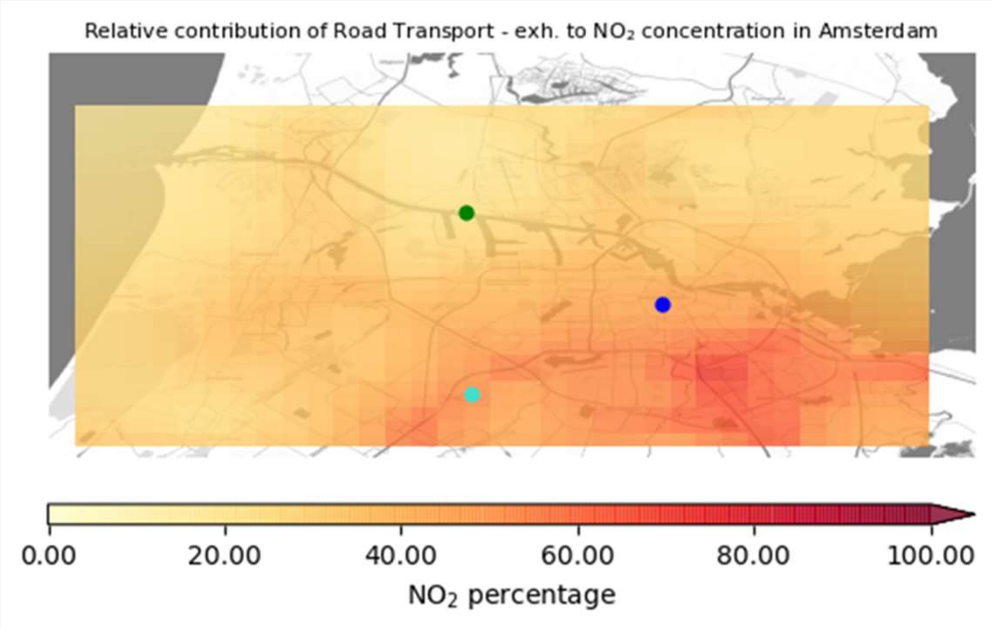
6x6 km resolution

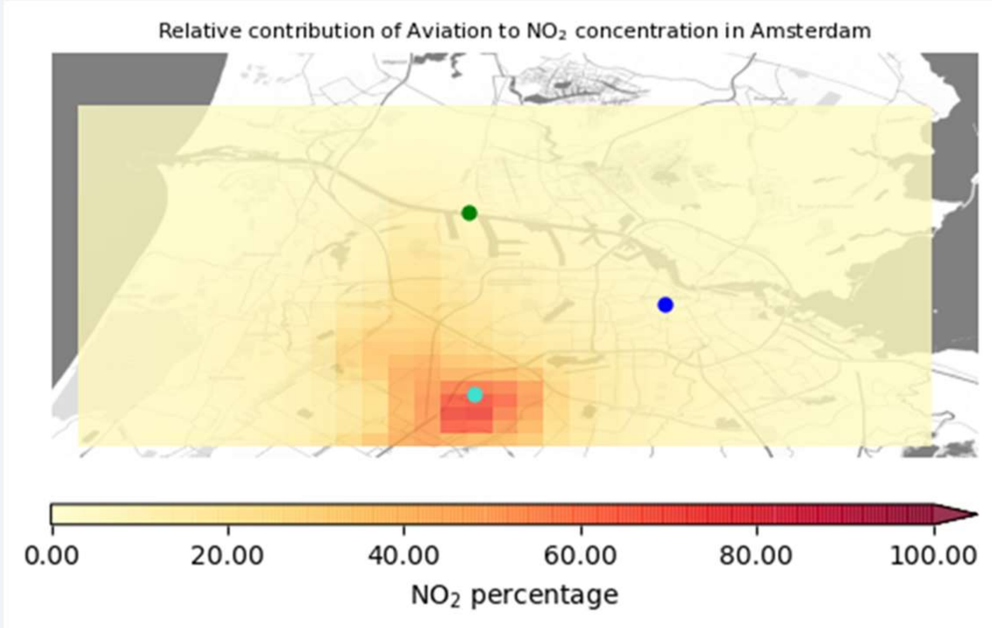


1x1 km resolution

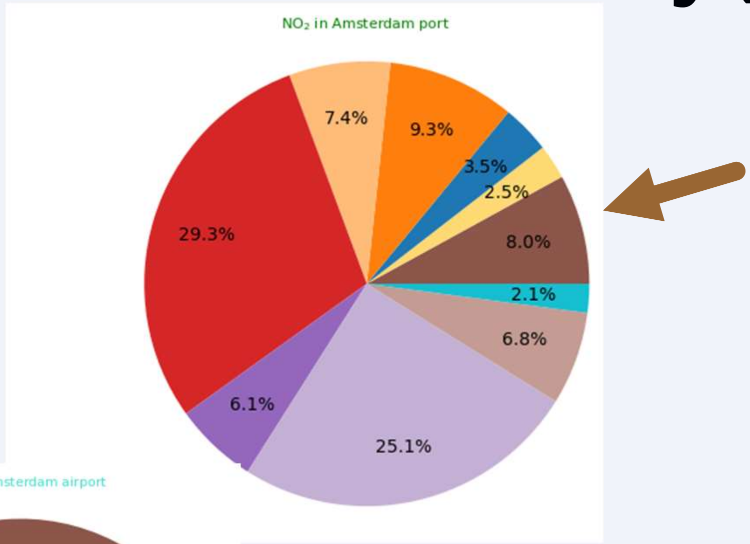


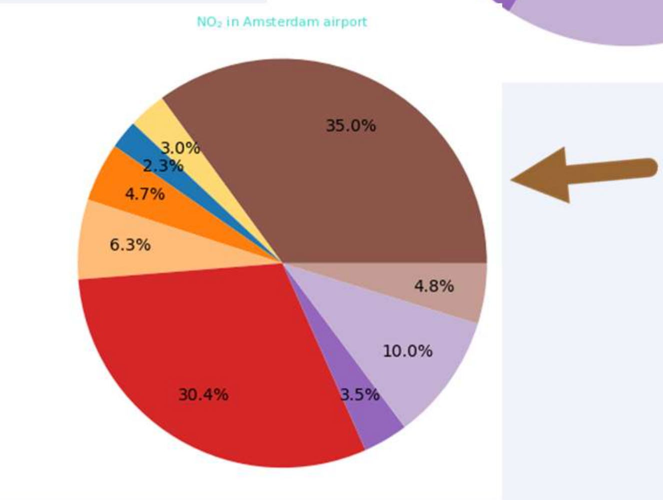
Results Aviation study (example Amsterdam)

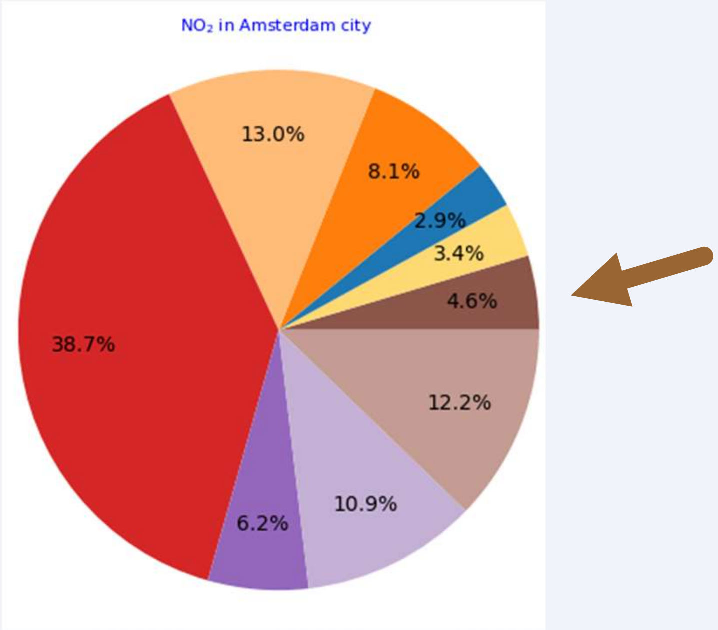




Results Aviation study (example Amsterdam)





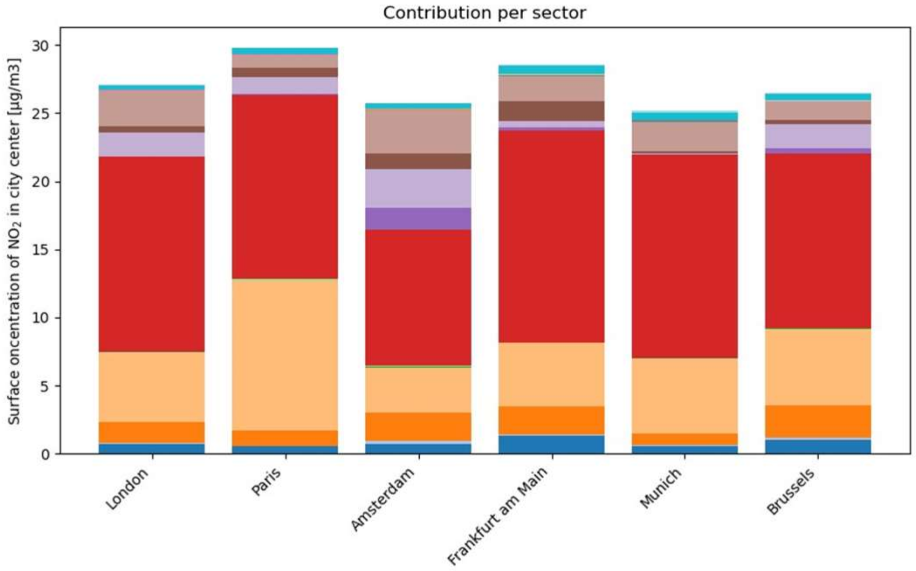


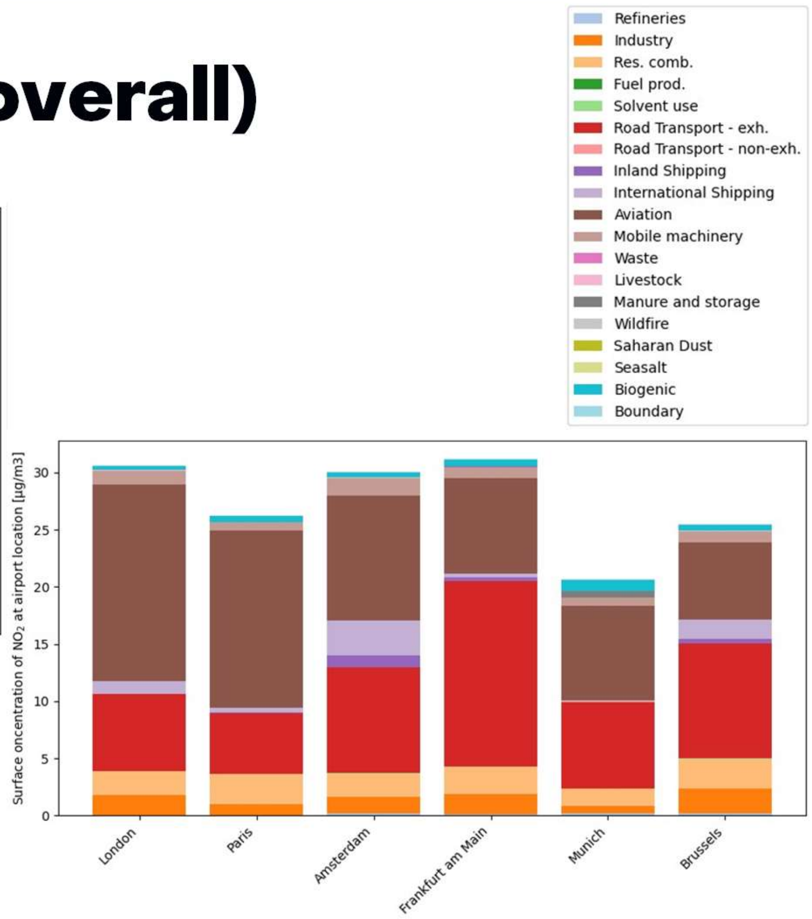
Results Aviation study (overall)

	Annual average NO_2 concentration [µg/m³]	Aviation contribution to annual NO_2 concentration (%)	Distance from city centre to airport [km]	Airport source type
London	27	1.6	25	Point
Paris	30	2.3	30	Point
Amsterdam	26	4.6	15	Surface
Frankfurt am Main	29	5.0	12	Surface
Munich	25	0.5	35	Surface
Brussels	27	1.2	9	Point
Average	27	2.5	-	-

The relative contribution of aviation (%) to the annual average concentration of NO_2 in the city centres.

Results Aviation study (overall)





Conclusions

- **Maritime study:**
  - International shipping can be the dominant contributor to NO_2 concentrations in cities.

    (Bremen, Le Havre and Genoa they contribute respectively 59%, 51% and 48%)
  - International shipping is the responsible for the second biggest fraction of the NO_2 concentration (after road transport exhaust emissions)
  - Other pollutants on average: 18% for SO_2, 8% for $PM_{2.5}$ and 6% for PM_{10}.
  - Inland shipping has only a minor contribution to AQ

- **Aviation study:**
  - Aviation emissions contribute for 0.5 to 4.6 % to NO_2 concentrations in studied city centres.
  - Near airports the contribution can be an order of magnitude higher (depending on location)

Conclusions

- **Overall:**
  - ➢ The maritime and aviation sectors are important targets for improving air quality in cities

  - ➢ Key in making the correct analysis:
  - ○ Spatial resolution and completeness of the emissions used in AQ modelling is key
  - ○ Correct analysis of sectoral analysis on basis of source apportionment

  - ➢ Comparison of model results against observations indicate that improvement of emission timing in the models can improve such analysis

References:

- The impact of shipping emissions to urban air quality in Europe – Detailed port-city analysis – Concawe

- The impact of aviation emissions to urban air quality in Europe – Detailed airport-city analysis – Concawe

- Kuenen, J. et al. (2022) ‘CAMS-REG-v4: a state-of-the-art high-resolution European emission inventory for air quality modelling’, Earth System Science Data, 14(2), pp. 491–515. Available at: https://doi.org/10.5194/essd-14-491-2022.

- Johansson, L., Jalkanen, J.-P. J.-P. and Kukkonen, J.: Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution, Atmos. Environ., 167(Fig 1), 403–415, doi:10.1016/j.atmosenv.2017.08.042, 2017

Thank you for your attention