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Enhancing fine PM emissions assessment from urban traffic through bottom-up approach: case study for the city of Milan

Andrea Piccoli, Valentina Agresti, Marco Bedogni, **Giovanni Lonati**, Guido Pirovano

RSE Ricerca Sistema Energetico

AGENZIA MOBILITÀ AMBIENTE TERRITORIO

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KIT Karlsruher Institut für Technologie

Background

- Exhaust and non-exhaust emissions from road traffic are the most relevant contributors to airborne particulate matter (PM) in urban areas, especially in the warm season when space heating sources are not active
- Emission quantification, temporal modulation and spazialization are key points for developing accurate air quality modelling studies
- Annual emissions data are usually available from emission inventories, mostly obtained through top-down (TD) approach and related to the whole urban area, thus lacking of detailed space and time resolution

Research goals

- Air quality model development
  - ✓ Lagrangian puff model **Linear Plume in Grid** (LPiG) for **hybrid modeling techniques in CAMx** Eulerian chemical and transport model

- Emission assessment enhancement
  - ✓ **Bottom-up** modeling chain for **road traffic emissions** to connect a traffic model to the air quality model using a **macroscopic approach** to traffic and emission modeling

- Test case analysis
  - ✓ Analysis of an **electric mobility scenario** in an urban area: the **Milan test case**

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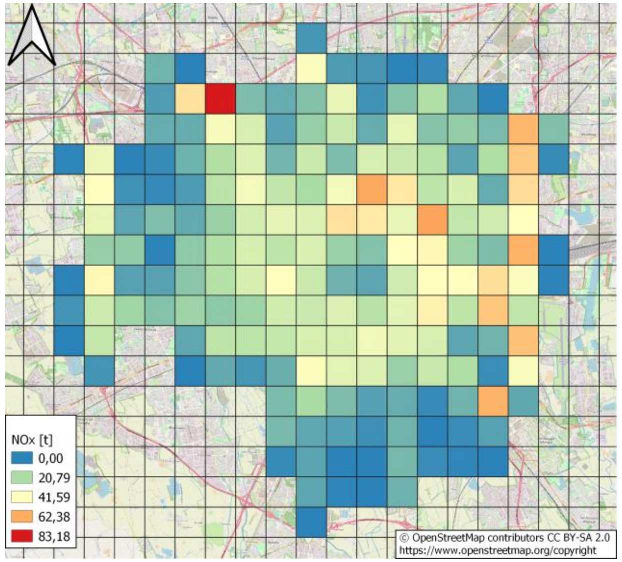
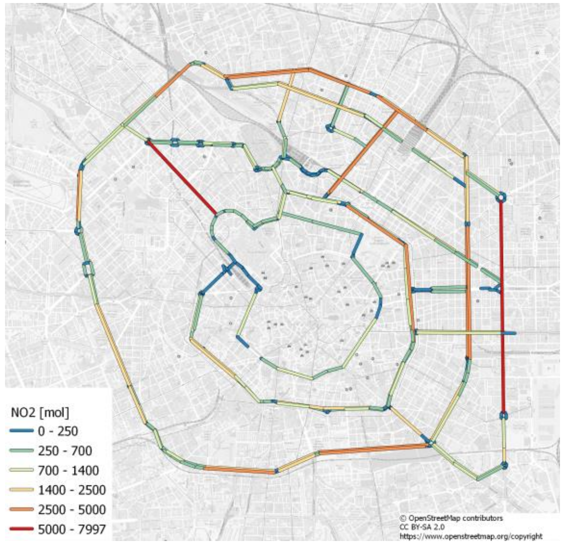
- Test case analysis
  - ✓ Analysis of prospected **mobility scenarios** in an urban area: the **Milan test case**

Rationale for emission assessment enhancement

- Modelling air quality with **street detail** requires great accuracy in estimating **input road traffic emissions**
- Spatial gridded emission from inventories are not suitable for hybrid Eulerian-Lagrangian (CAMx + LPiG) systems

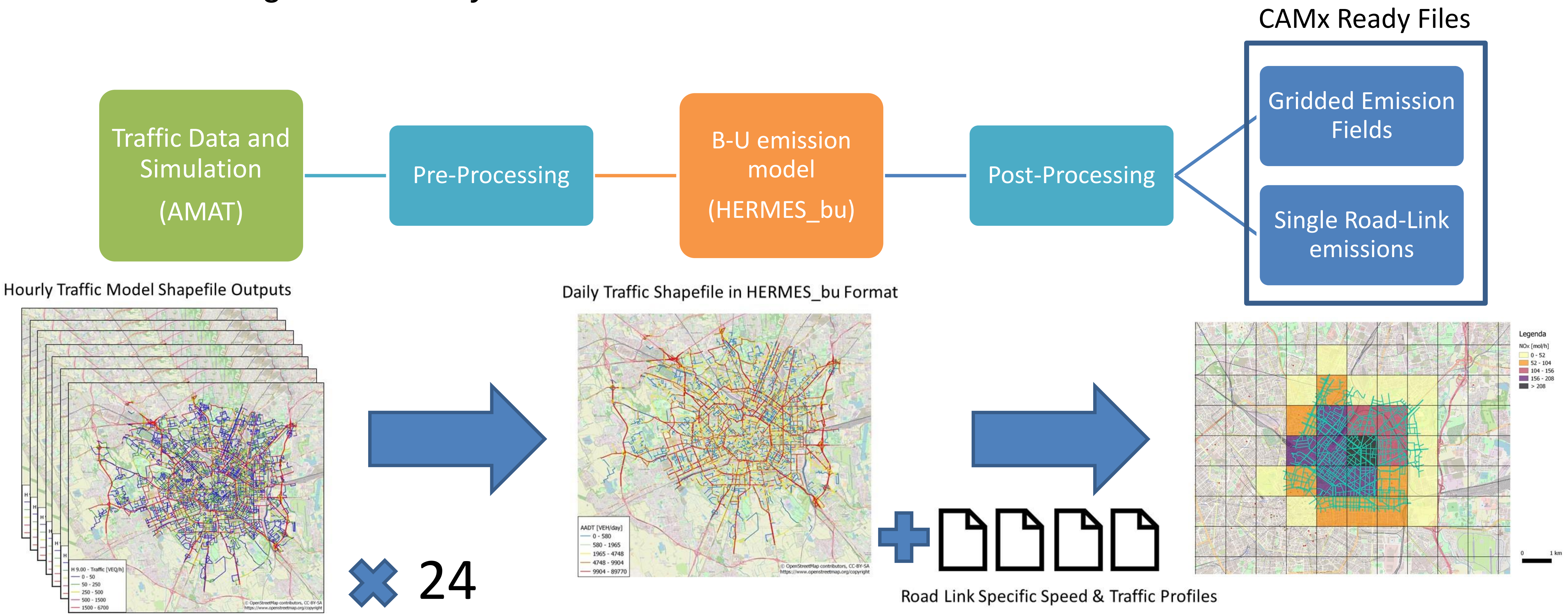




- Effects of local intervention on traffic may be not properly reproduced by gridded emissions

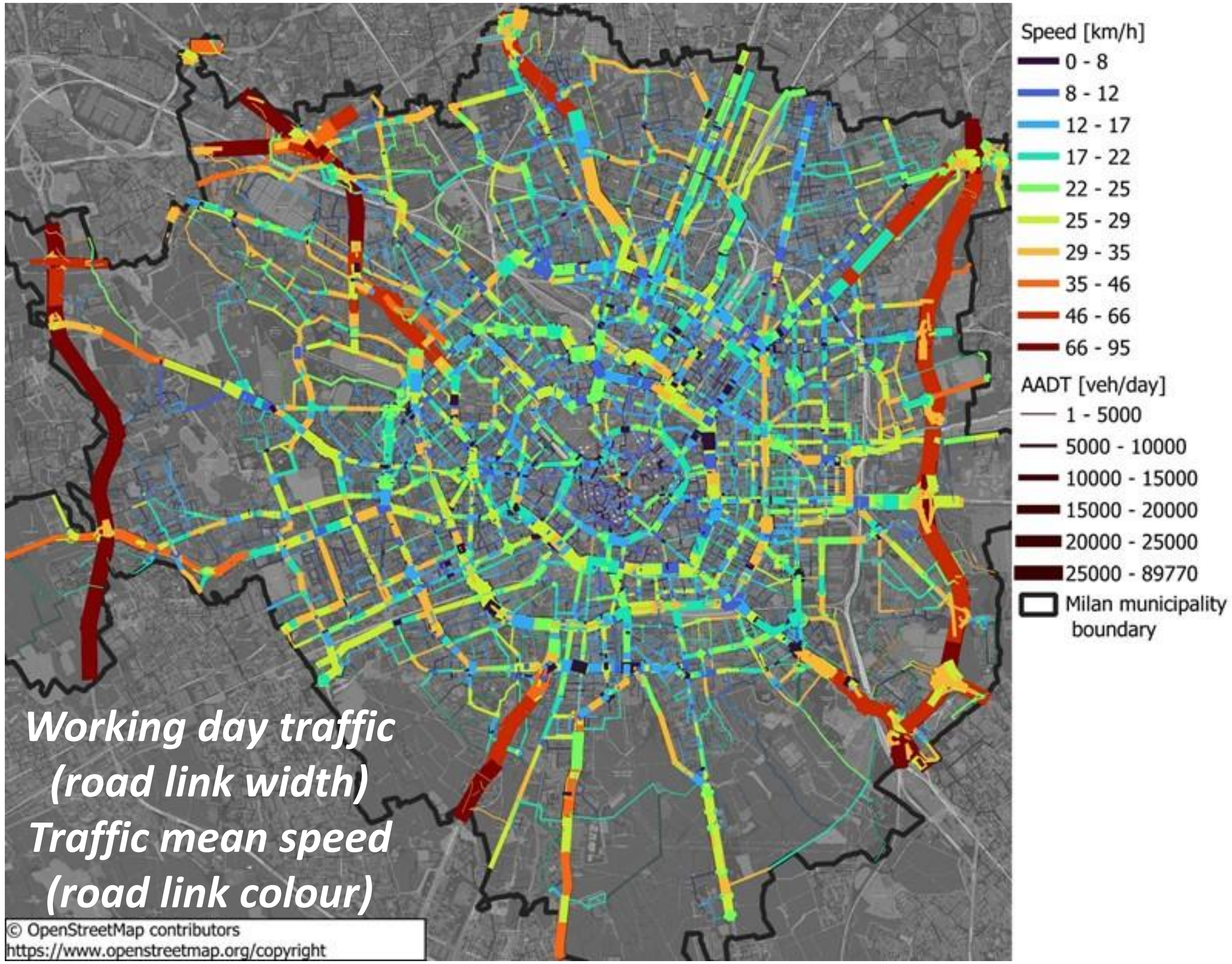
Bottom-Up Traffic Emission Model

Create high accuracy bottom-up emission fields for the road transport sector in Milan to be used as base for the green mobility scenarios assessment



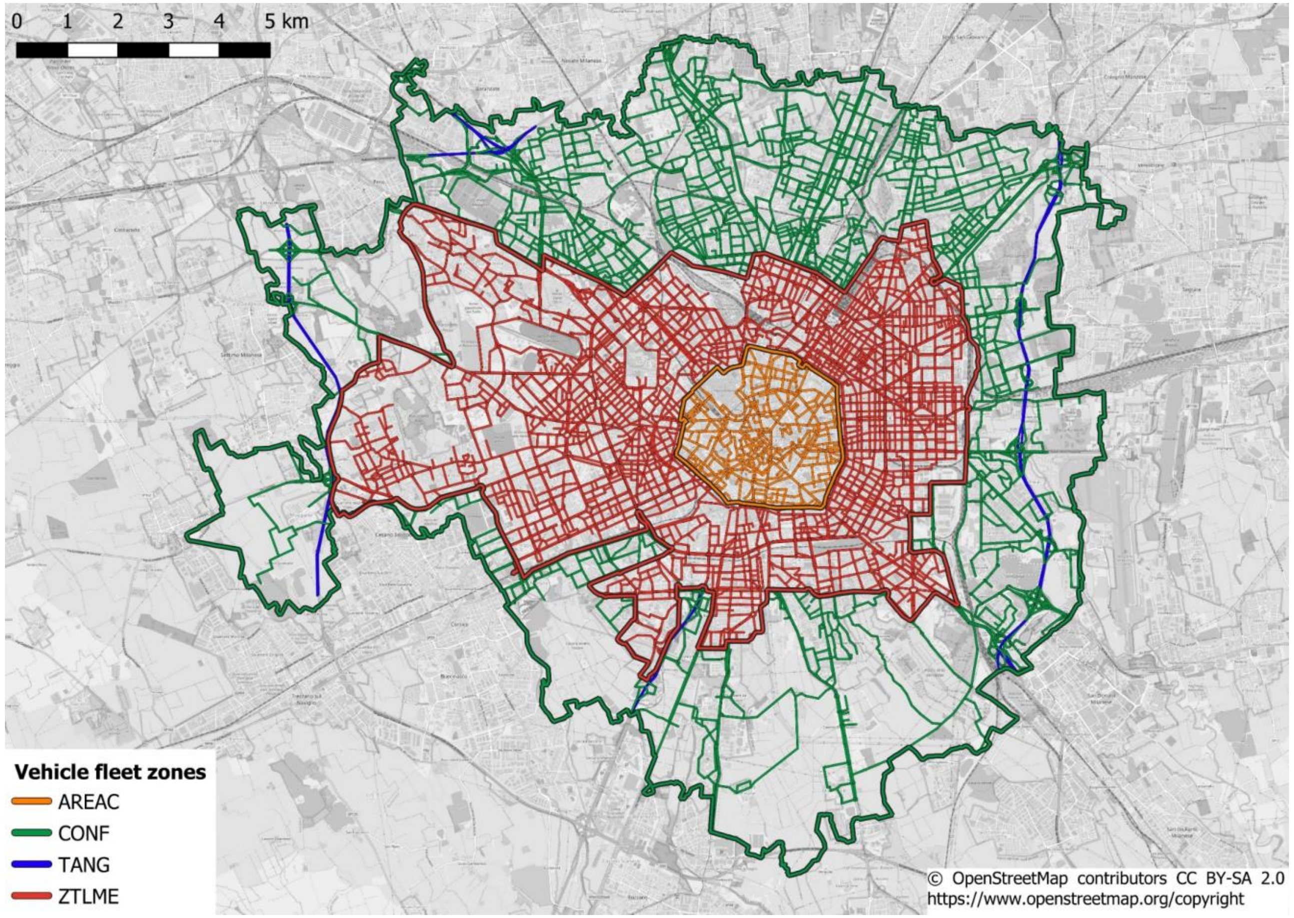
Methods – Traffic modeling

- Private traffic data from AMAT (Milan municipality mobility agency)
  - ✓ Macroscopic traffic modeling approach
  - ✓ Model simulation for 19069 road links in the city of Milan
  - ✓ Hourly traffic results for a working day
  - ✓ Fractional composition of traffic for vehicle macro classes (cars, motorcycles, L&HDVs)
  - ✓ Zonal fleet composition according to current restrictions to circulation



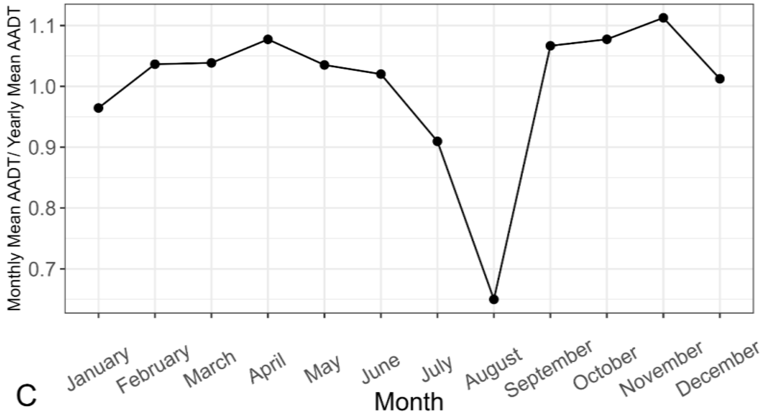
Methods – Traffic modeling

- Private traffic data from AMAT (Milan municipality mobility agency)
  - ✓ Zonal fleet composition according to current restrictions to circulation
    - Milan Low Emission Zone (LEZ AREAC)
    - urban area with restrictions for heavy duty vehicles (ZTLME)
    - highways (TANG)
    - area without specific restrictions



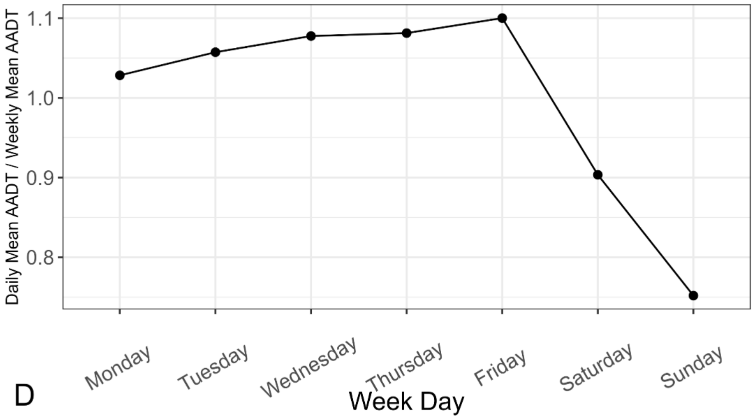
Methods – Traffic temporal profiling

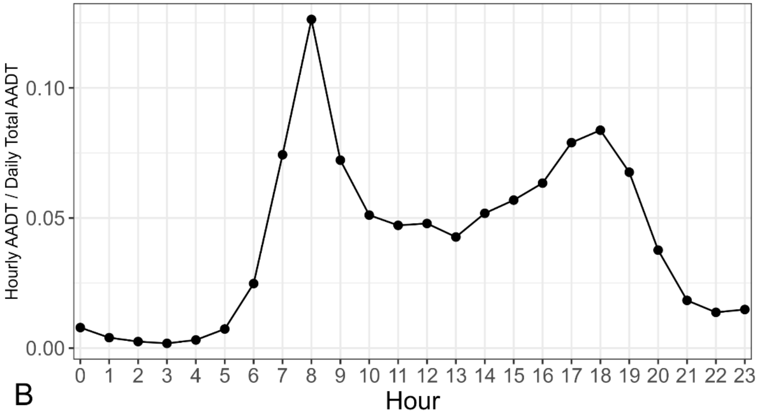
Monthly, weekly and hourly profiles based on traffic counts data



Normalized **monthly** traffic profile
(fractions of mean total annual traffic)

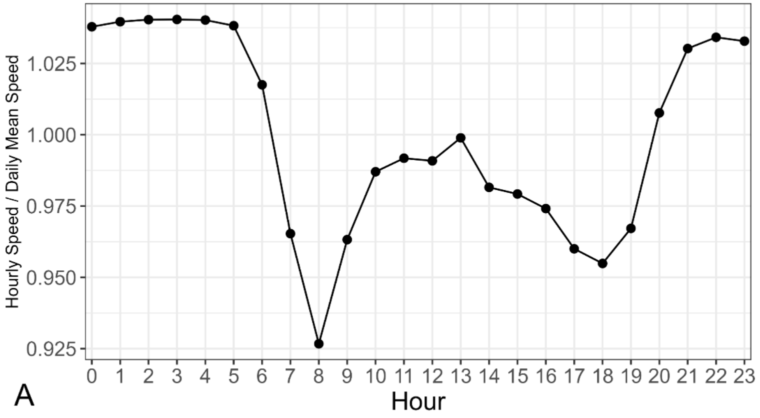
Normalized **weekly** traffic profile
(fractions of mean total weekly traffic)





Normalized **hourly** daily traffic profile
(fractions of mean total daily traffic)

Normalized hourly **mean speed profile**
(ratios of hourly speed to daily average speed)

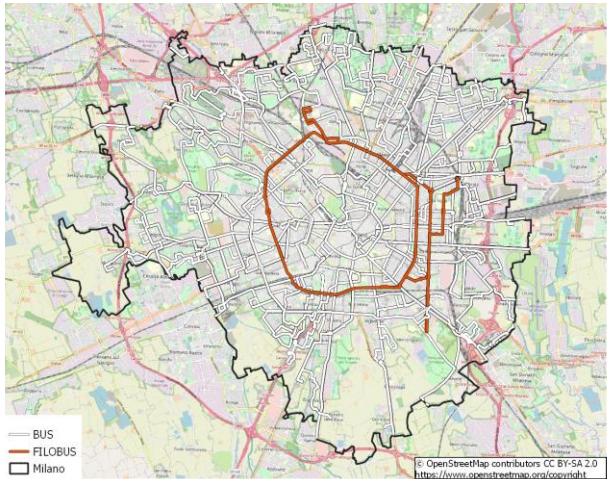


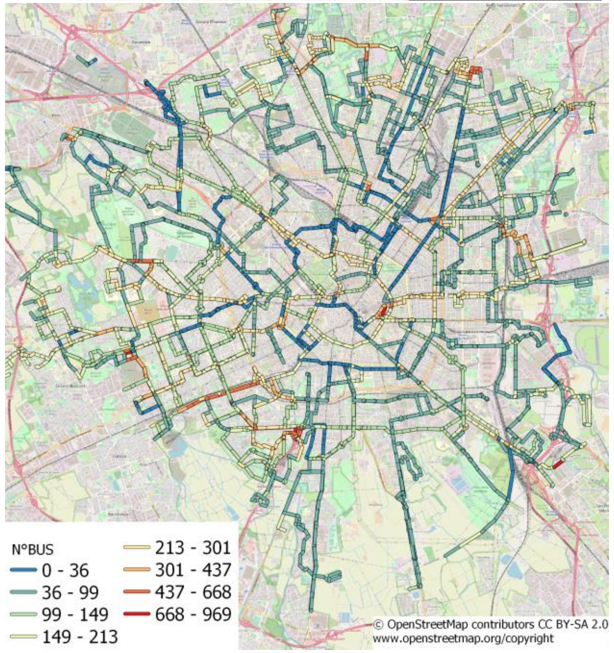
Bottom-Up Traffic Emission Model

➢ Public traffic data from Milan municipality

Urban Public transport service including buses and electric bus

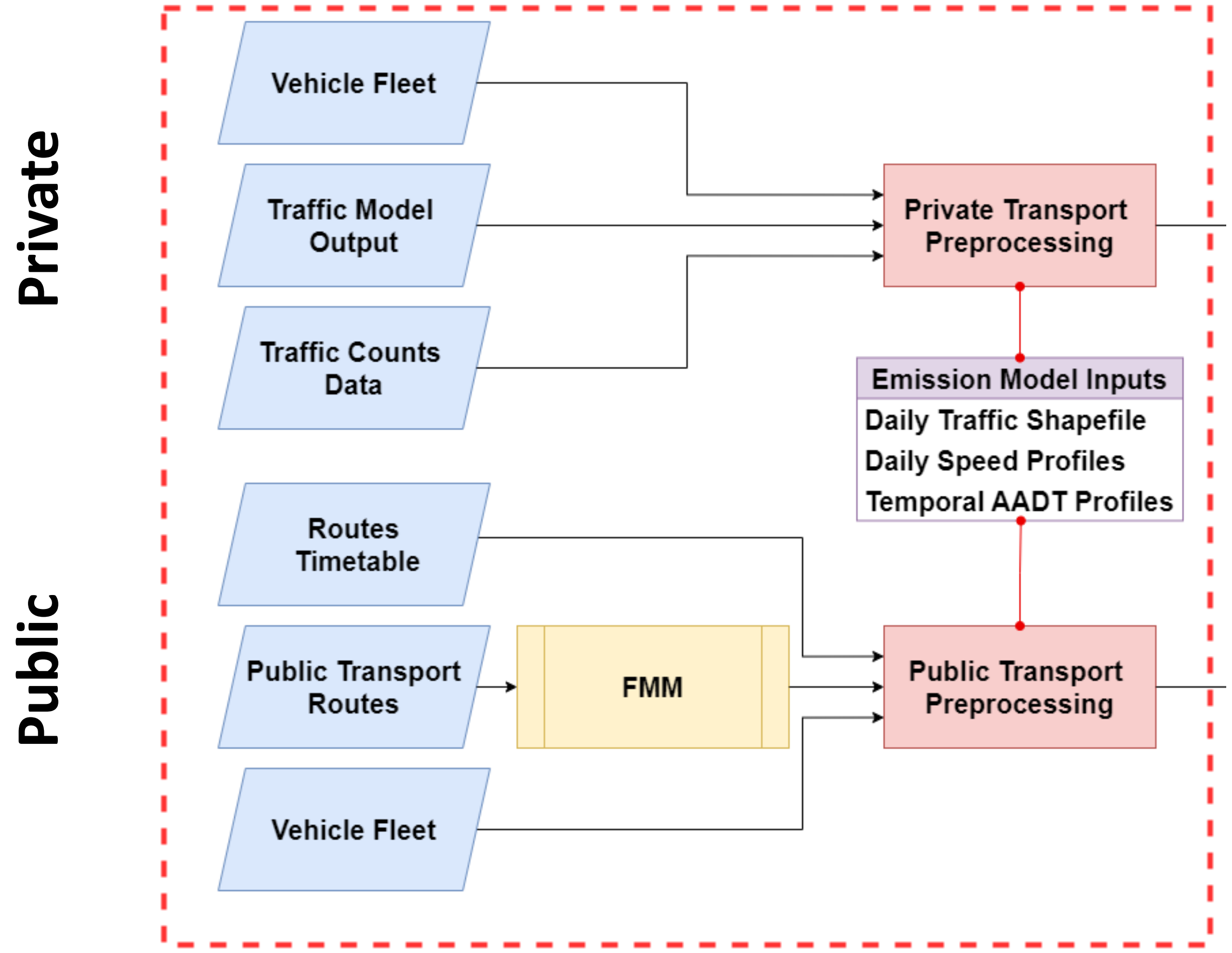
- ✓ Based on Open Data[1] of Bus and Trolleybus
- ✓ Three main steps:
  - ➢ Assignment of bus routes to the urban road network through map matching programs (FMM)
  - ➢ Computation of the total daily public traffic for each road link
  - ➢ Definition of monthly, weekly and daily profiles for the public traffic flows variation
  - ➢ Bus fleet composition (EURO classes) evaluated based on municipality data (50% Euro4 or older)



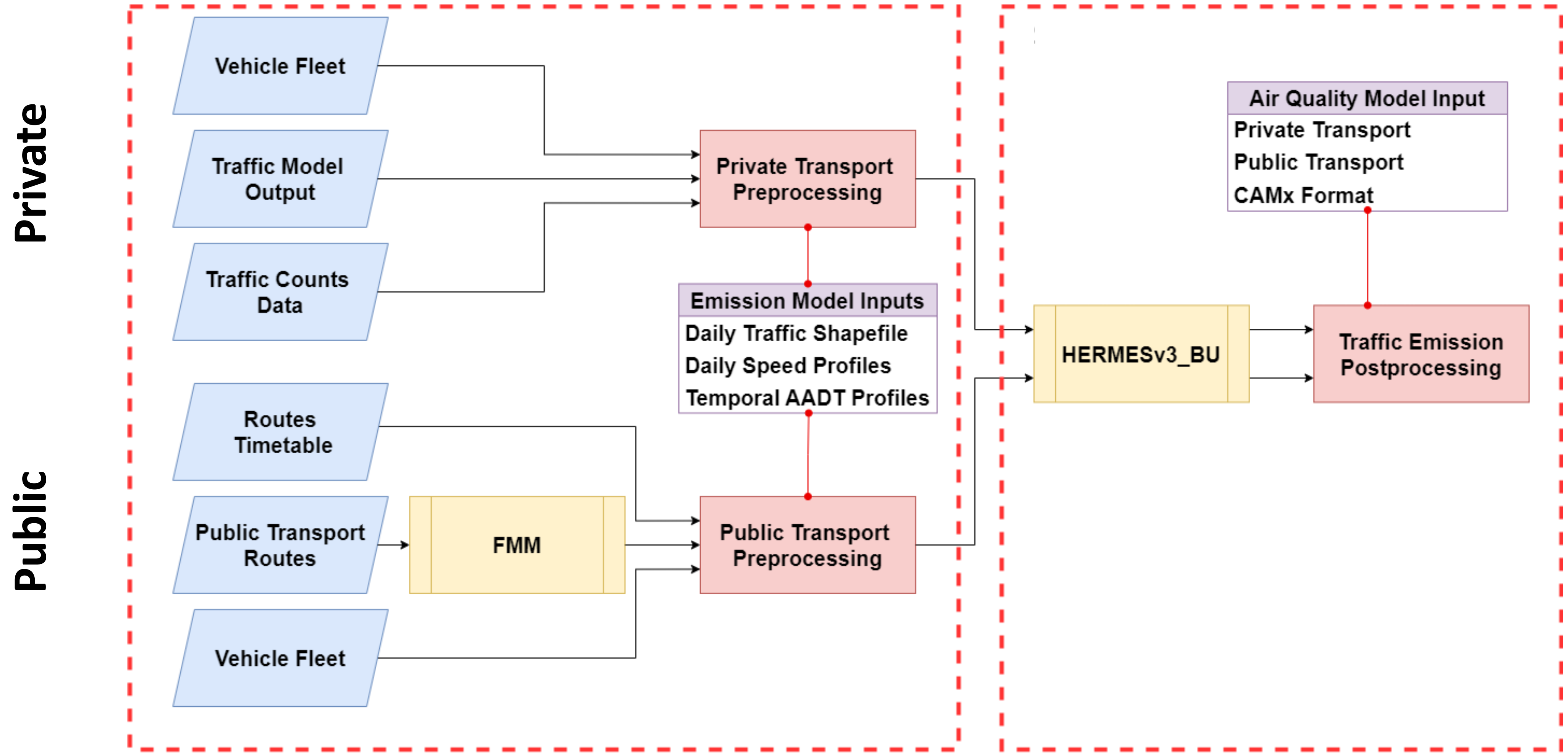


1 - https://dati.comune.milano.it/group/32bbfe8c-ca16-4ec3-bd6f-c12380ca3a11?tags=TPL&page=1

Bottom-Up Traffic Emission – Traffic module



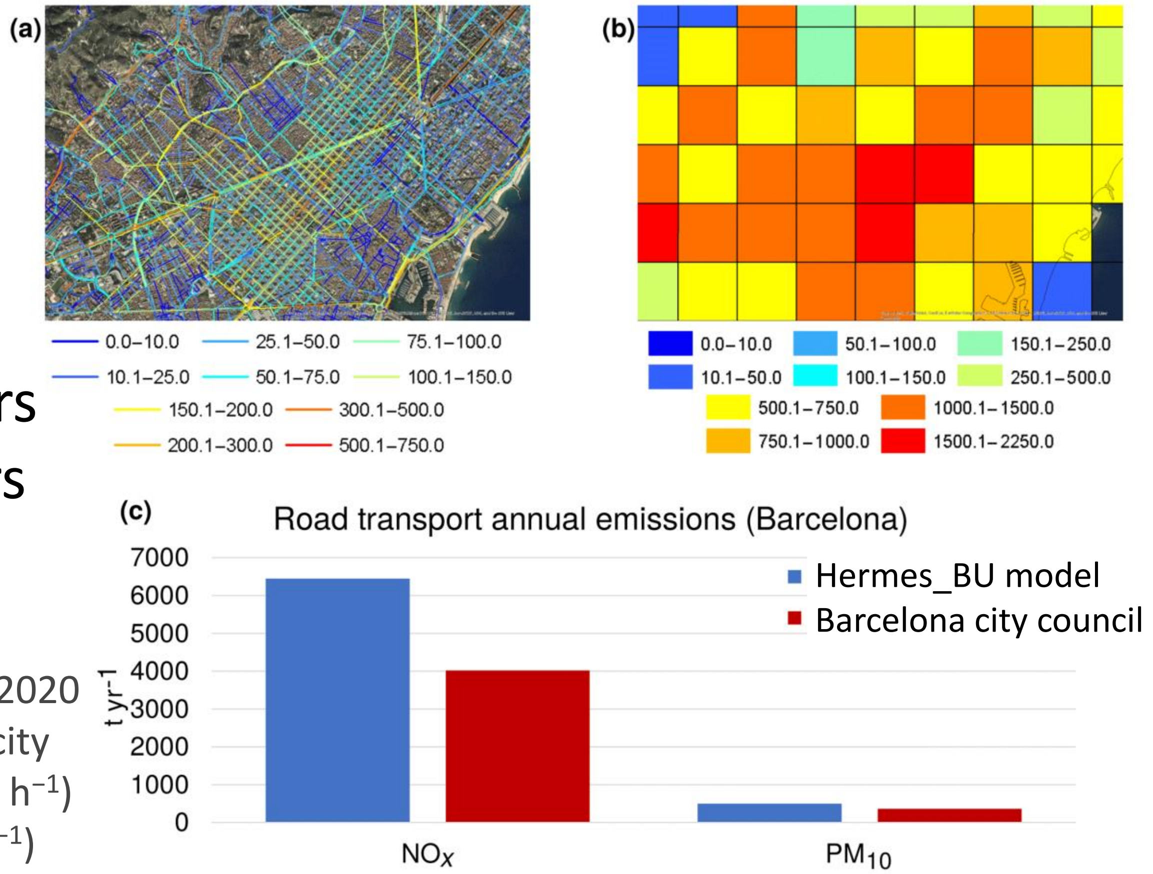
Bottom-Up Traffic Emission Model – Traffic & emission module



Methods – Emission model

- HERMESv3_bu model (*Guevara et al., 2020*)
  - ✓ High-Elective Resolution Modelling Emission System version 3 for Bottom-Up
  - ✓ Can estimate anthropogenic emission from various sectors including Road Traffic
  - ✓ COPERT V methodology
  - ✓ Both exhaust and non-exhaust (wear) emissions
  - ✓ Includes road dust resuspension

vehicle-type dependent resuspension emission factors correction factor as a function of the number of hours after a precipitation event



Guevara et al. 2020

Hourly $PM_{2.5}$ road transport emissions estimated for an area of Barcelona city at **(a)** the road link level (kg km^{-1} h^{-1}) and **(b)** grid cell level (1 km×1 km) (kg h^{-1}) **(c)** Barcelona city total annual NO_x and PM_{10} road transport emissions (t yr^{-1})

Bottom-Up Traffic Emission Model - Post-Processing steps

3 consecutive tools to create road links emission for CAMx while reducing the computational effort for CAMx

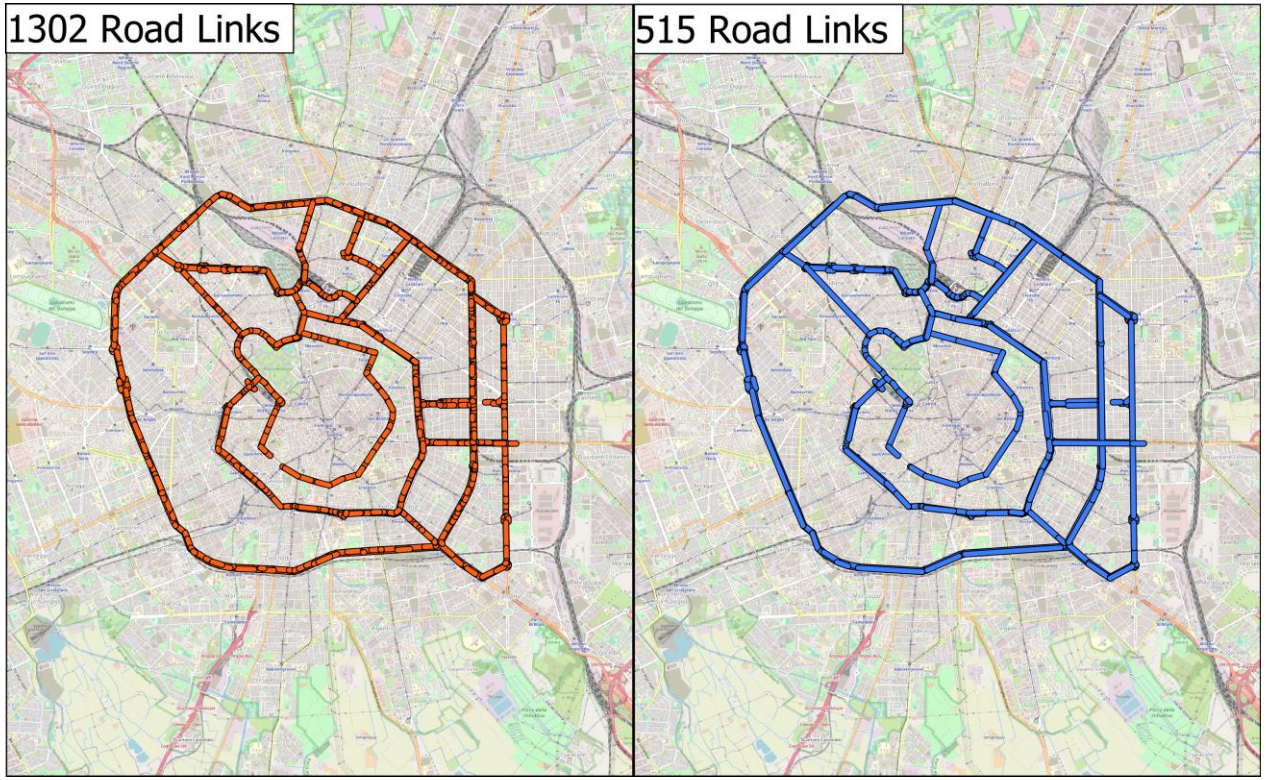
Reduces the number of roads by merging consecutive short links that lie in a straight line

↓

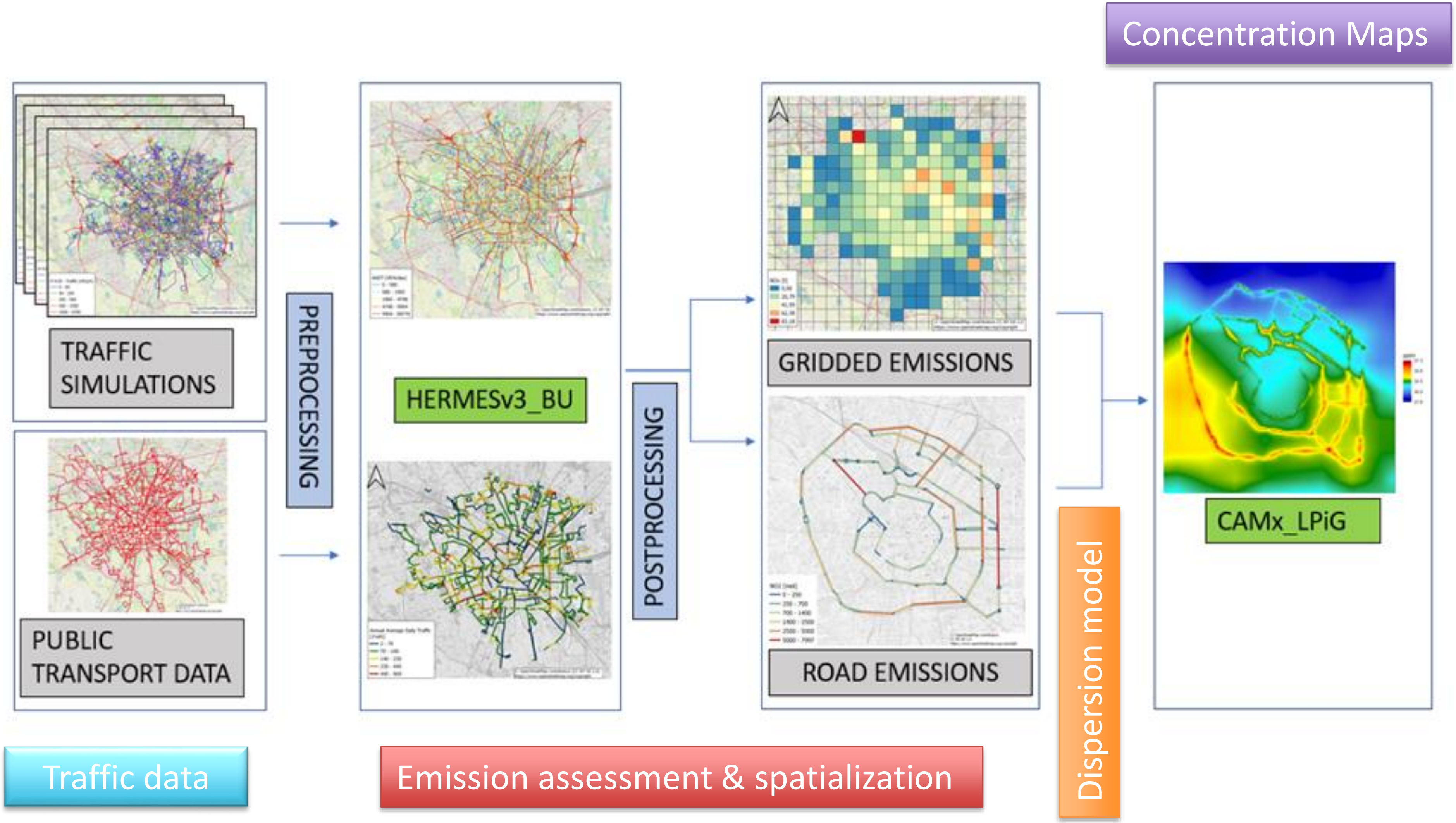
Sums hourly emission for each old road links into the new longer links

↓

Writes the CAMX ready hourly road links emission file for each day

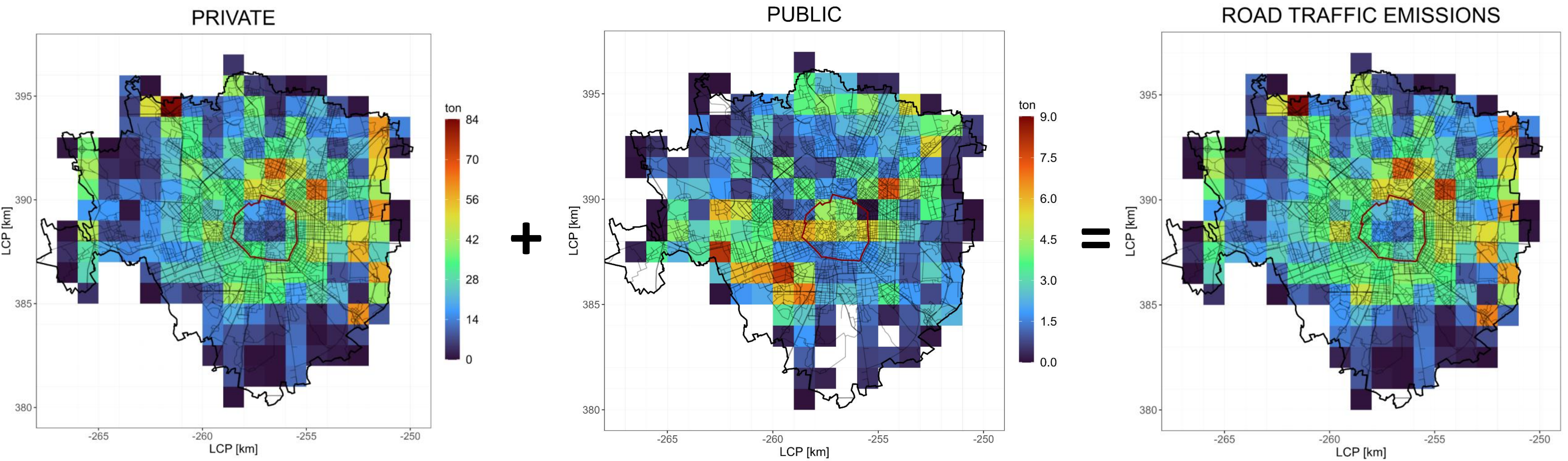


Bottom-Up traffic emission modelling chain



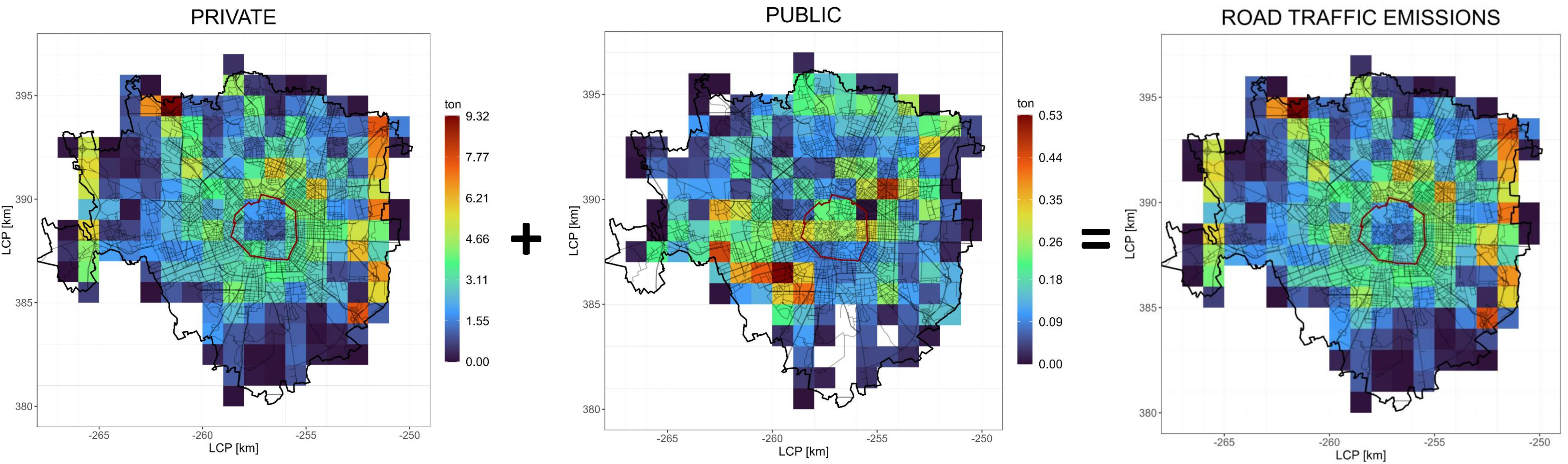
Bottom-Up vs Top-down emission estimates

Gridded annual emissions NOx (tons $year^{-1}$) for the traffic sector in the city of Milan



Bottom-Up vs Top-down emission estimates

Gridded annual emissions PM10 (tons year^{-1}) for the traffic sector in the city of Milan



Bottom-Up vs Top-Down emission estimates

Annual emissions (tons year^{-1}) for the private and public traffic sector in the city of Milan

	Bottom-up				Top-down	Difference	
	Private traffic	Public traffic	Total road traffic	Public/Total traffic ratio	Total road traffic	Absolute	%
SO_2	7.88	0.34	8.22	4.13 %	8.58	-0.35	-4.12
NH_3	47.83	0.15	47.98	0.31 %	56.50	-8.53	-15.09
NOx	3966.21	382.11	4348.32	8.79 %	4394.09	-45.77	-1.04
VOC	1534.43	14.89	1549.33	0.96 %	1508.72	40.61	2.69
PM10	425.46	23.03	448.50	5.14 %	299.14	149.36	49.93
OC	65.84	2.00	67.84	2.95 %	48.90	18.95	38.74
PM2.5	258.40	13.42	271.82	4.94 %	219.68	52.14	23.74

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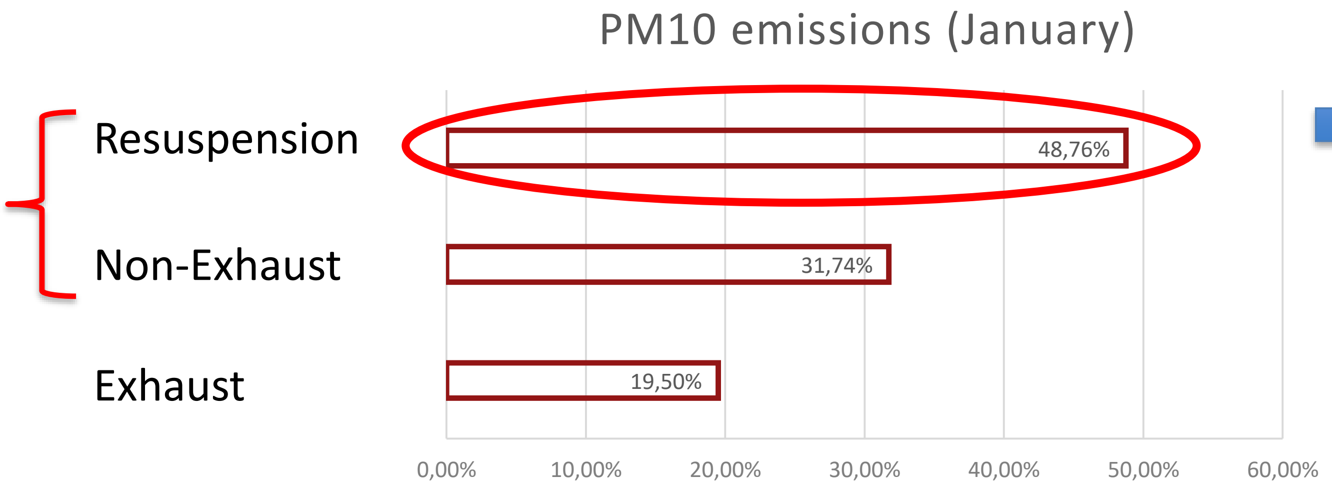
80% of traffic emissions are of non-exhaust origin



Conclusions

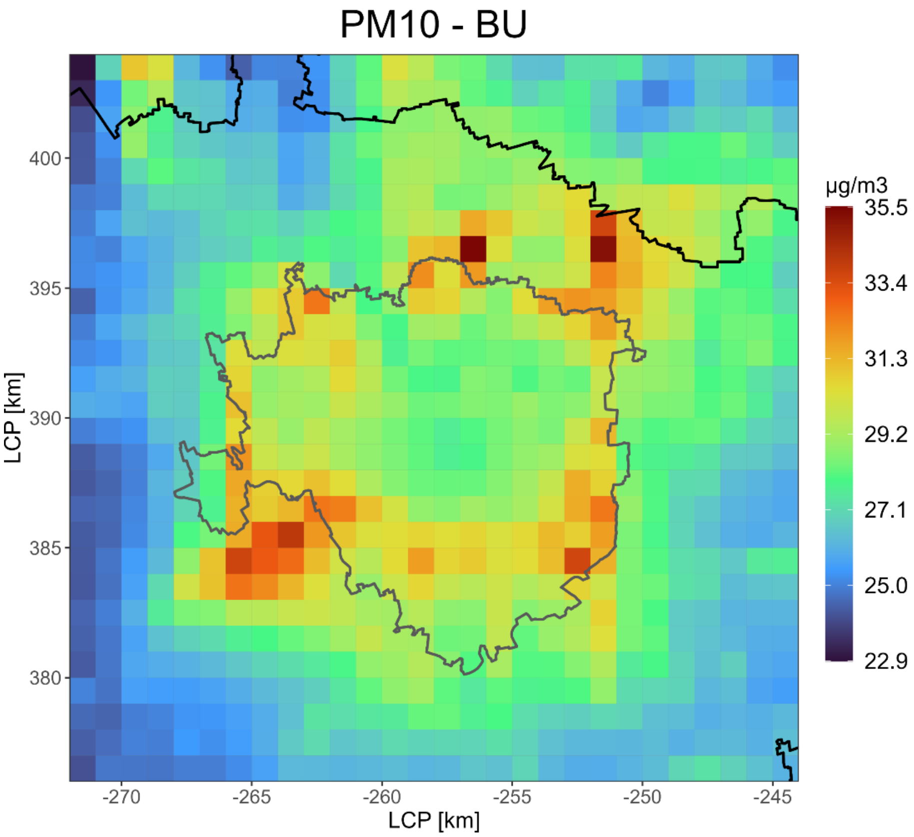
- ✓ The high resolution of traffic data allowed to precisely reconstruct the main features of the emission spatial distribution over the urban area
  - ➢ LEZ presents lower emissions from private traffic compared with the surrounding areas thanks to a cleaner vehicle fleet and lower traffic volumes

- ✓ Bottom-up emission estimates in agreement with top-down inventory data for gases
  - ➢ PM10 emissions estimated by bottom-up are 49% higher than the top-down inventory thanks to the inclusion of resuspension

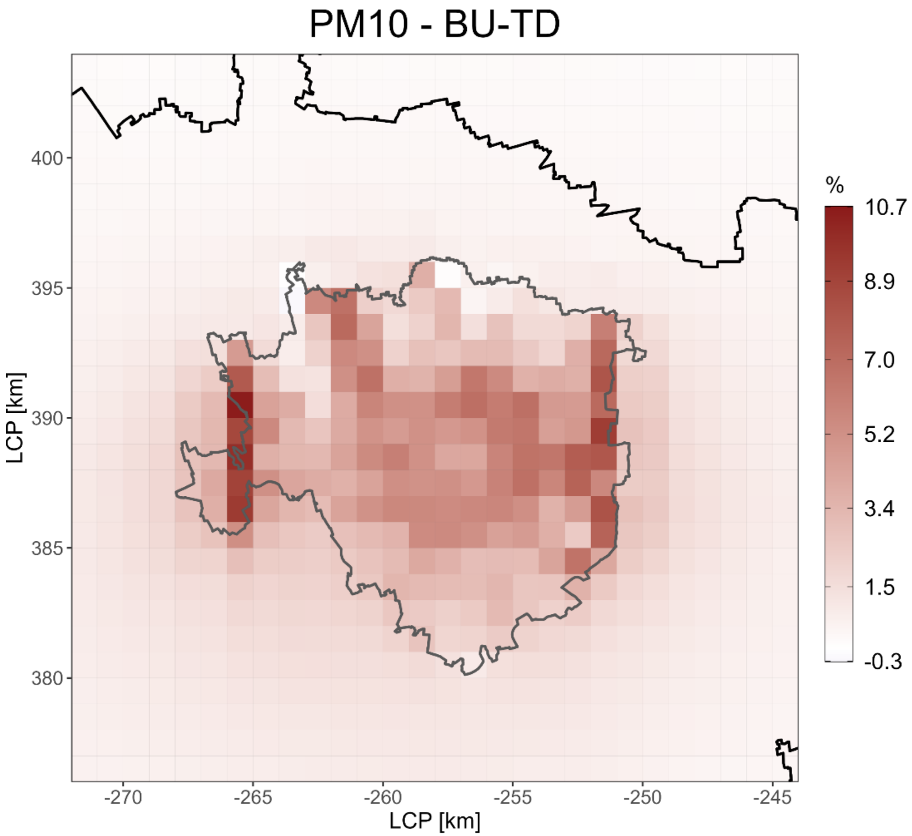
- ✓ Bottom-up modelling chain input slightly improved PM10 simulation results compared with the top-down approach, lowering the underestimation of observed values
  - ➢ a better spatialization of emissions and inclusion of dust resuspension are the main reasons for these improvements

Conclusions

Improvement in PM10 simulation results



Yearly mean concentration field for the CAMx-BU simulation

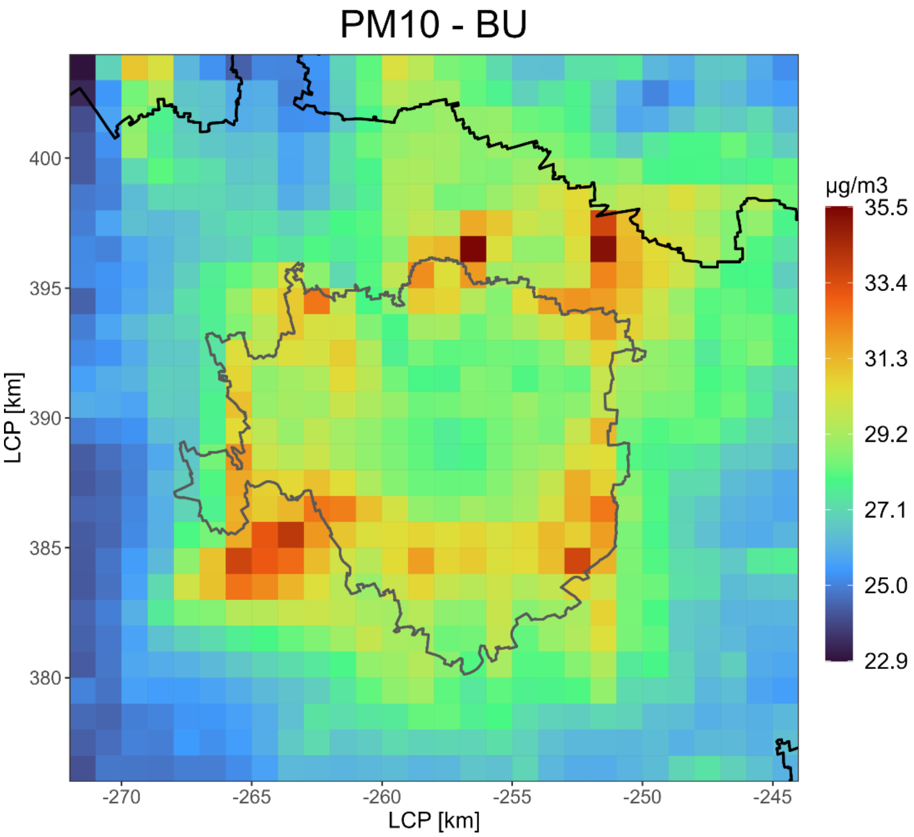


Concentration difference field for the CAMx-BU vs. CAMx-TD

		Annual mean			
Site	Model	Obs. ($\mu g\ m^{-3}$)	Mod. ($\mu g\ m^{-3}$)	MB ($\mu g\ m^{-3}$)	R (-)
UT	BU	39.4	28.0	-11.5	0.80
	TD		26.7	-12.8	0.79
UB	BU	40.4	29.2	-11.1	0.80
	TD		27.9	-12.5	0.79

Conclusions

Improvement in PM10 simulation results



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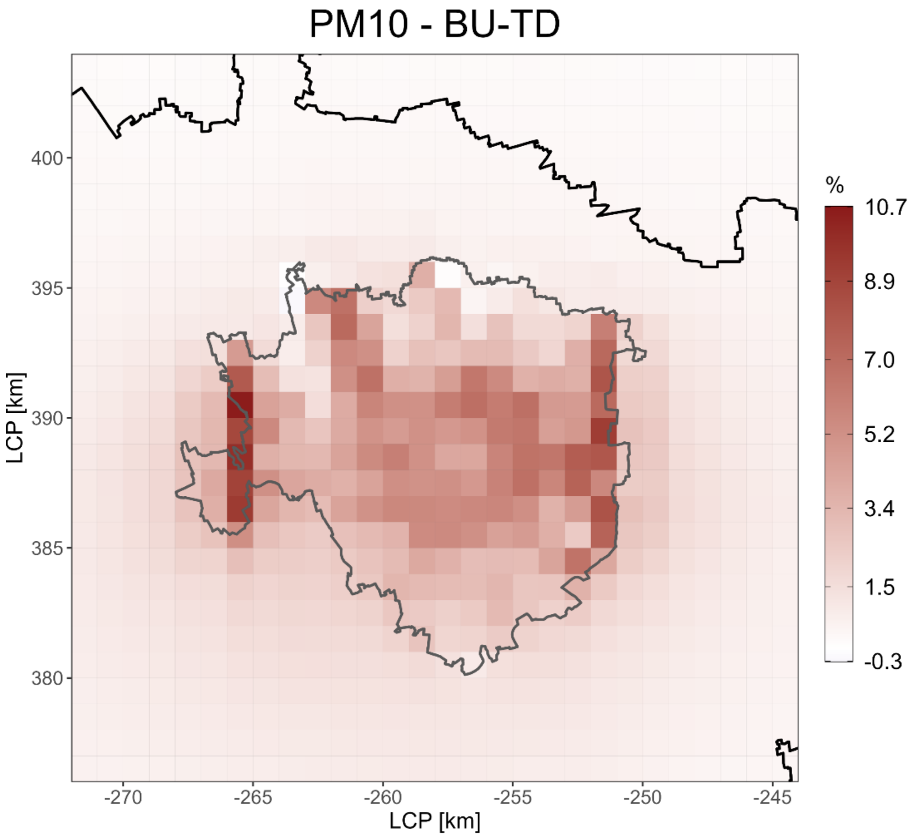

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Final remarks

- ✓ The BU approach provided several **advantages** compared to the standard TD approach: better **spatialization** of emissions, higher **level of control** of every step of the process, as updated *emission factors*, vehicle *fleet composition*, traffic *temporal profiling*
- ✓ The **flexibility** of the modelling chain is crucial to simulate the impacts of **mobility policies**: reduction of traffic flows promoted by *behavioural changes*, the implementation of *Zero Emission Zones* or city-wide *low-speed limits*
- ✓ Inclusion of **resuspension** is a strength point of the BU emission model, as the future of road traffic is headed towards *electric vehicles* whose weight could lead to *lower reductions* of primary PM emissions

- ✓ Access to **traffic data** is the main limitation of BU approach, as refined road traffic data is usually challenging to acquire
- ✓ **Correction factor** for dust resuspension assessment to be defined based on local studies

Thanks for you attention