The Effect of Electro Mobility on Air Quality in Hamburg

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2nd Korea-Germany Environmental Workshop, 13-14 November 2018, Stuttgart

SMURBS

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Motivation

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- **Health impact of high nitrogen dioxide in cities:**
  It is estimated that excessive amounts of nitrogen oxides (NO_2) in the air responsible for the premature death of between 3,000 and 13,000 people in Germany every year, causing a range of health conditions, from strokes to asthma.

- **Electro Mobility concept:**
  Electric cars could help reducing exposure to air pollutants in the city of Hamburg.
  Build up infrastructure for charging electric cars.
  Electric car sharing.
  Fleet quota for electric cars?
  Subsidies or tax deduction for buying electric cars?

About the SMURBS Project

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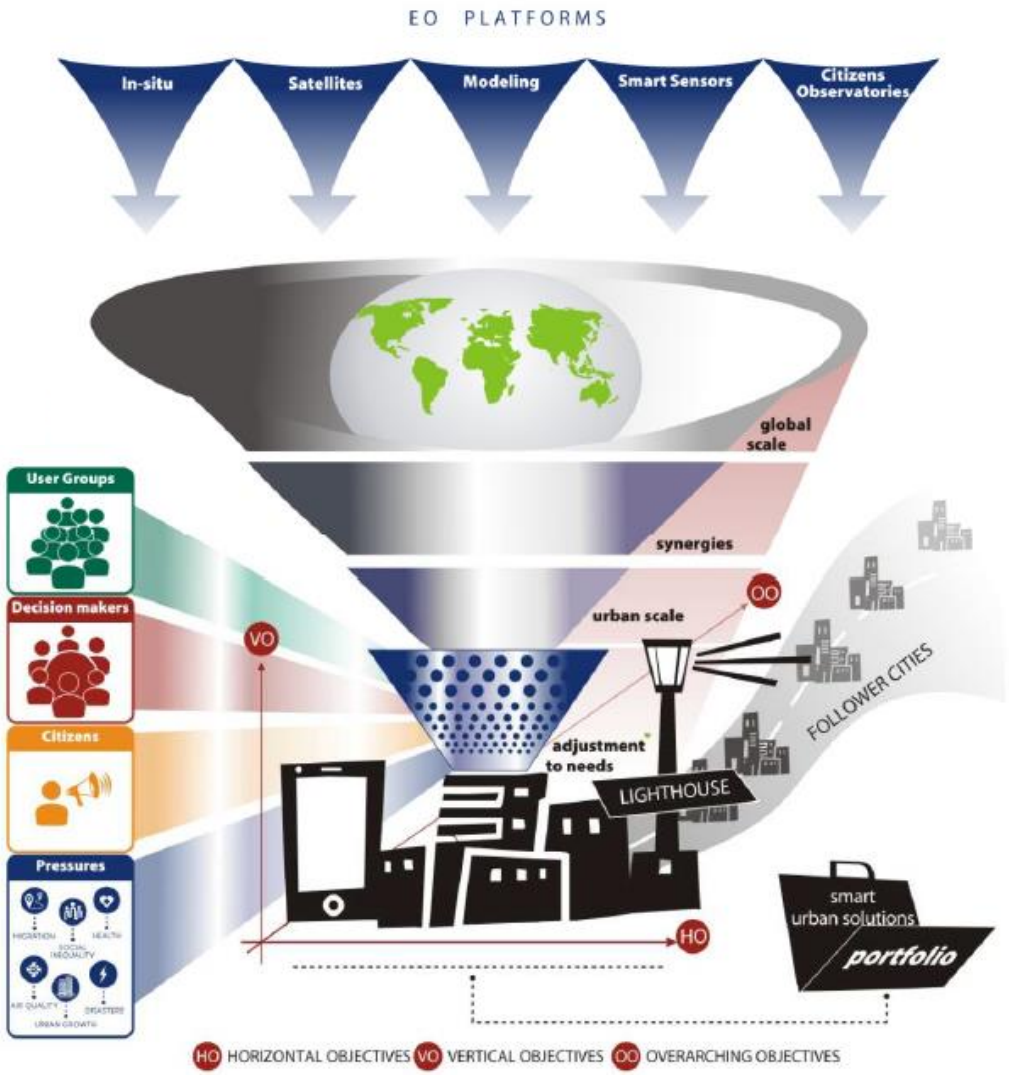
ERA-PLANET project SMURBS

www.smurbs.eu

Smart Urban Solutions for air quality, disasters and city growth.

Integrate „smart city“ methods with Earth Observation expertise to produce new tools for citizens and authorities to enable informed decision making.



Hamburg Air Quality Plan

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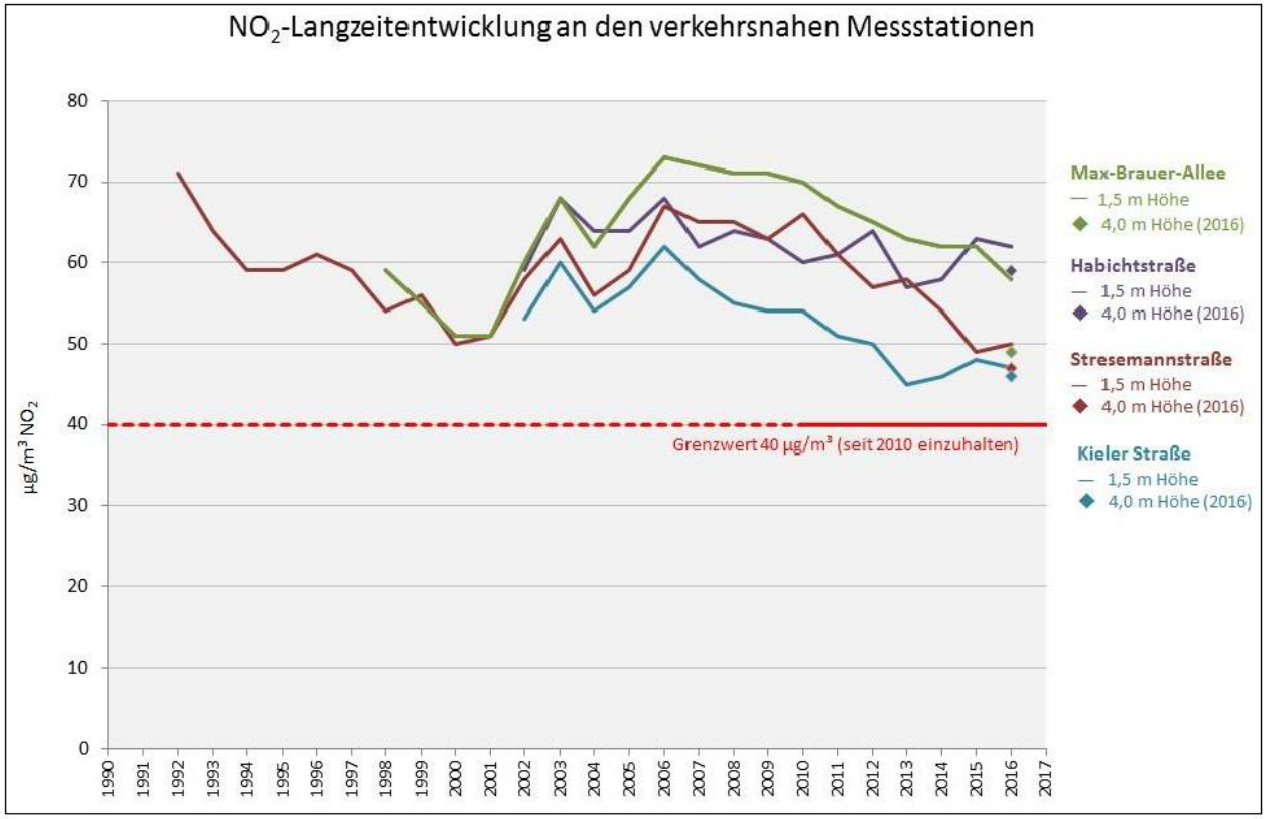
Exceedance of Limit Value at four traffic sites

EU Limit value of 40 micrograms per m^3 has been introduced in Hamburg in 2010 and since then regularly exceeded at all four traffic monitoring stations



Hamburg Luftreinhalteplan, 2017

The Guardian 27.02.2018 / Photograph: Fabrizio Bensch/Reuters

German court rules cities can ban diesel cars to tackle pollution

Landmark ruling could cause traffic chaos and dramatically hit the value of diesel vehicles

Traffic bans in Germany

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City	From	Street / banned vehicle types
Hamburg	06/2018	Stresemannstr. / diesel trucks
Hamburg	06/2018	Max-Brauer-Allee / diesel trucks and cars except Euro 6
Cologne	04/2019	Low emission zone / diesel cars Euro 4 from 09/2019 also diesel Euro 5
Bonn	04/2019	Bälderberg / diesel cars except Euro 6
Bonn	04/2019	Reuterstr. / diesel cars except Euro 6
Mainz	09/2019	to be defined
Berlin	07/2019	11 street segments (total 15 km) diesel trucks and cars except Euro 6
Frankfurt	02/2019	to be defined / diesel cars Euro 4, petrol cars Euro 1+2
Stuttgart	01/2019	diesel cars Euro4 and less banned from entire city
Aachen	01/2019	?

Electro Mobility plan for Hamburg

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Air Quality Plan Hamburg 2017, 7.1.6 MP6 on Electro Mobility

- *Infrastructure for charging → 1000 public charging points in Hamburg*
- *E-Carsharing: 1000 electric cars for car sharing until 2019*
- *Electric LD vehicles for postal delivery*
- *Subsidies for small enterprises: 25 % off for new electric LD vehicles*
- *Free parking in public car parks*
- *29 emission free busses (fuel cells) for public transportation in 2020 (MP5)*

Basis for scenario "EPLAN 2020"

Is the HH electro mobility plan sufficient to improve air quality?

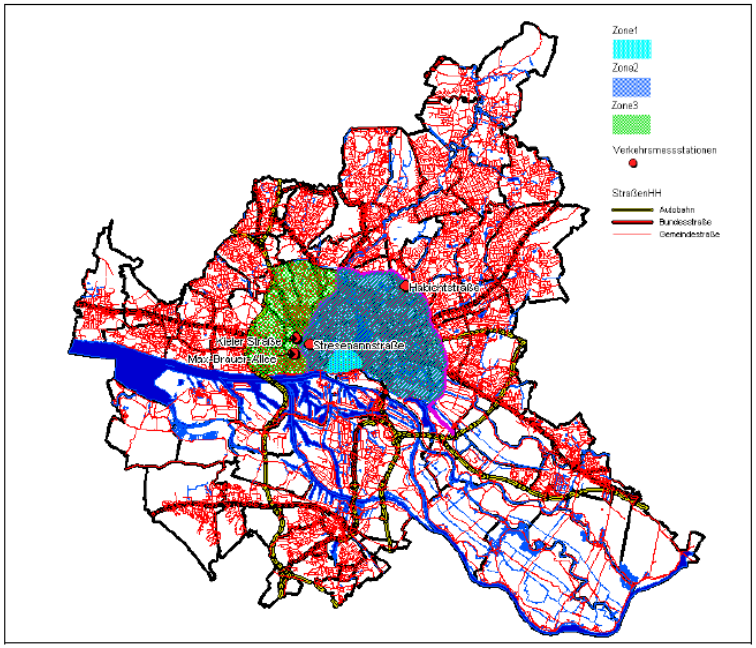
Additional measures: subsidies for citizens to replace their diesel vehicles by electric cars; City tax; open bus lanes for electric cars.

Hamburg City zone

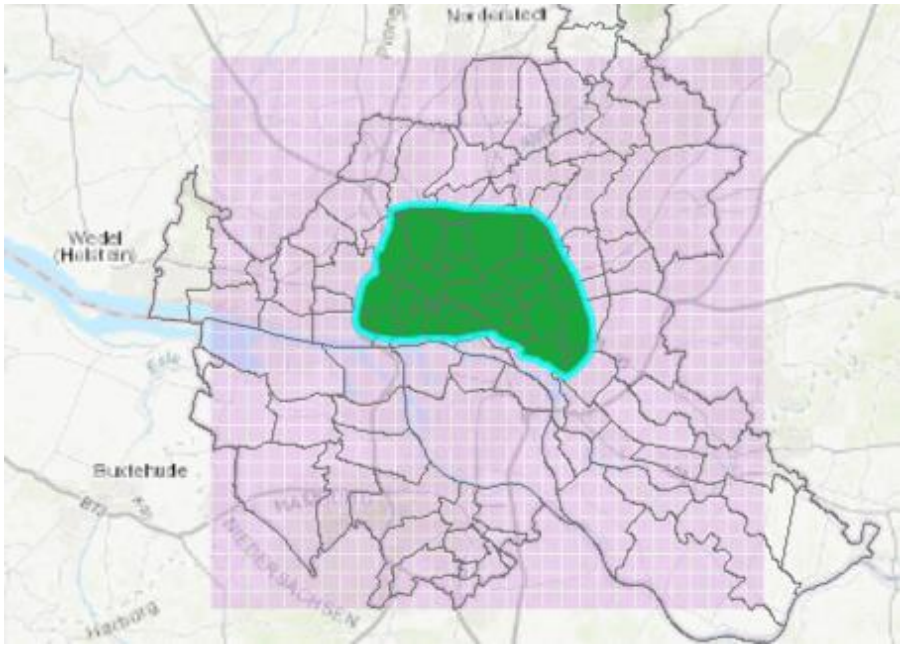
Electric car scenarios for 2020

Replace fuel cars inside / driving through the inner city using the defined **City Zone**.

Exception for HD and LD vehicles



Report on City-Maut Hamburg (2011). IVT, www.ivt-verkehrsforschung.de



Method for 2020 emissions

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Emission of NO_X from passenger vehicles in 2020:

$$E_{cars}(2020) = E_{cars}(2012) \cdot (f_{Euro6}(1 - f_{red}) + f_{El} \times 0 + f_{2012})$$

f_{Euro6}	Fraction of Euro 6 passenger vehicles
f_{El}	Fraction of electric cars
f_{red}	Emission control factor (Euro 6)
$f_{2012} = 1 - f_{Euro6} - f_{EL}$	Fraction of remaining current fleet

E-Mobility Scenarios for 2020

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	BASE	EPLAN	EFAST	EMAX_R	EMAX_F
Description	Baseline (as HH air quality plan)	HH electro mobility plan (MP6)	City zone 15% electro cars	City zone 100% electro cars	City zone 100% electro cars, coal power
Fuel driven km (electric driven) [10^6km/year]	8382 (0)	8298 (84)	8030 (352)	6622 (1760)	6622 (1760)
Total NO_X traffic emission [t/year]	3574	3533	3482	2889	2889
NO_X emissions City zone [t/year]	920	879	828	235	235
NO_X reduction in City zone [%]	0	4.5	10	75	75
Power supply for electric cars	0	178 Wh/km regenerative	178 Wh/km regenerative	178 Wh/km regenerative	178 Wh/km 0.7 gNO_X/KWh

EPISODE-CityChem

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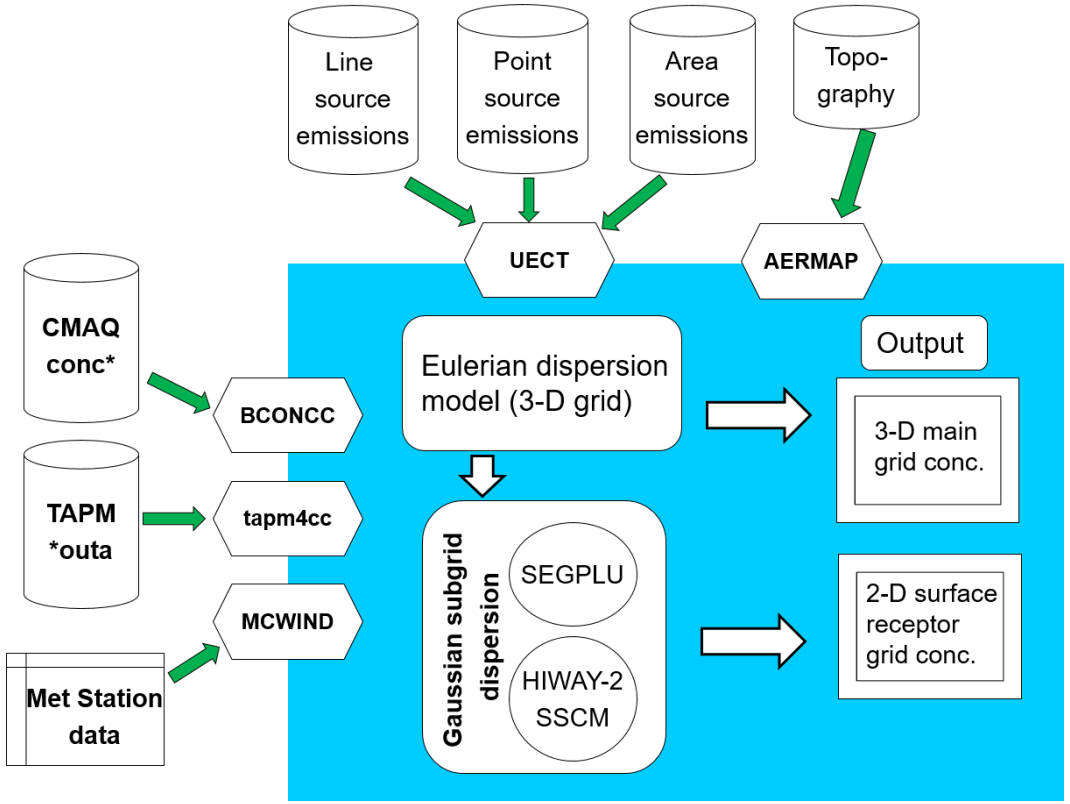
- Variant of the urban dispersion model **EPISODE** developed at **NILU** [Slørdal et al., 2003,2008]
- Calculates spatial and temporal dispersion and **chemical reactions** of multiple air pollutants on 3-D Eulerian grid
- **Photochemistry solver** [Walker et al., 2003]
- Prognostic meteorology from simulations with **TAPM** [Hurley, 2008]
- Boundary conditions from **CMAQ** model run [Byun & Schere, 2006]
- Treatment of point / line / area emissions
- Point source segmented plume model [Walker & Grønskei, 1992]
- Line source model HIWAY-2 [Peterson, 1980]
- Simplified street canyon model based on **OSPM** [Berkowicz et al., 1997]



EPISODE-CityChem (Karl, 2018)

AQ monitoring in Hamburg

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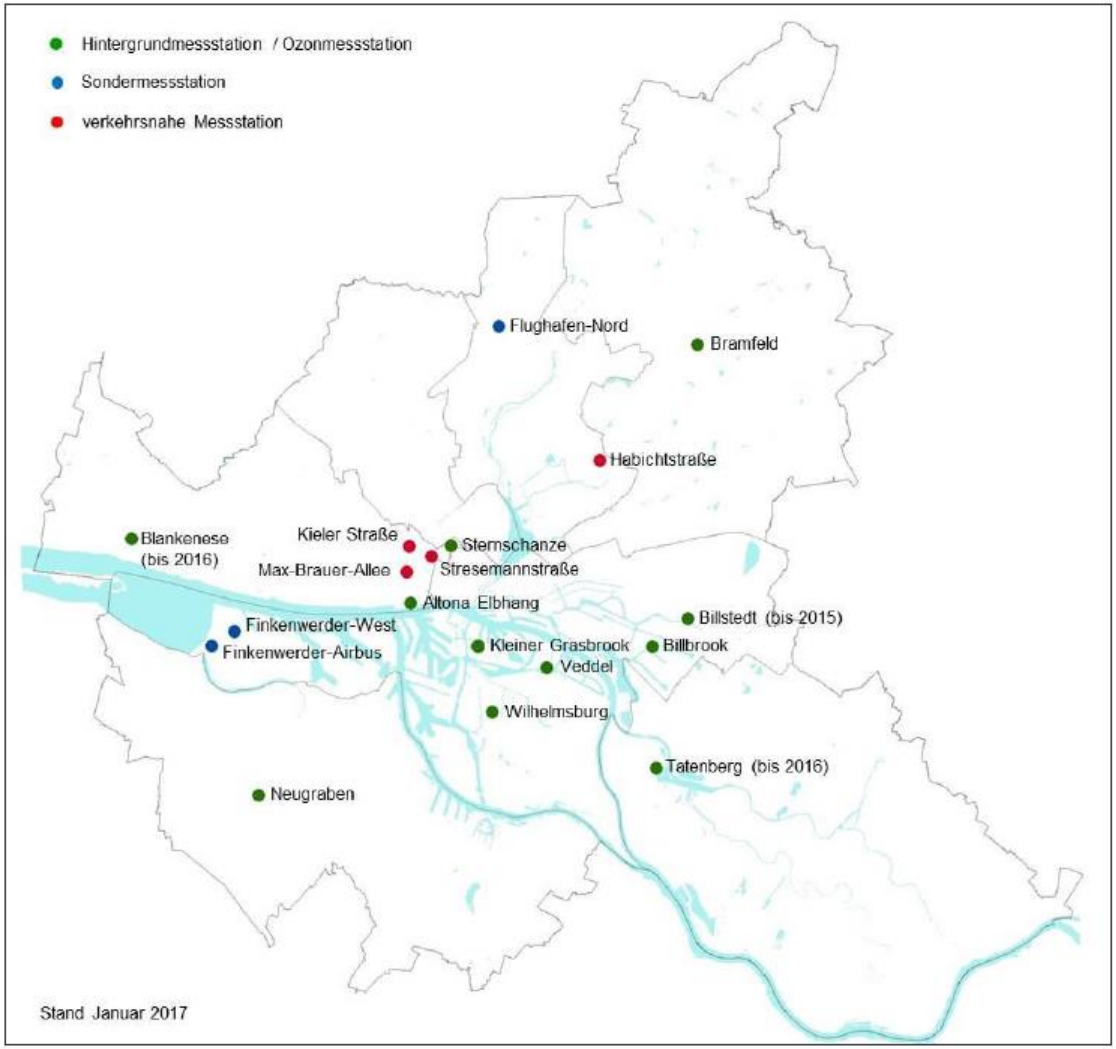

Hamburg Luftreinhalteplan, 2017

Hamburg Air Monitoring (HLM)
http://luft.hamburg.de/

Traffic AQ stations in red

Model evaluation

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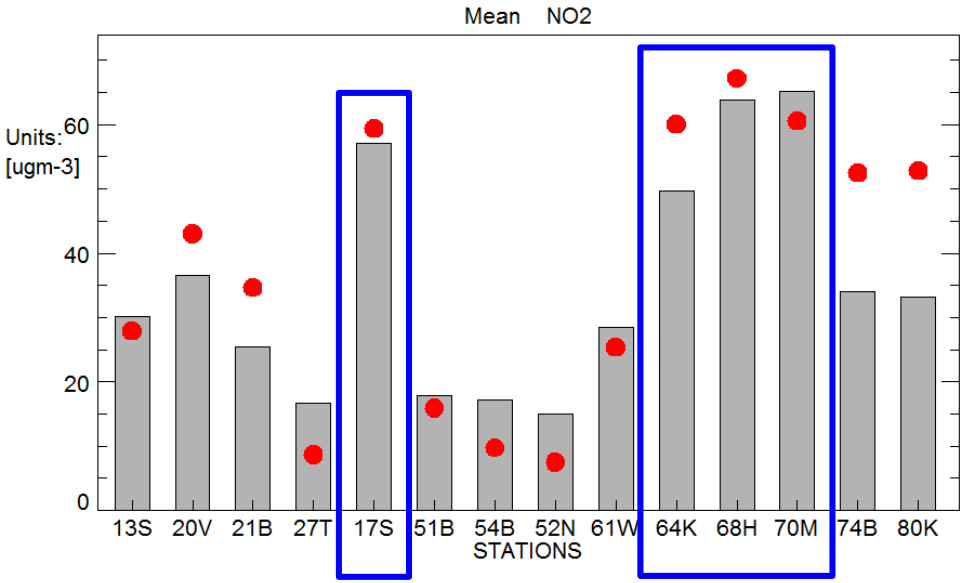
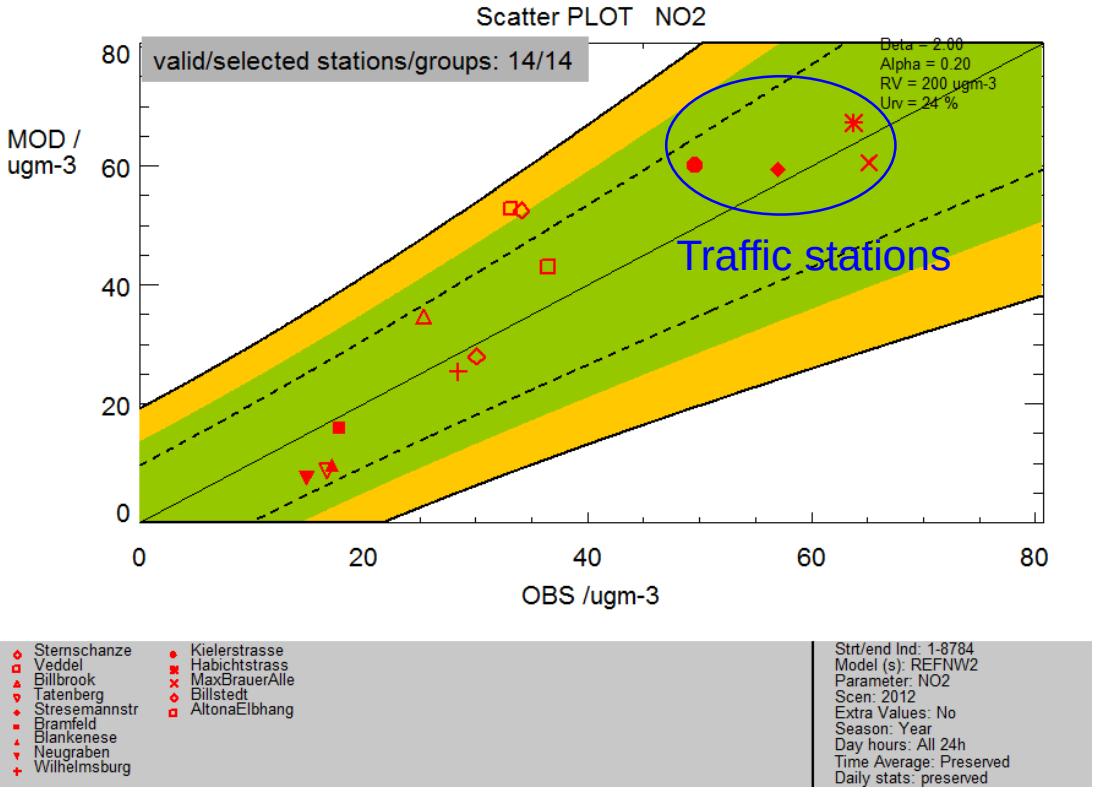
- Spatial comparison and correlation of annual mean NO_2 for 2012



Traffic stations



Fairmode DELTA Tool v. 5.5

Baseline 2012 and 2020

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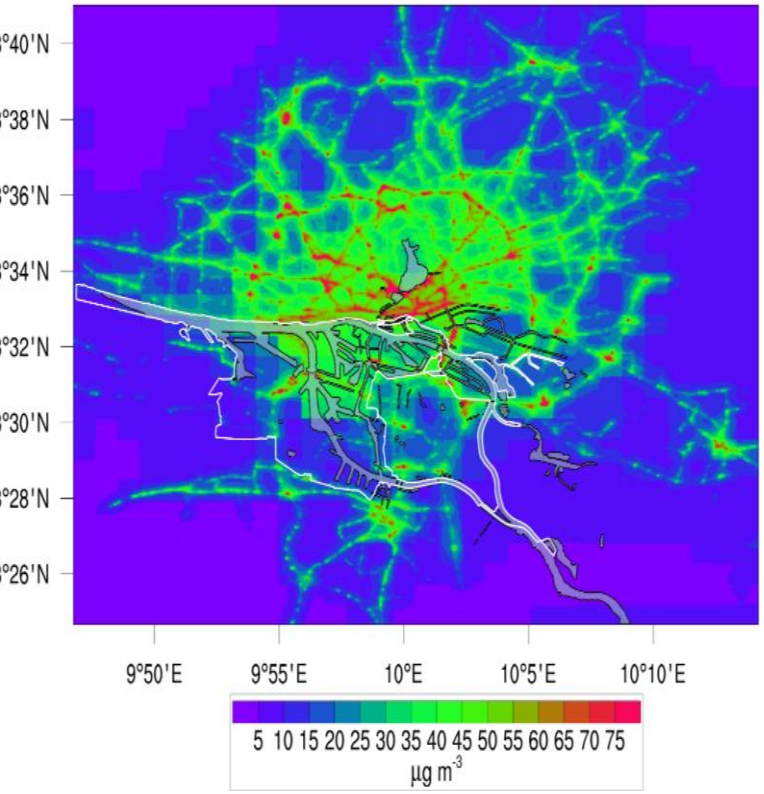
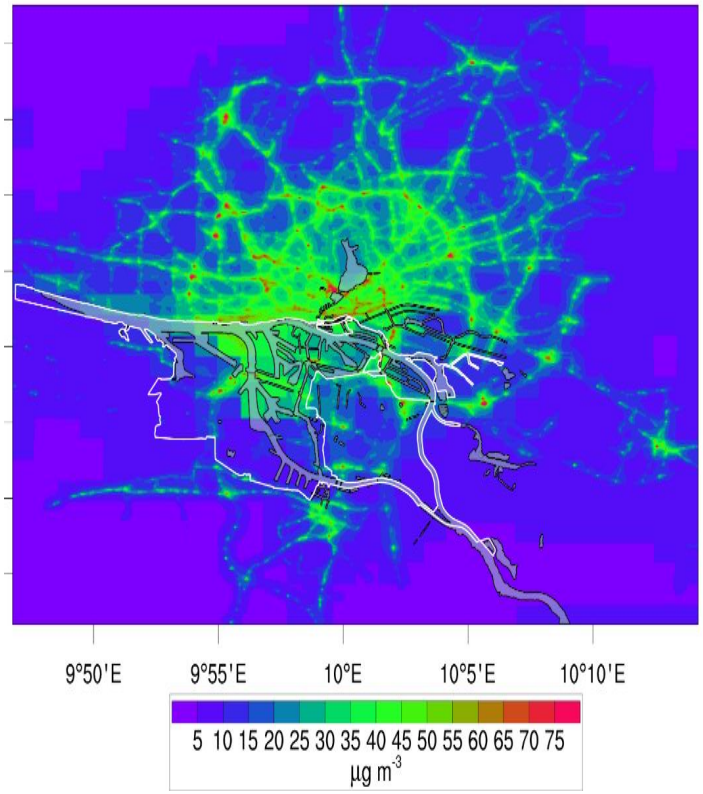
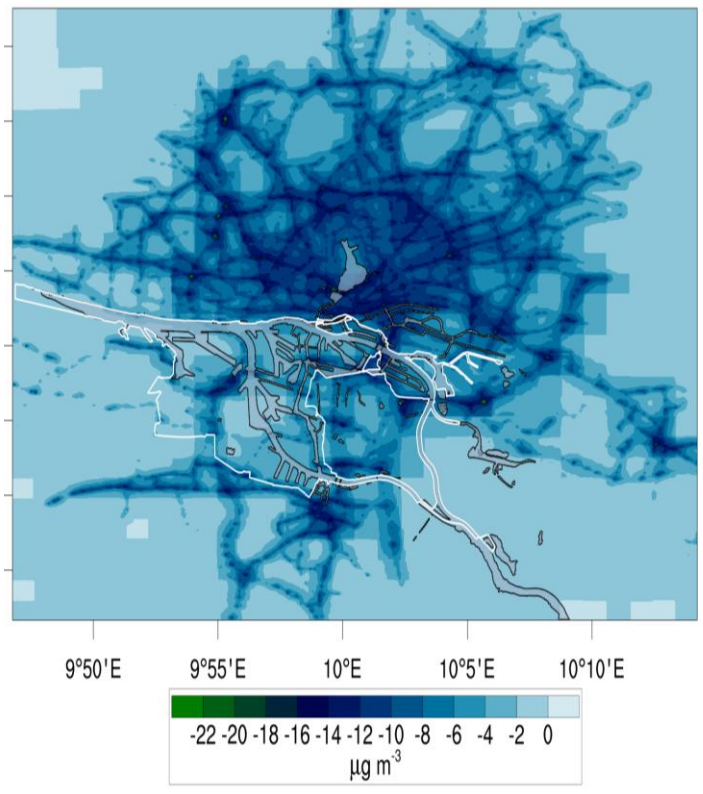
BASE 2012



BASE 2020



BASE 2020 – BASE 2012



Modelled annual mean NO2

Scenarios for 2020

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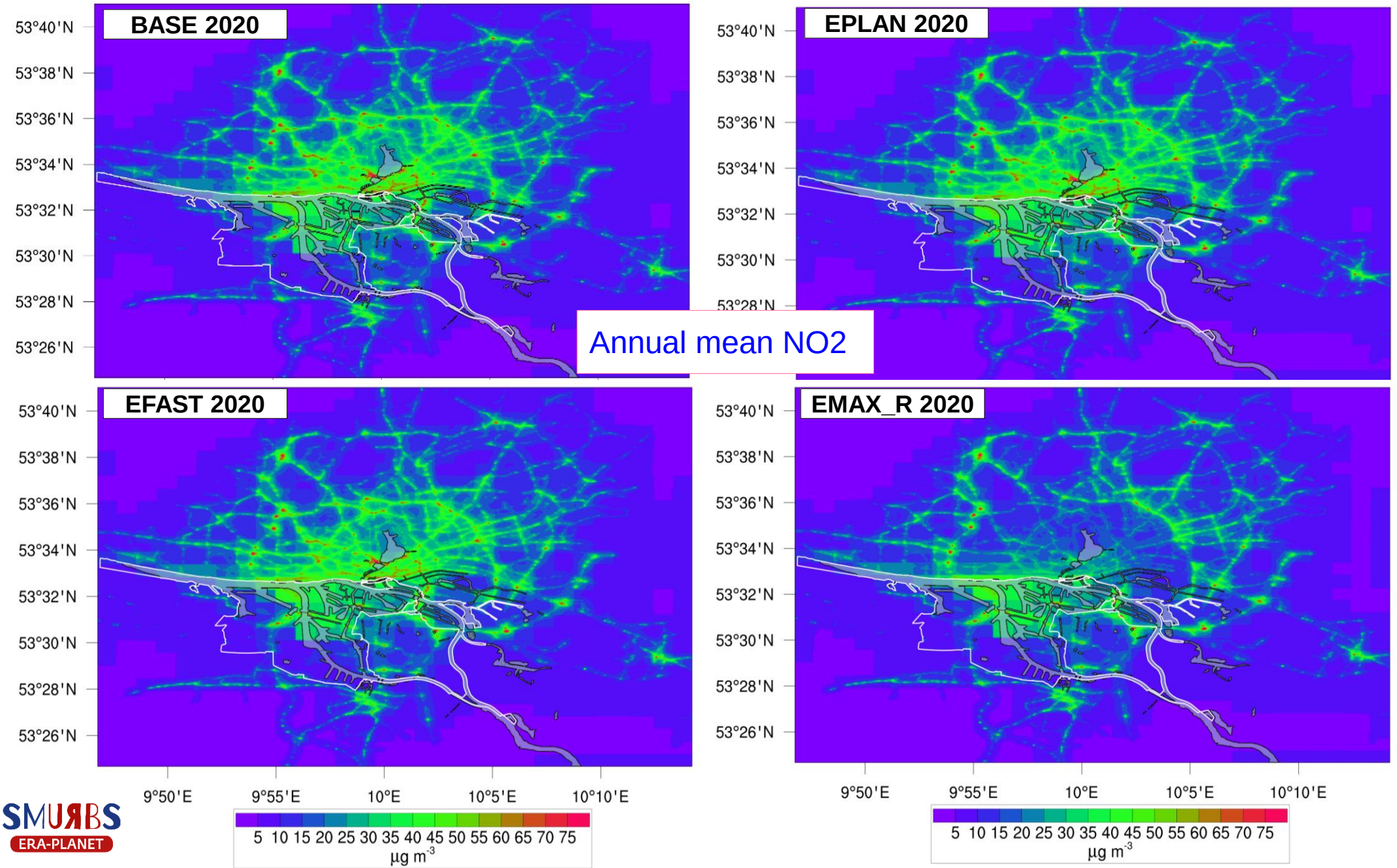

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Difference to Baseline 2020

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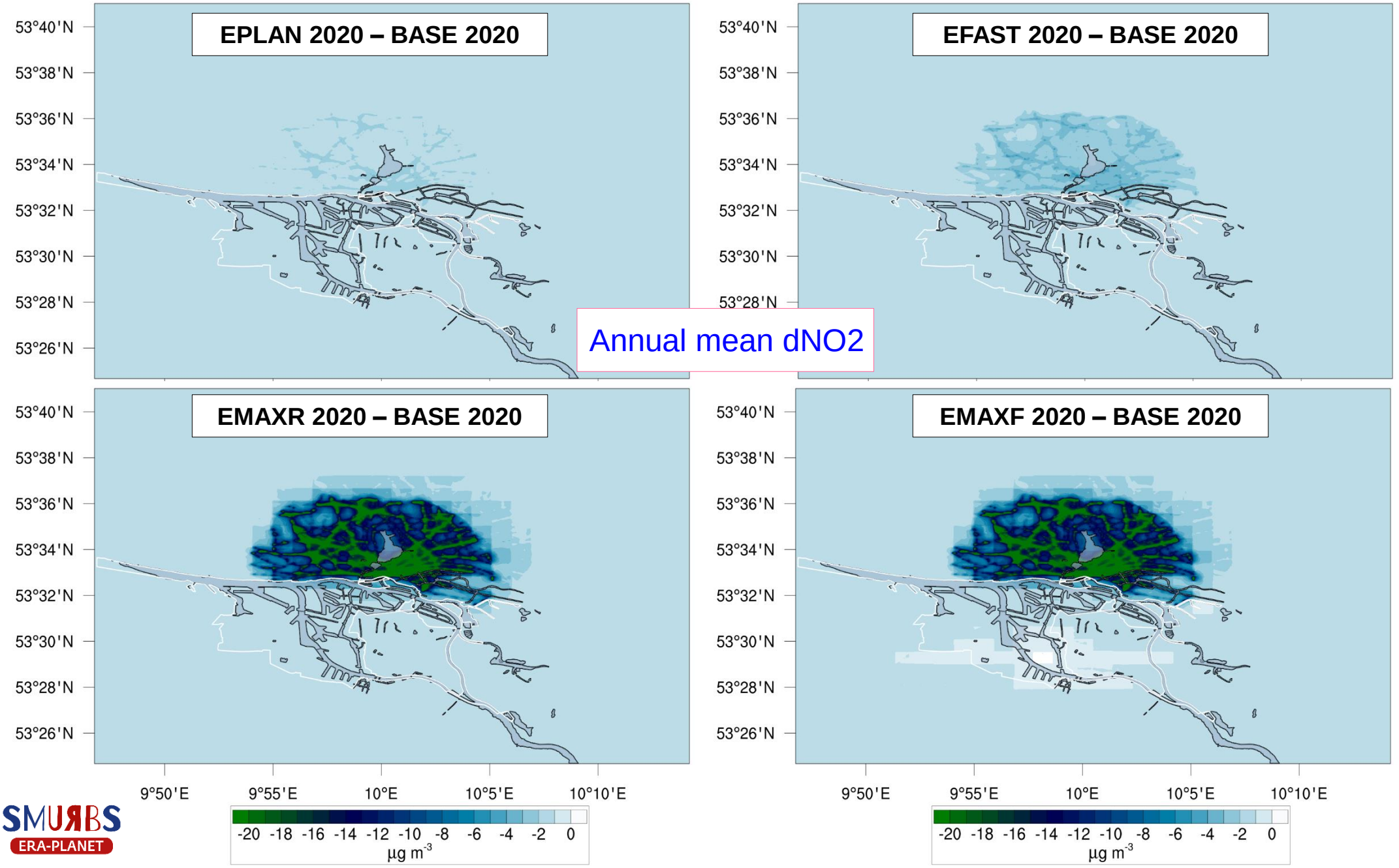

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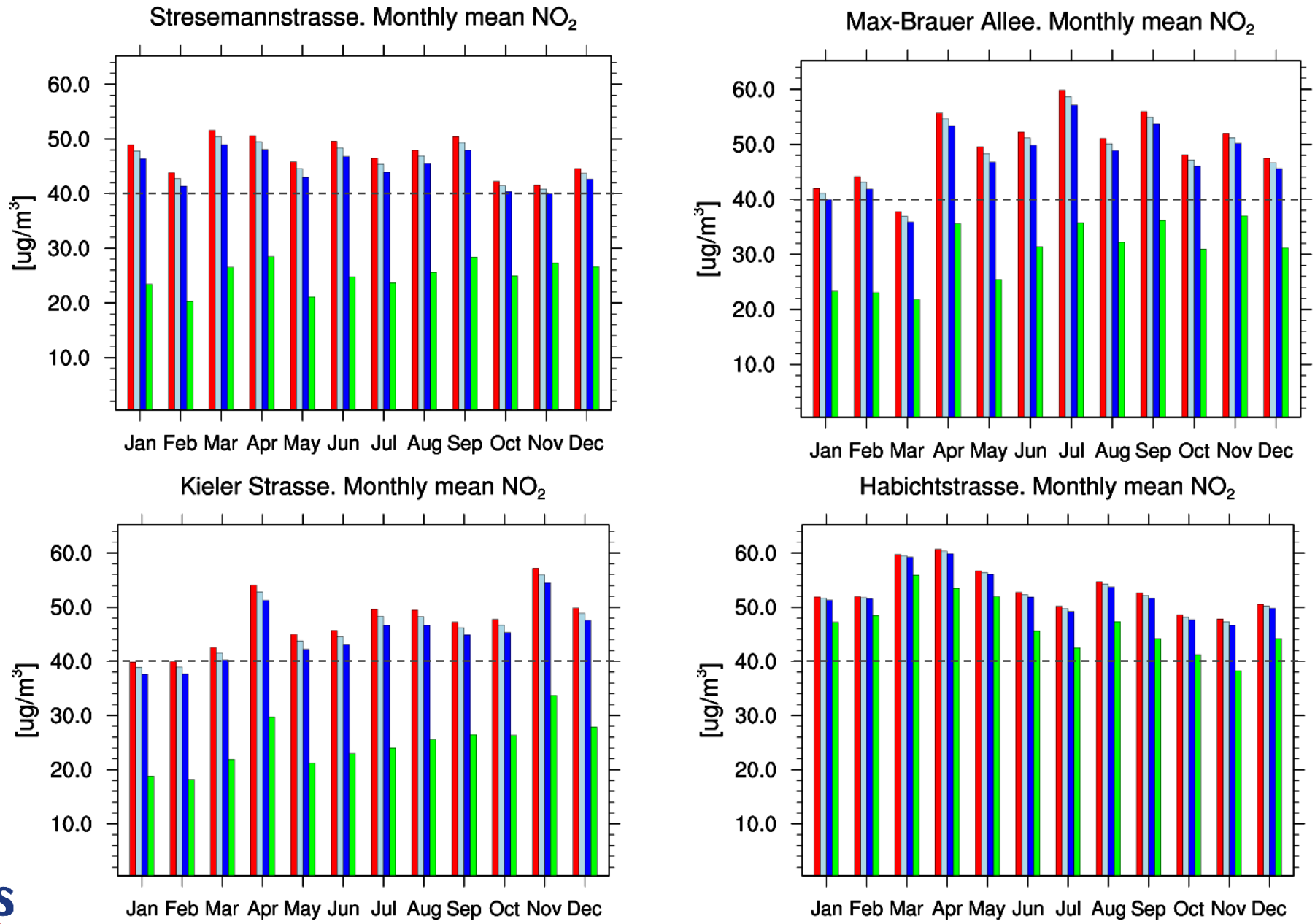
Comparison at traffic sites



Energy supply for electric cars

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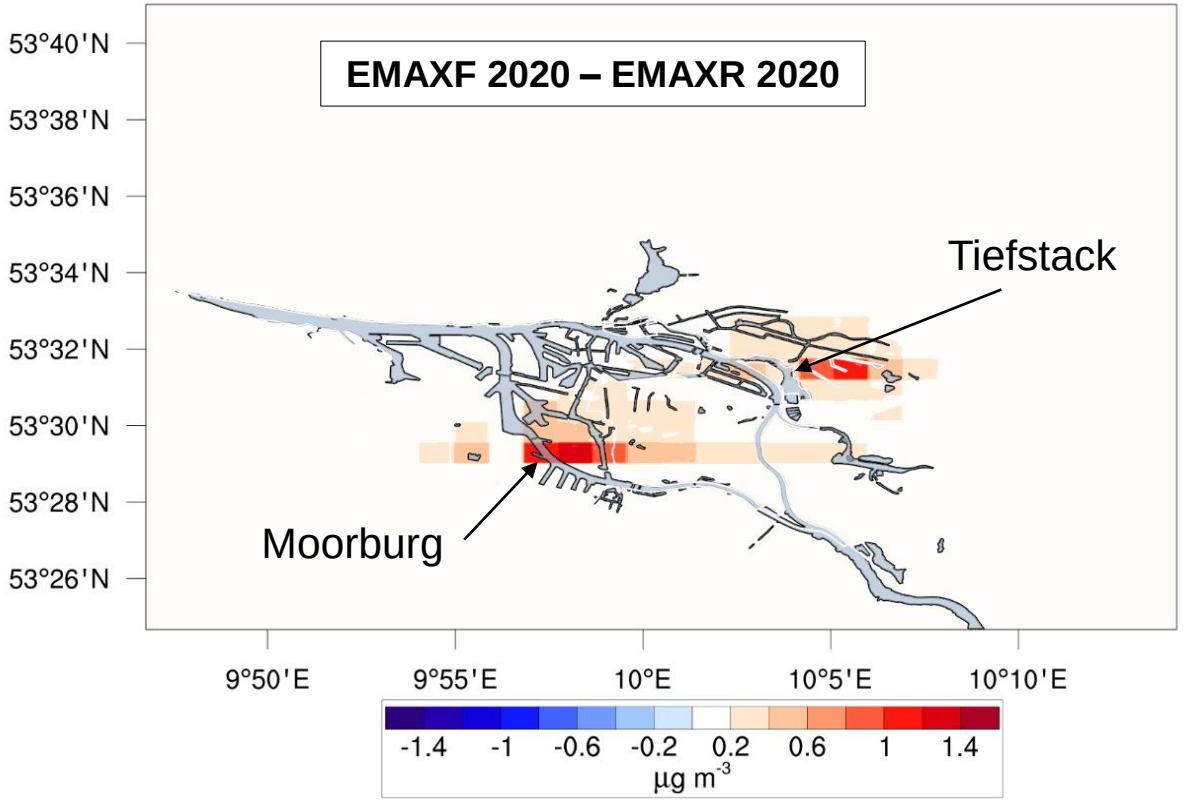
- 100% coal vs. 100% regenerative energy
- Energy consumption of electric car: 178 Wh per km [Helms et al., 2010]
- NO_X emission factor for coal-fired power plant: 0.7 gNO_X/KWh
  [German electricity mix: 0.454 gNO_X/KWh (2015)]
- Change ≤ 1.5 µg/m³ NO_2 on annual average



Annual mean NO2

Discussion

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- The study does not consider that commuters will switch to electric cars resulting in lower NO_X emissions in the surroundings of Hamburg
- Exhaust and non-exhaust particle emissions contribute equally to total traffic related PM10 (Grigoratos & Martini, JRC report 2014). No scientific studies on fine particulate matter emissions due to tyre & break abrasion and road dust resuspension from electric cars
- No ultrafine particle emissions from electric cars
- Current electricity mix in Germany: 40 % renewable energy → electric cars emit 86 g CO_2 per driven km compared to 152 g CO_2 per driven km for fuel cars
- After 20,000 km driving, an electric car is more environmental friendly than a fuel car in terms of a life cycle assessment

Conclusions

- Electro mobility plan proposed in Hamburg air quality plan (2017) brings only marginal reduction of NO_2 compared to Baseline 2020.
- EFAST: 15 % electric cars in City zone (Exception LD & HD) brings some reduction
- EMAXR: 100 % electric cars in City zone (Exception LD & HD): NO_2 at 3 out of 4 traffic stations below EU limit, but at Habichtstrasse (outside City zone) still above
- Bans for LD and HD vehicles might be necessary even in 2020 if high electric car share is not reached
- Model system now ready for rapid assessment of suggested abatement measures

Acknowledgement

The authors acknowledge the funding received by ERA-PLANET (www.era-planet.eu), trans-national project SMURBS (www.smurbs.eu) (Grant Agreement n. 689443), funded under the EU Horizon 2020 Framework Programme.

Thank you for your attention

CO_2 emissions

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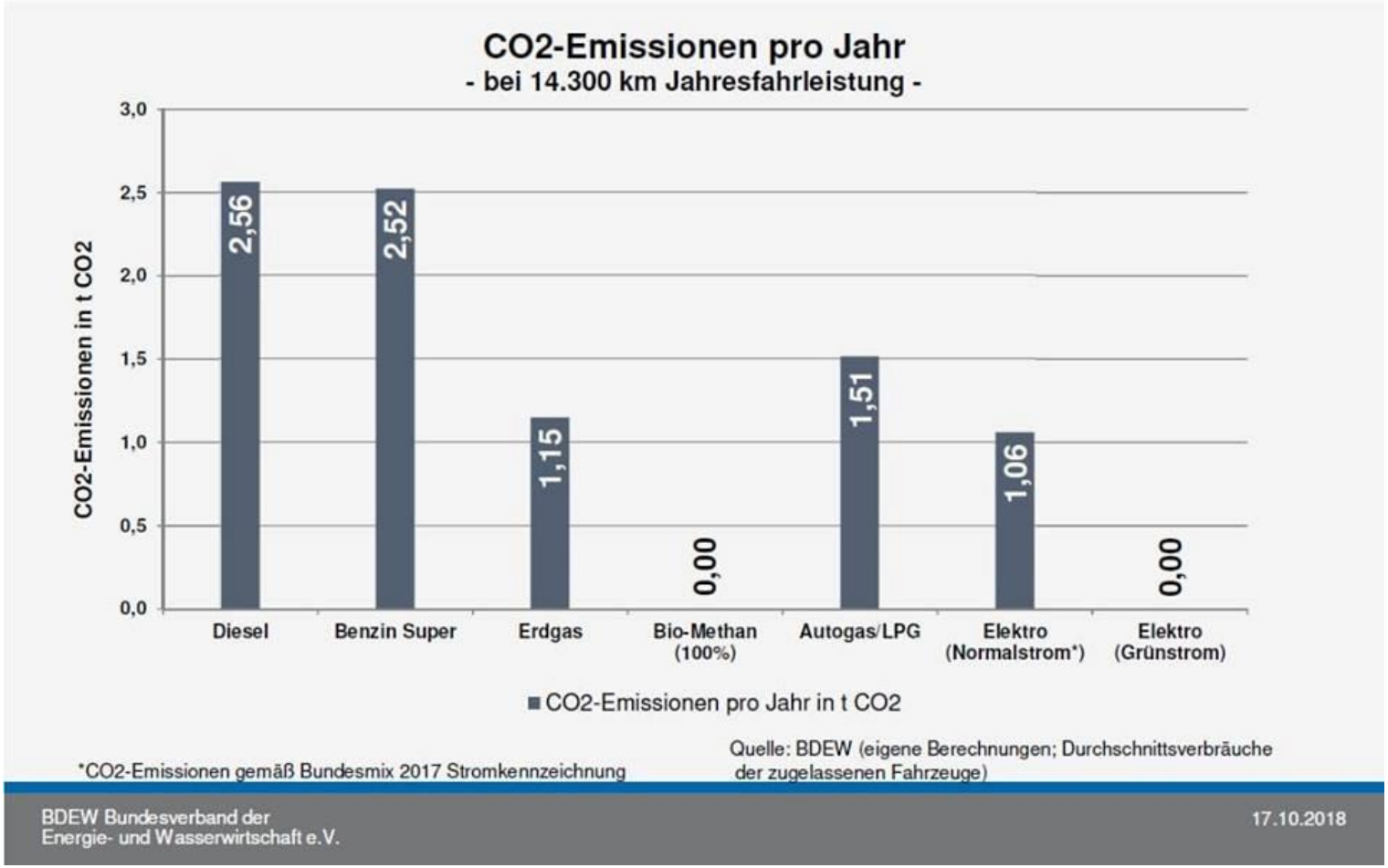
CO_2-Emissionen PKW bei 14.300 km Jahresfahrleistung

bdew
Energie. Wasser. Leben.



Sensitivity of O3 to VOC emissions

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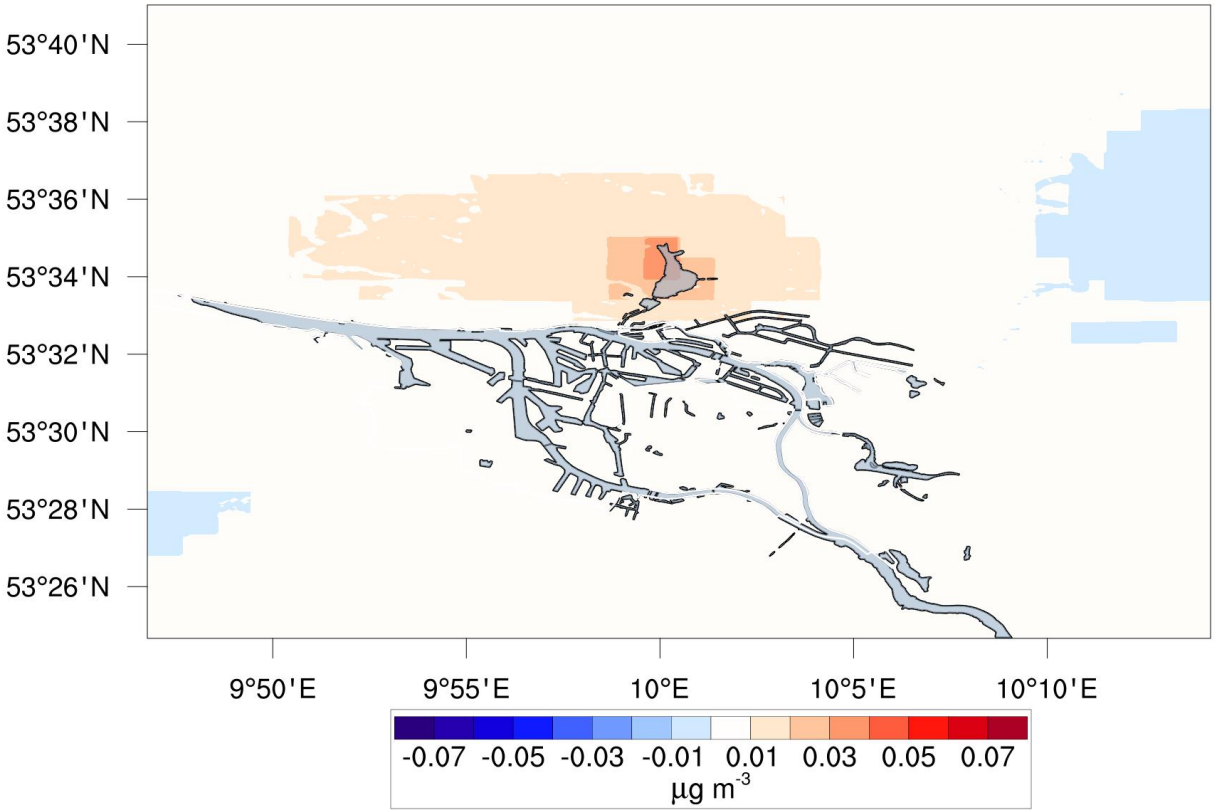
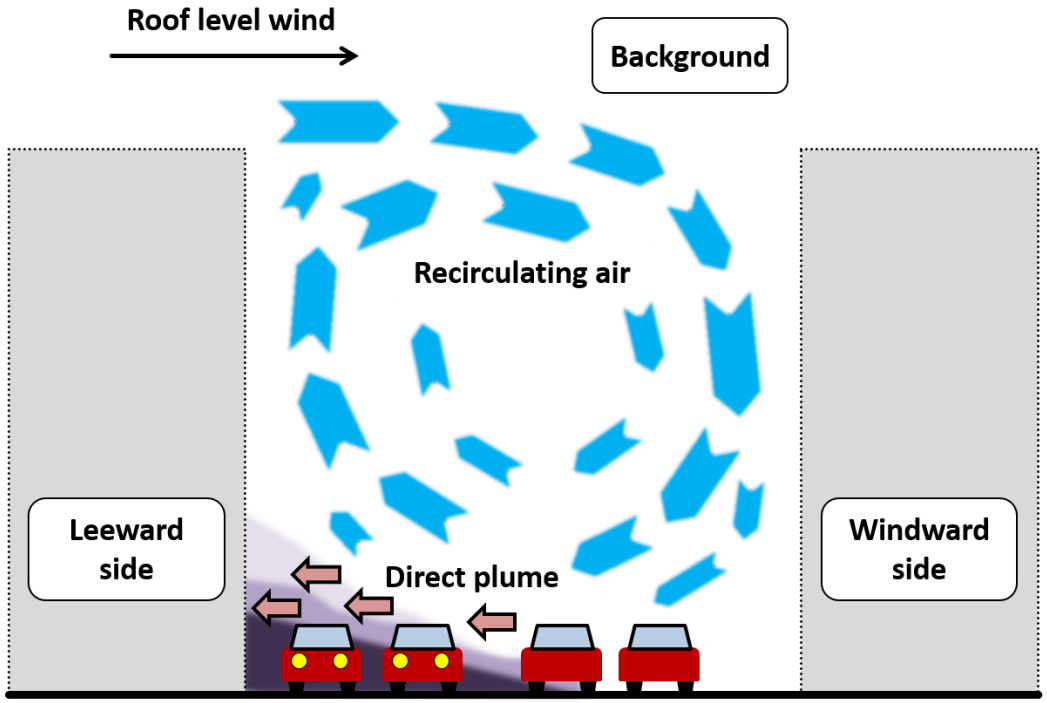
- Ozone not sensitive to reduced VOC emissions due to introduction of electric cars in scenario EMAXR 2020

Monthly mean O3
July 2020



Street Canyon Model

- The simplified street canyon model SSCM in CityChem follows in most aspects the Operational Street Pollution Model (OSPM) [Berkowicz et al., 1997]
- The complex and divers geometry of street canyons is approximated by three generic types
- Each line source for which the geometric mid-point is located in a grid cell with urban land use is identified as street canyon
- SSCM gives higher concentrations than the open road dispersion module HIWAY because it considers reduced ventilation and the recirculation of the traffic plume



Modified after Berkowicz et al. (1997)

Line source model HIWAY-2

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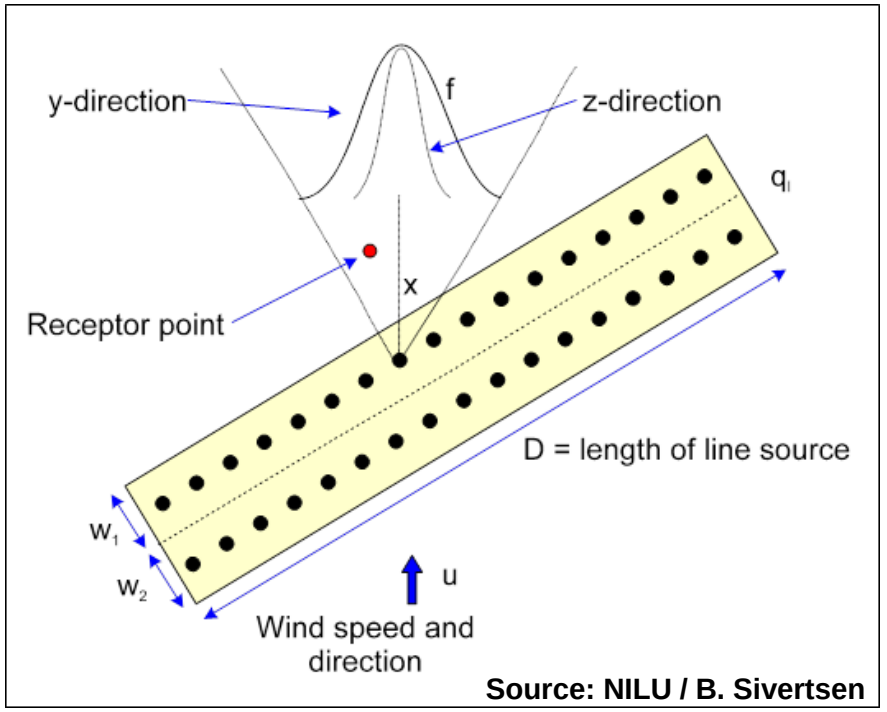
- In Hamburg study ca. 15 000 road links are modelled
- Gaussian dispersion to compute concentrations close to sources (r = 500m)
- Each line source is allocated to the line source model
- Turbulent diffusion coefficients: “profile method” Monin-Obukhov similarity theory, uses recommended parameterizations from COST action 710
- Line source sub-grid model:
  - Integration of Gaussian concentrations along the street in a receptor point
  - Stability classification:

$$
\begin{aligned}
&< \Delta T \leq -0.5 && \Leftrightarrow \text{ Stability Class 1: Unstable conditions}\\
-0.5 &< \Delta T \leq 0.0 && \Leftrightarrow \text{ Stability Class 2: Neutral conditions}\\
0.0 &< \Delta T \leq 0.5 && \Leftrightarrow \text{ Stability Class 3: Moderately stable conditions}\\
0.5 &< \Delta T && \Leftrightarrow \text{ Stability Class 4: Stable conditions}
\end{aligned}
$$



Source: NILU / B. Sivertsen

EPISODE grids

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Horizontal dimension

- Eulerian 3-dim. grid for Hamburg:
  Meteorology, area emissions
  Grid res. 1000 m; domain 30 x 30 km^2

Vertical dimension

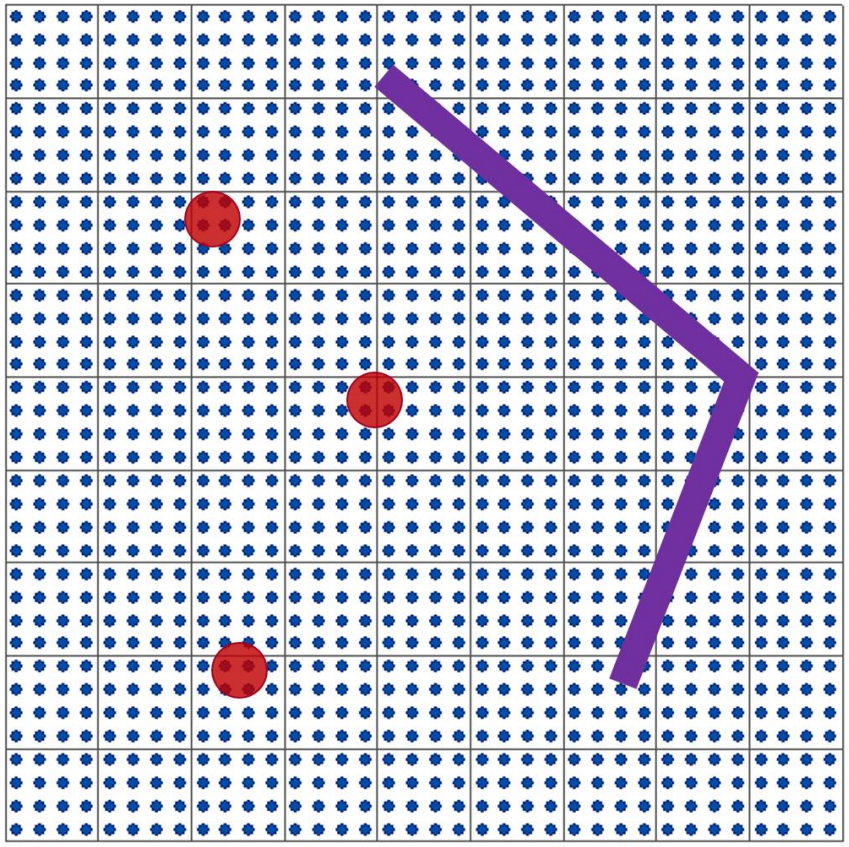
- CityChem layer top heights in the BL:
  17.5m, 37.5m, 62.5m, 87.5m, 125m, 175m, 225m,
  275m, 350m, 450m, 550m, 675m, 875m, 1125m, …

Receptor grid

- Regular surface receptor grid:
  100 x 100 m^2

Traffic sources

- Hamburg: 15850 road links (=source objects)



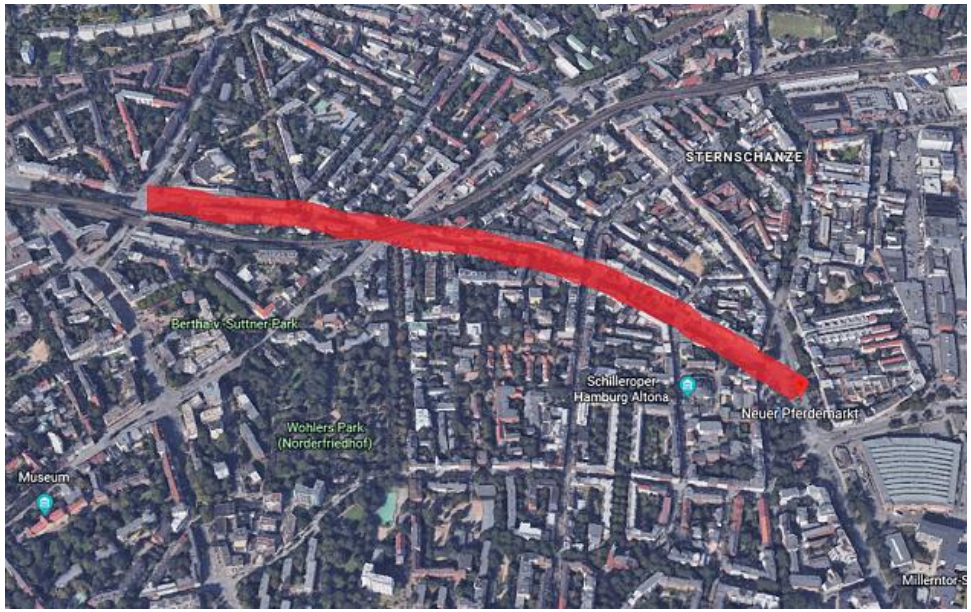
Karl, M., Walker, S.E., Solberg, S., Ramacher, M. (2018): Eulerian urban dispersion model EPISODE. Part II: CityChem-EPISODE and its application to the air quality in Hamburg, manuscript in prep.

Traffic bans in Hamburg

Traffic bans in Hamburg starting in June 2018:

- Two highly trafficked inner-city streets
- Ban for diesel trucks and passenger cars until NO_2 below limit value

Stresemannstrasse
Ban for diesel trucks



Max-Brauer Allee
Ban for diesel cars & trucks except Euro VI

Focus online 27.02.2018 / Google Maps, FOL