Modelling the Effect of Electro Mobility on the Air Quality of Hamburg

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Motivation

- **Health impact of high nitrogen dioxide in cities:**
  It is estimated that excessive amounts of nitrogen oxides (NO_2) in the air is responsible for the death of between 6,000 and 13,000 people in Germany every year, causing a range of health conditions, from strokes to asthma.

- **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.

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

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

Bans in Hamburg

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Traffic bans in Hamburg starting end of April:

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

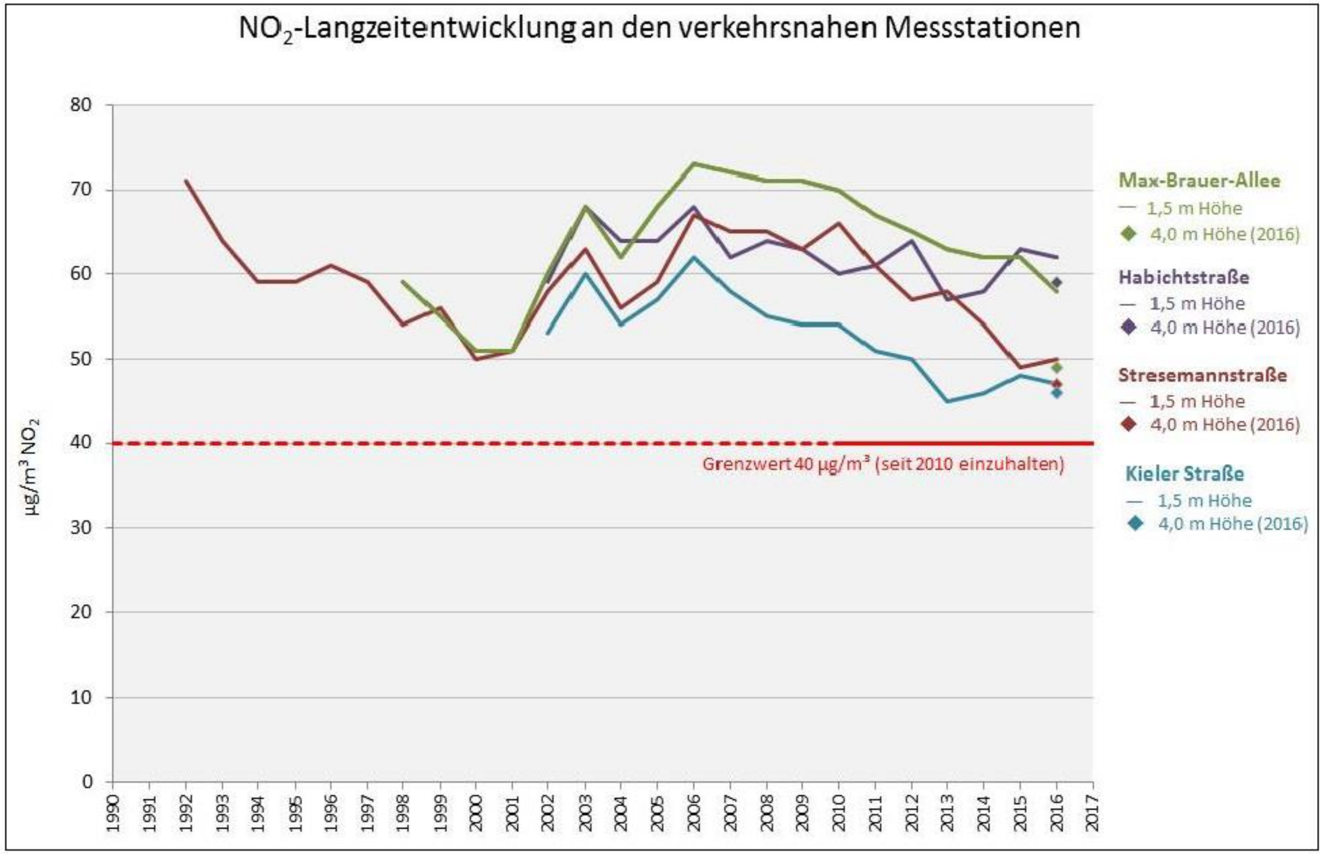
Stresemannstrasse
Ban for diesel trucks

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

Focus online 27.02.2018 / Google Maps, FOL

Exceedance of Limit Value at four traffic sites

EU Limit value of 40 micrograms per m³ has been introduced in Hamburg in 2010 and since then regularly exceeded at all four traffic monitoring stations



Hamburg Luftreinhalteplan, 2017

Electro Mobility plan for Hamburg

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?

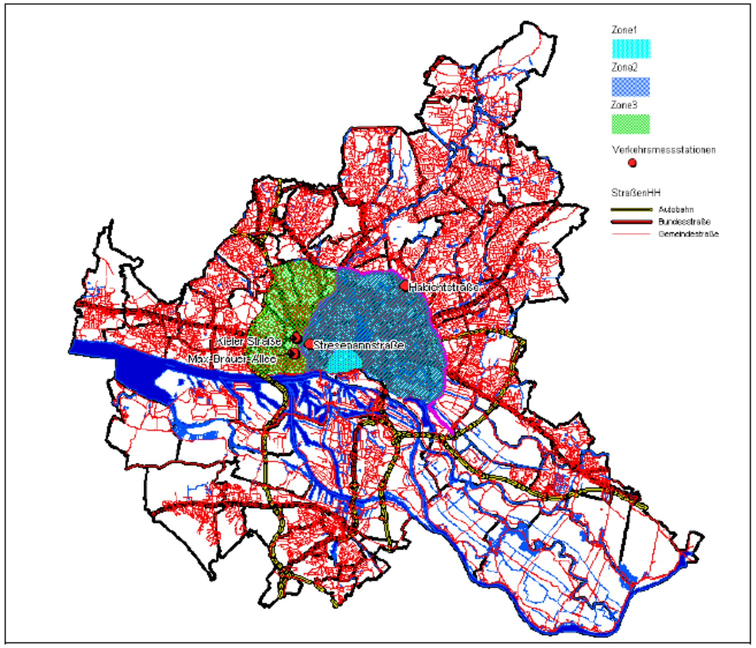
Additional measures: subsidies for citizens to replace their diesel vehicles by electric cars; City tax; open bus lanes for electric cars.

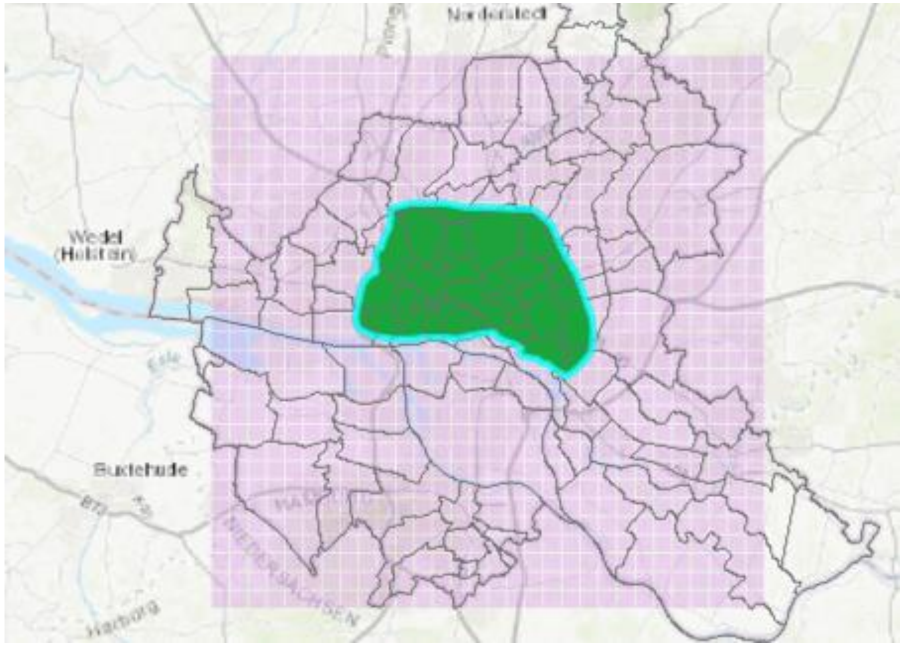
Hamburg City zone

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

E-Mobility Scenarios for 2020

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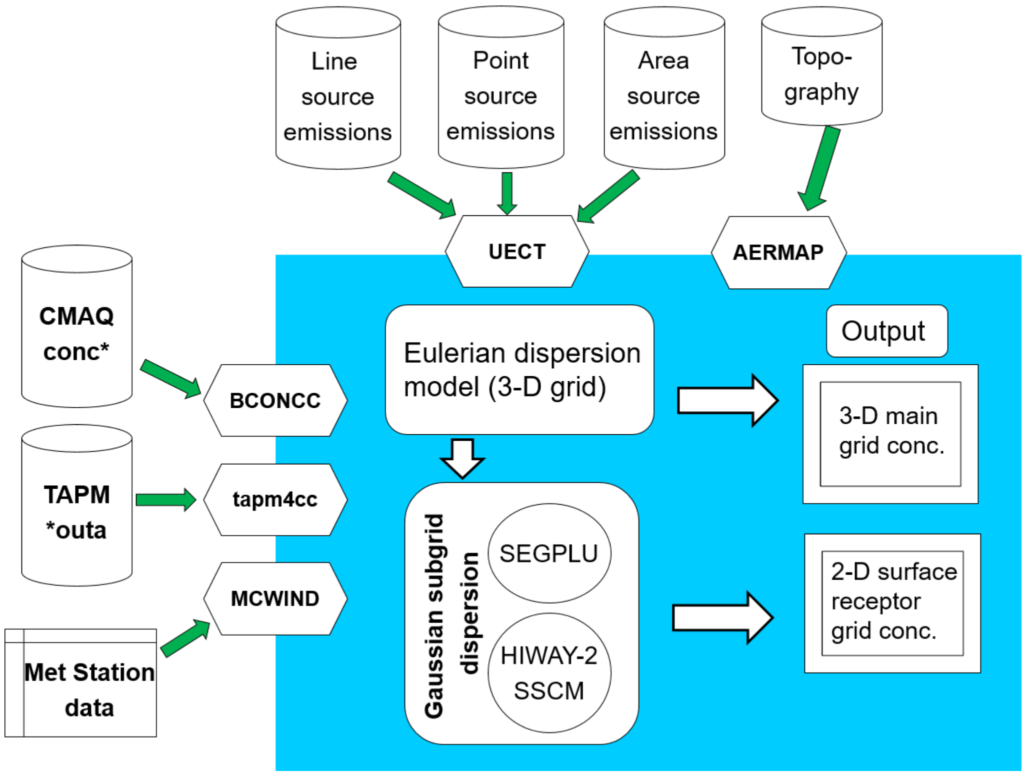
	BASE	EPLAN	EFAST	EMAX_R	EMAX_F
Description	Baseline (as HH air quality plan)	HH electro mobility plan (MP6)	City zone 20% electro cars	City zone 100% electro cars	City zone 100% electro cars, coal power
Fuel driven km **(electric driven)** [10^6km/year]	8382 **(0)**	8298 **(84)**	8030 **(352)**	6622 **(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

CityChem-EPISODE model (I)

City-scale chemistry transport model

- 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



CityChem-EPISODE (Karl, 2018)

CityChem-EPISODE model (II)

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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

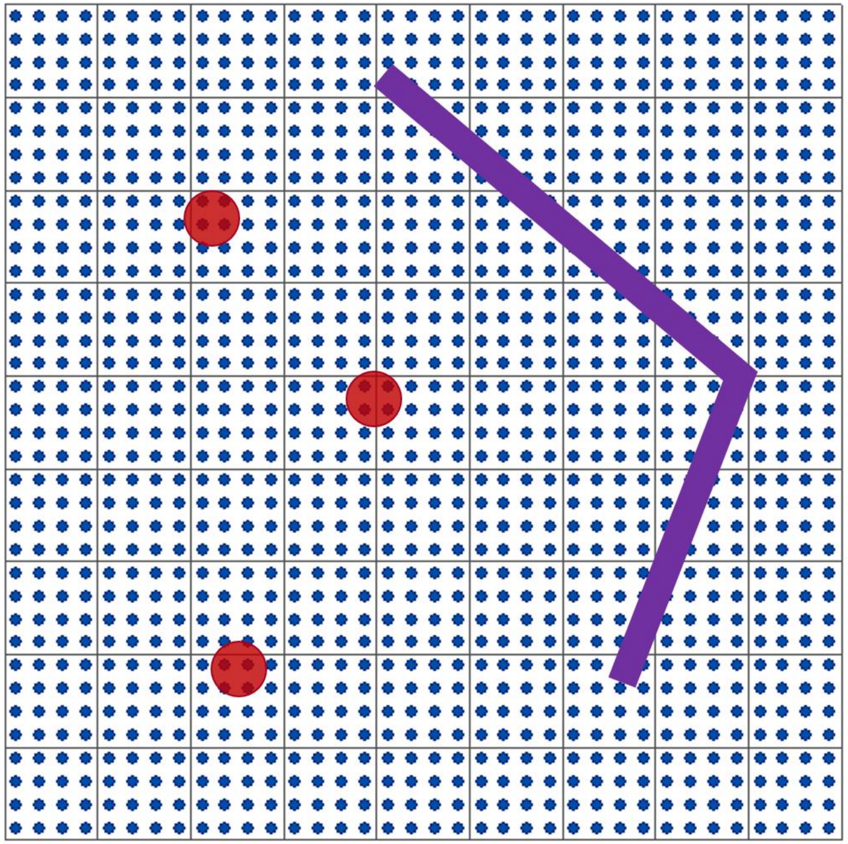
- CityChem layer top heights in the BL:
  17.5m, 37.5m, 62.5m, 87.5m, 125m, 175m, 225m, 275m, 350m, 450m, 550m, 675m, 875m, 1125m, …

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.

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AQ monitoring in Hamburg

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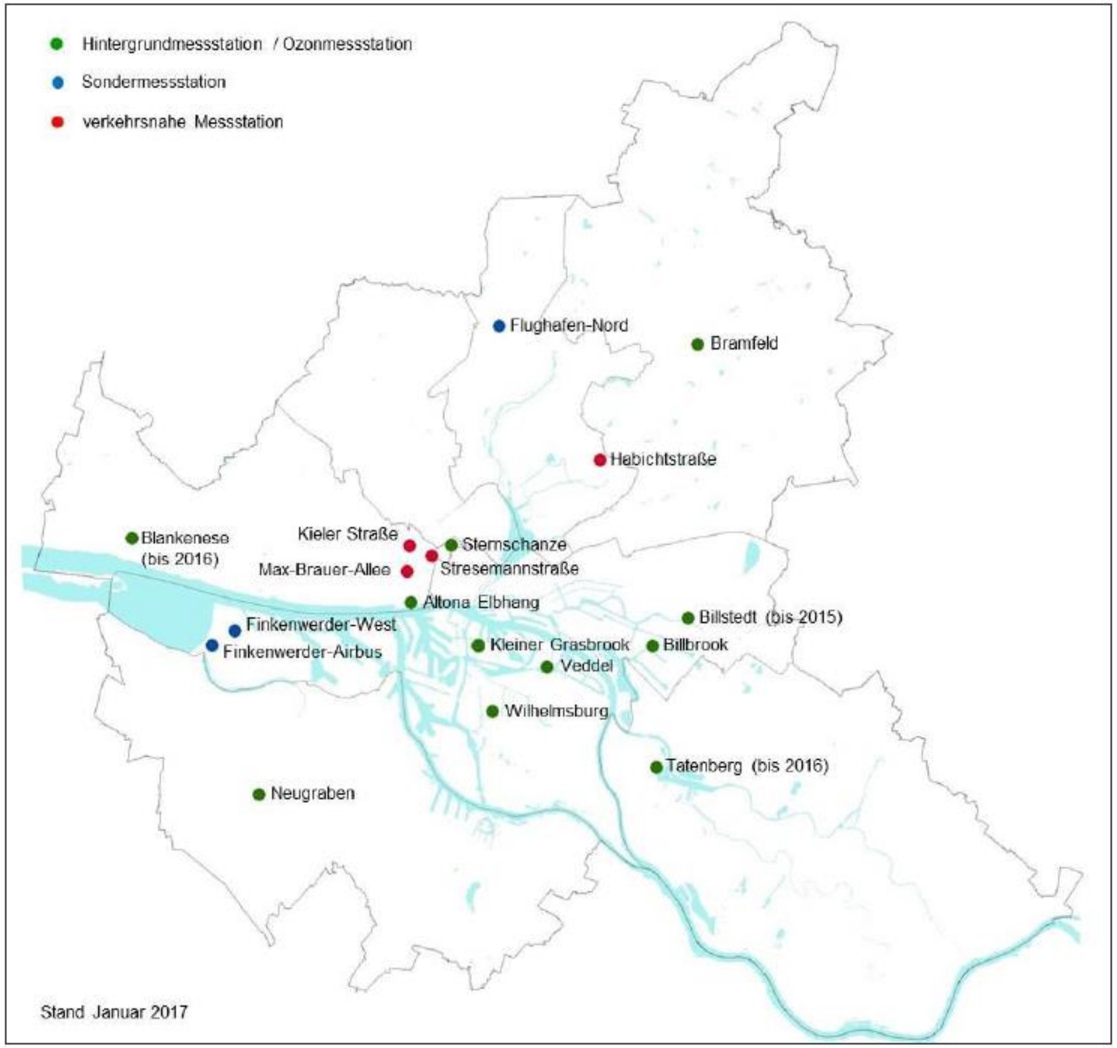


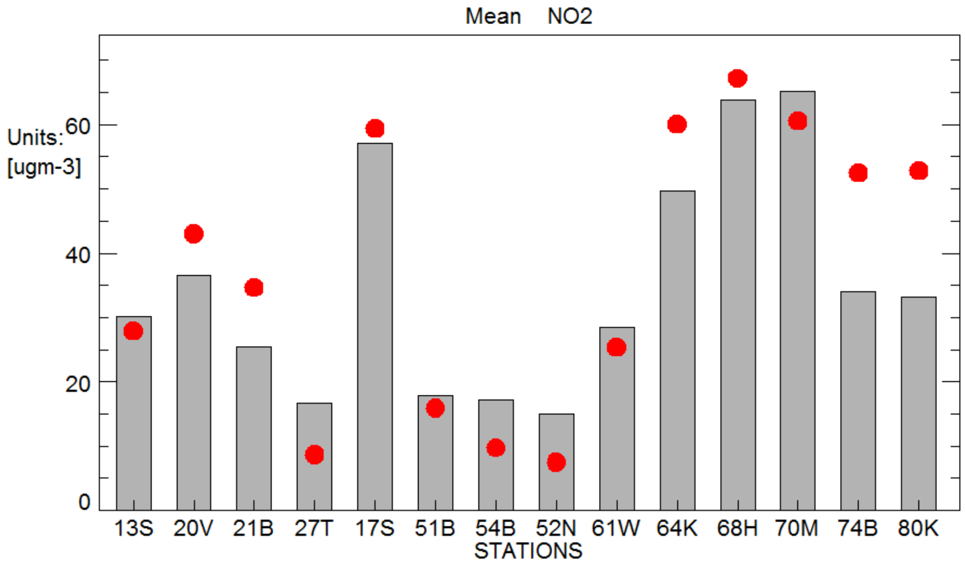
Hamburg Luftreinhalteplan, 2017

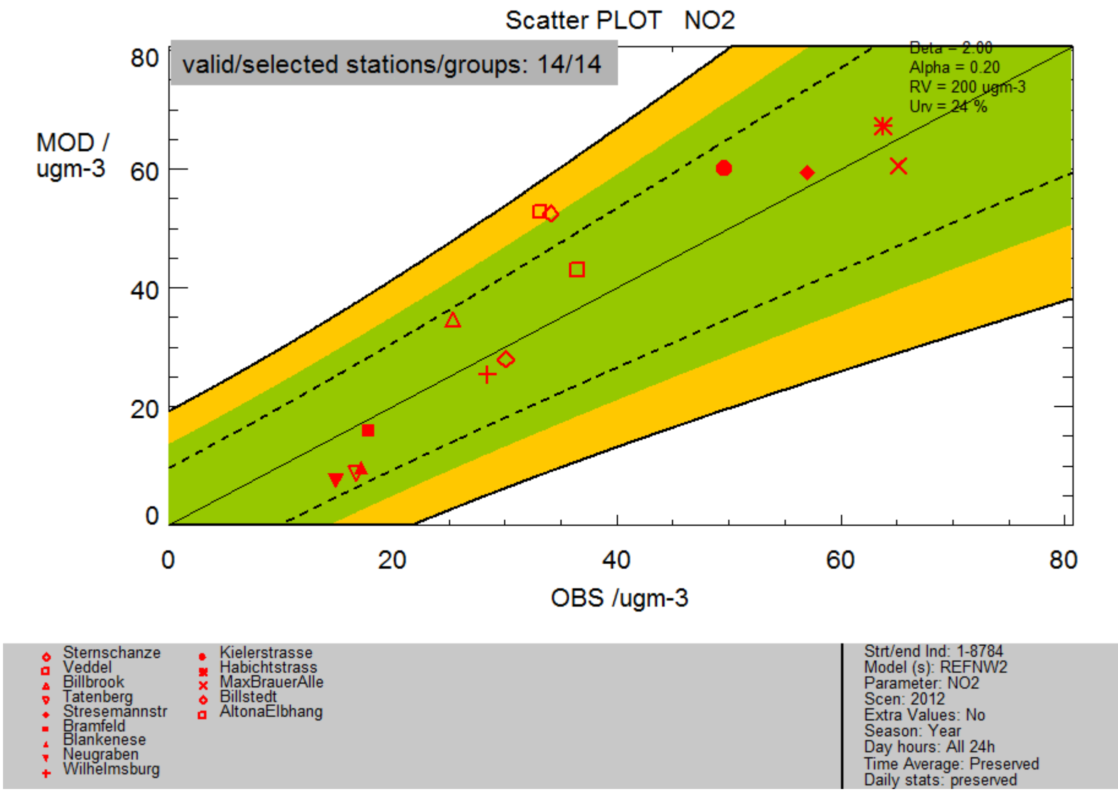
Hamburg Air Monitoring (HLM)
http://luft.hamburg.de/

Traffic AQ stations in red

Model evaluation

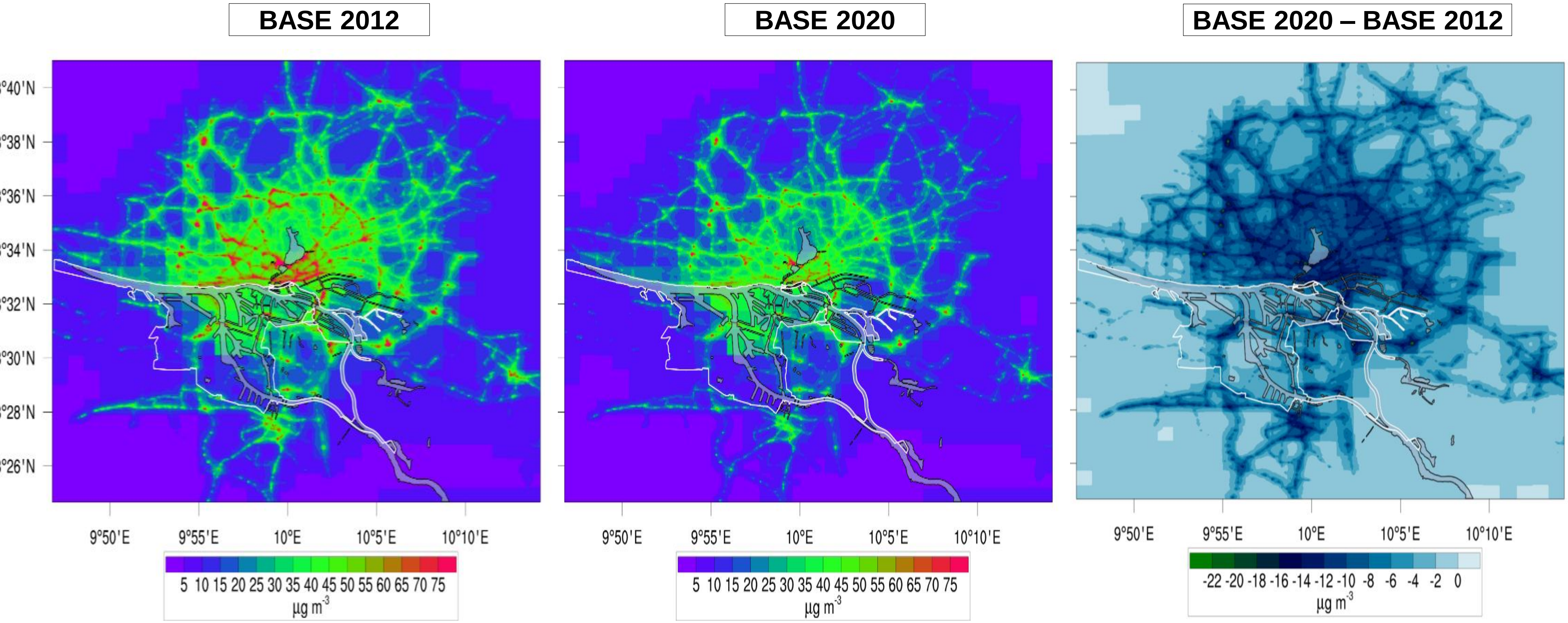
- Spatial comparison and correlation of annual mean NO_2 for 2012





Fairmode DELTA Tool v. 5.5

Baseline 2012 and 2020



Modelled annual mean NO2

Scenarios for 2020

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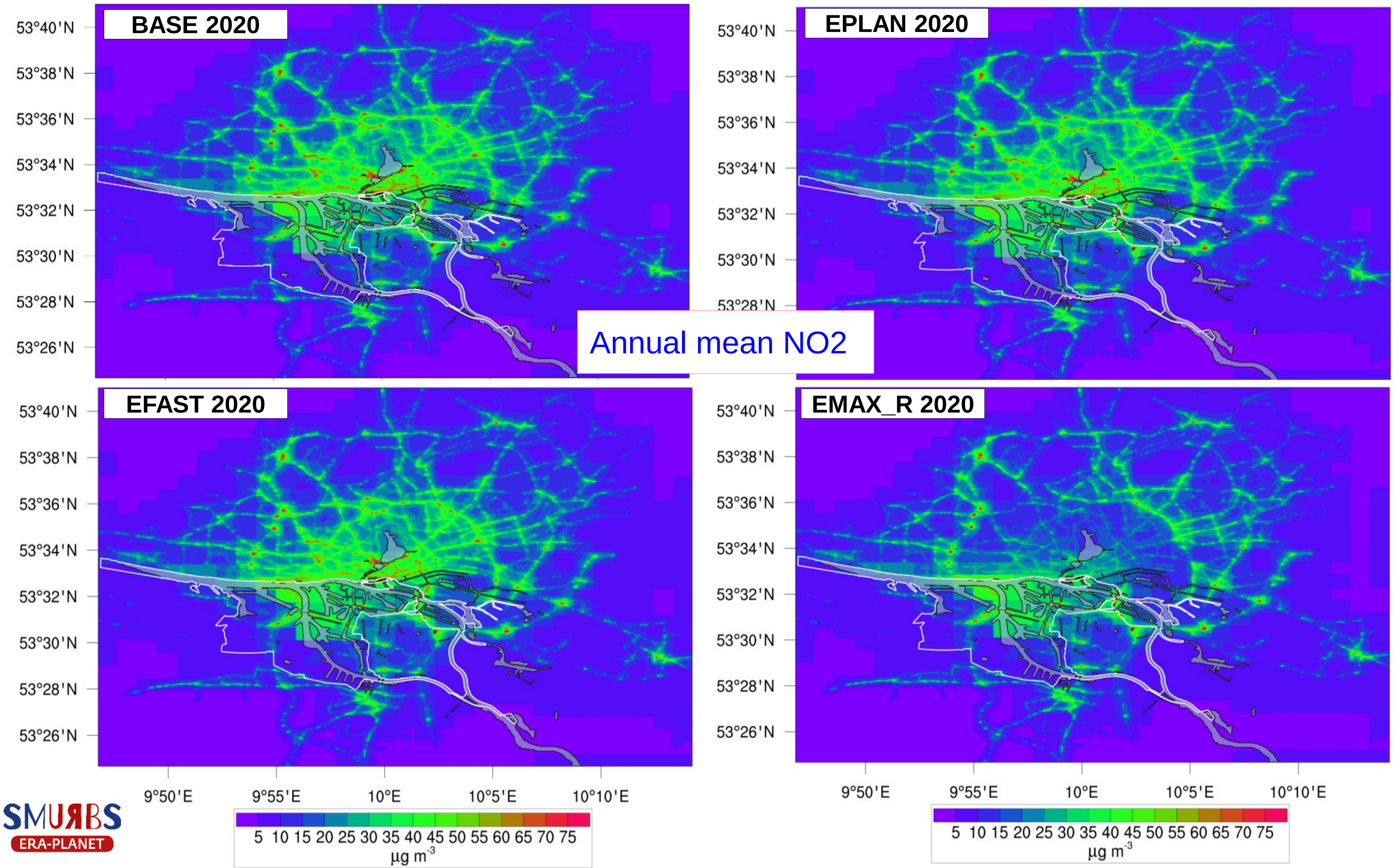

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Difference to Baseline 2020

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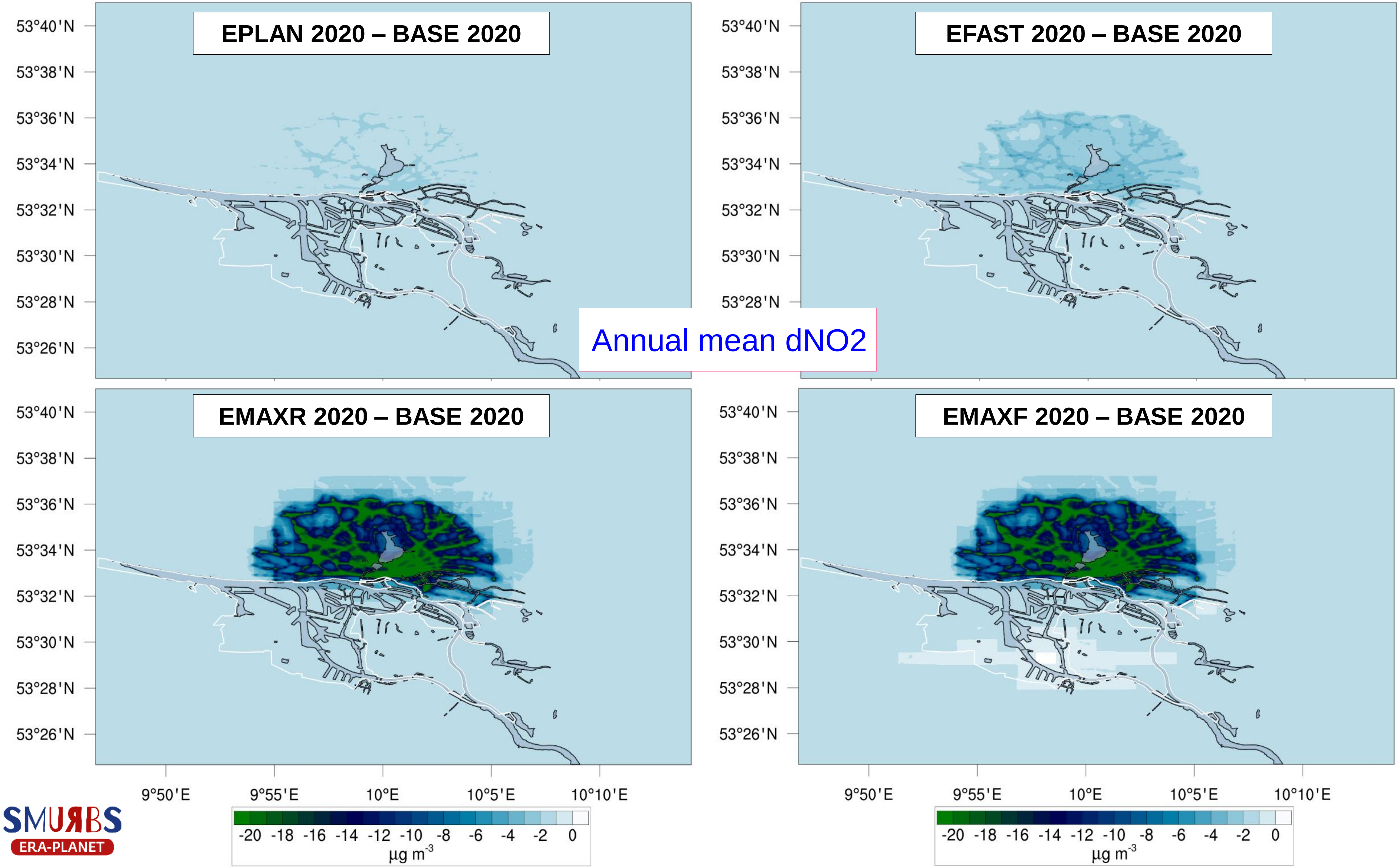

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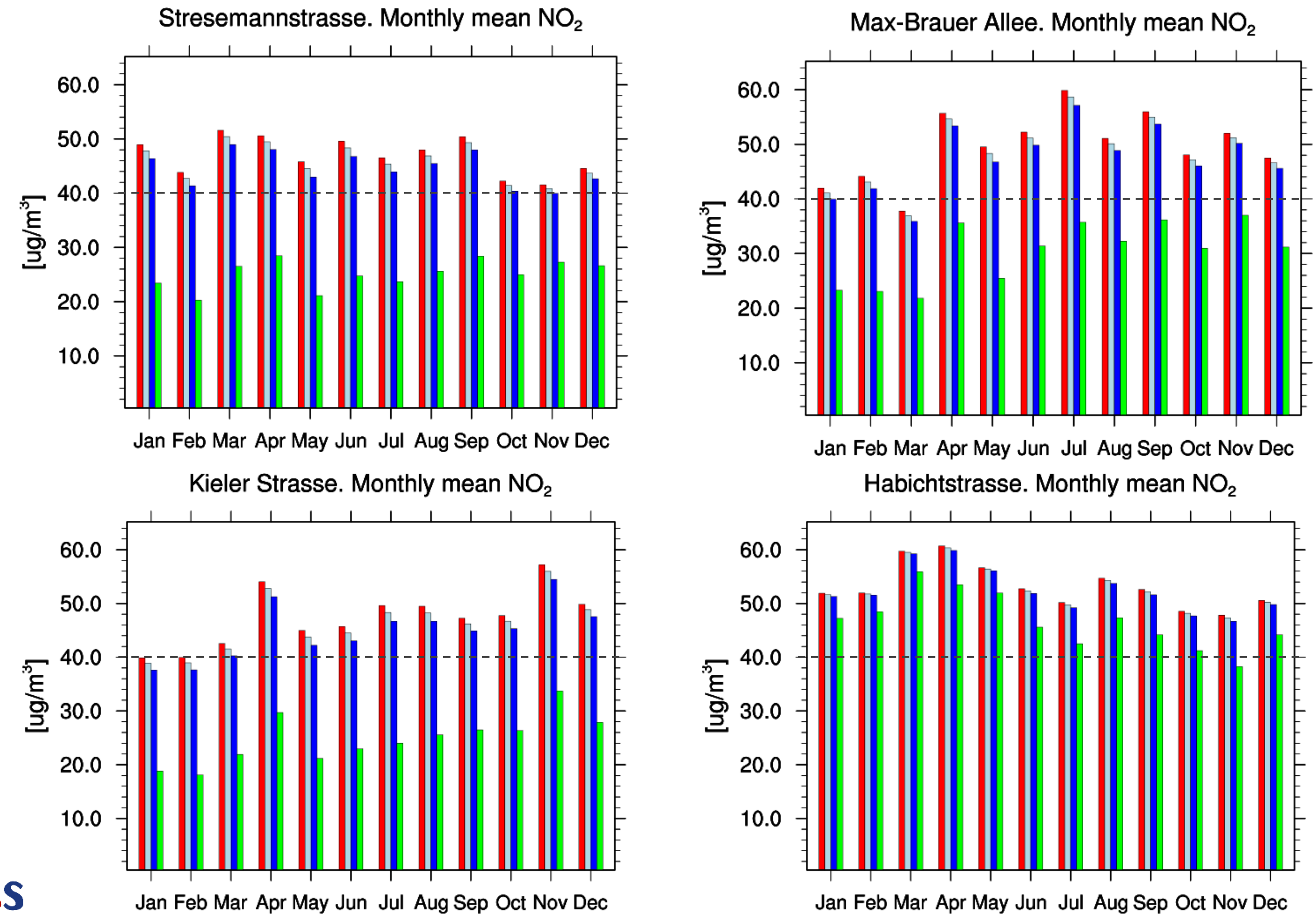
Comparison at traffic sites



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Energy supply for electric cars

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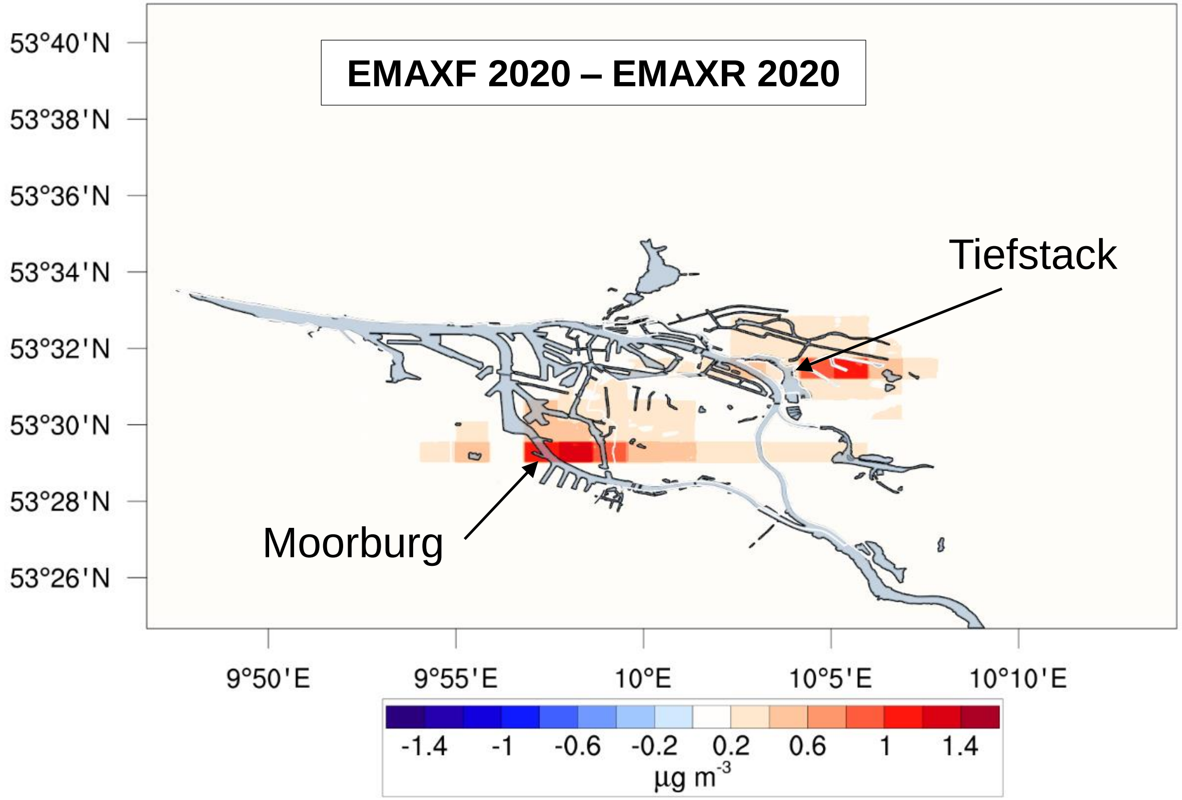
- 100% coal vs. 100% regenerative energy
- Energy consumption of electric car: 178 Wh per km [Helms et al., 2010]
- NO_X emission factor for coal-fired power plant: 0.7 gNO_X/KWh
  [German electricity mix: 0.454 gNO_X/KWh (2015)]
- Change ≤ 1.5 $\mu g/m^3$ NO_2 on annual average



Annual mean NO2

Conclusions

- Electro mobility plan proposed in Hamburg air quality plan (2017) brings only marginal reduction of NO_2 compared to Baseline 2020.
- EFAST: 20 % 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
- Electric cars avoid ultrafine exhaust particles but still emit brake and tyre wear PM
- Model system now ready for rapid assessment of suggested abatement measures

Acknowledgement

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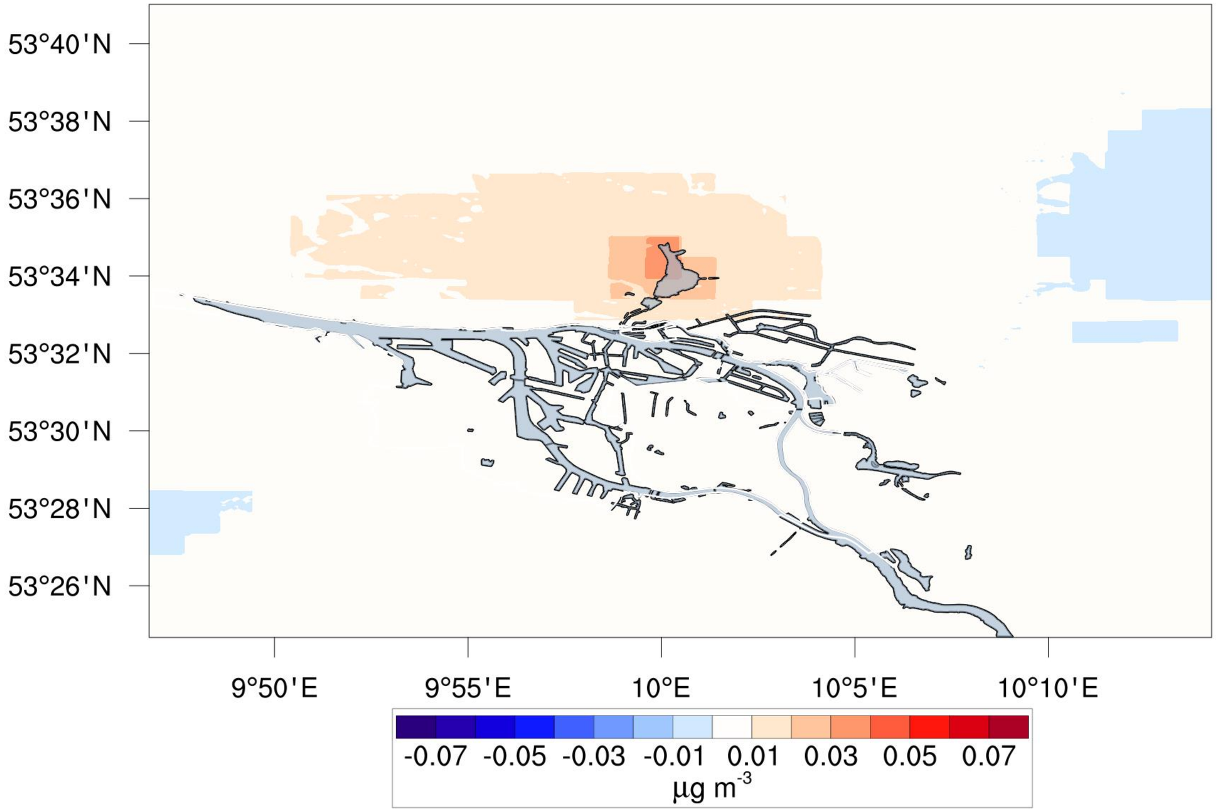
Thank you for your attention

Sensitivity of O3 to VOC emissions

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

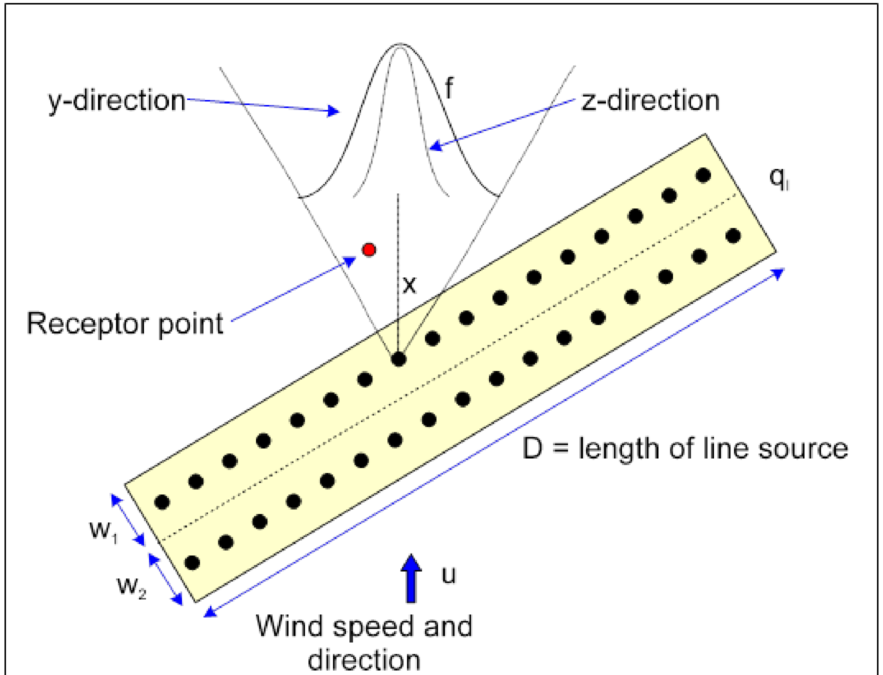
Monthly mean O3
July 2020



Line source model HIWAY-2

- 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:

$< \Delta T \leq -0.5$	$\Leftrightarrow$	Stability Class 1: Unstable conditions
$-0.5 < \Delta T \leq 0.0$	$\Leftrightarrow$	Stability Class 2: Neutral conditions
$0.0 < \Delta T \leq 0.5$	$\Leftrightarrow$	Stability Class 3: Moderately stable condition
$0.5 < \Delta T$	$\Leftrightarrow$	Stability Class 4: Stable conditions



Source: NILU / B. Sivertsen