Development and deployment of a real-time traffic emission and dispersion model in Bolzano / Bozen

3° workshop INTEGREEN – Bolzano, 26/02/2015

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Introduction

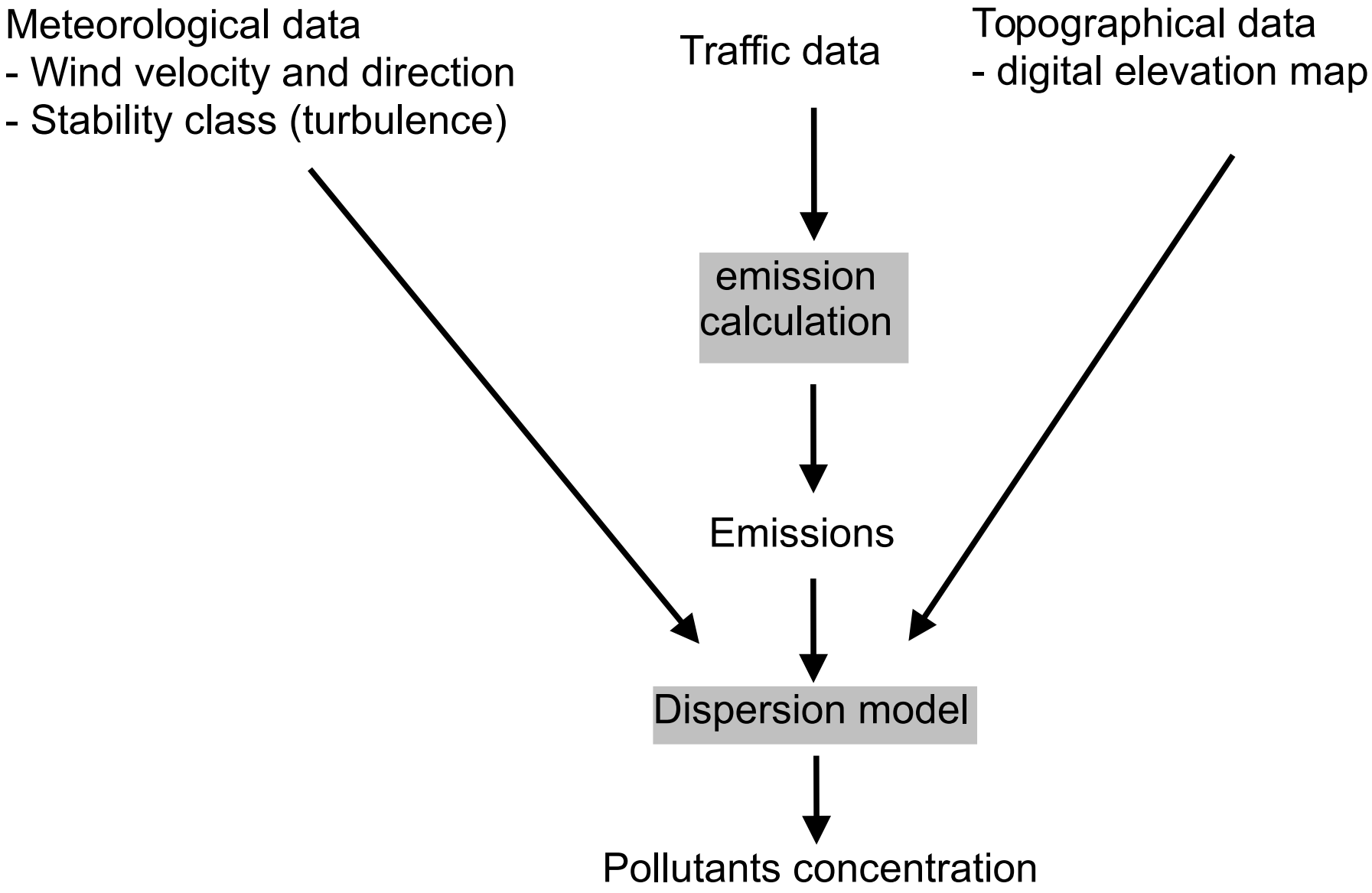
Aim of the work:
Provide a calculation method to estimate emission from traffic source in the town of Bolzano

Logical scheme:
Traffic data → distribution over the road network → pollutant **emission calculation** → pollutant **dispersion** in the atmosphere

Field of application:
Municipality of Bolzano, on major road network (in principle extensible, as the method is implemented in generalized way)

Major advantage:
Can perform **real-time** estimations that can be used for the adoption of eco-friendly traffic and environmental management policies, according to the main objectives of the INTEGREEN project

Model scheme



Methodologies for emission calculation

Known and established methodologies for pollutant emission from traffic and their peculiar characteristics

- Mobile6 (USA, Canada) – not easily adapted to EURO classification
- ARTEMIS (France) – most detailed but difficult to apply at a practical level
- HBEFA (Austria, Switzerland, Norway)
- COPERT IV (Italy, UK, Greece, Spain, Germany) – compliant to EMEP standard and compatible with the methodology already adopted from the Province of Bolzano for its emission inventory → was chosen for the INTEGREEN project

COPERT methodology

Fuel Variables
- consumption
- specifications per fuel type

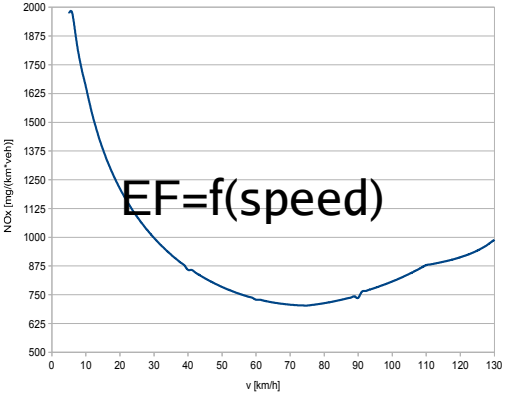
Activity Data
- number of vehicles per vehicle category
- distribution of vehicles into different exhaust emission legislation classes
- mileage per vehicle class
- mileage per road class

Driving Conditions
- average speed per vehicle type
- average speed per road

Other Variables
- climatic conditions
- mean trip distance
- evaporation distribution

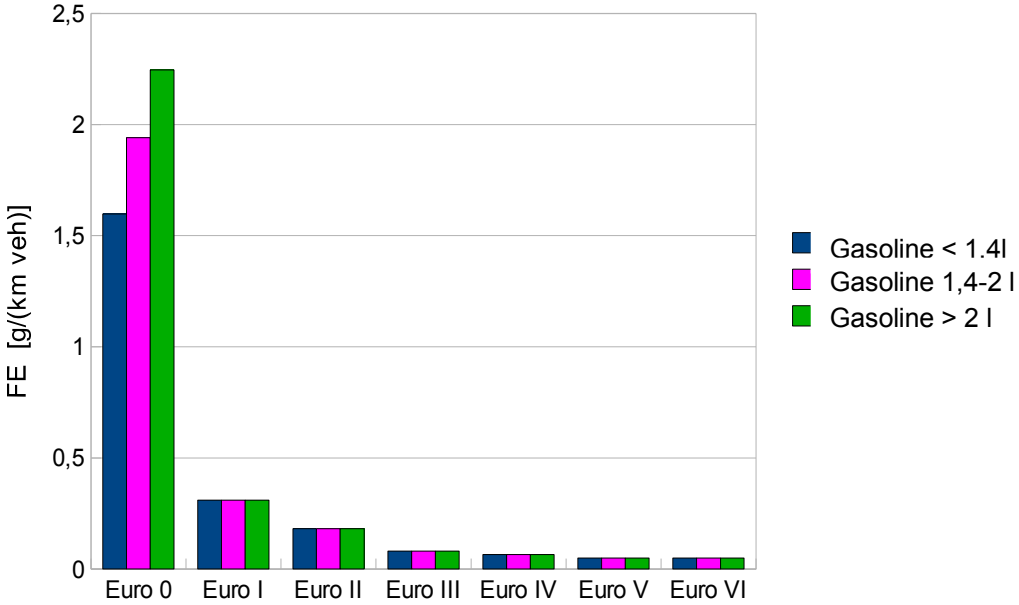
Emission Factors
- per type of emission (hot, cold, evaporation)
- per vehicle class
- per road class

COPERT procedure, as Adopted by European Environmental Agency

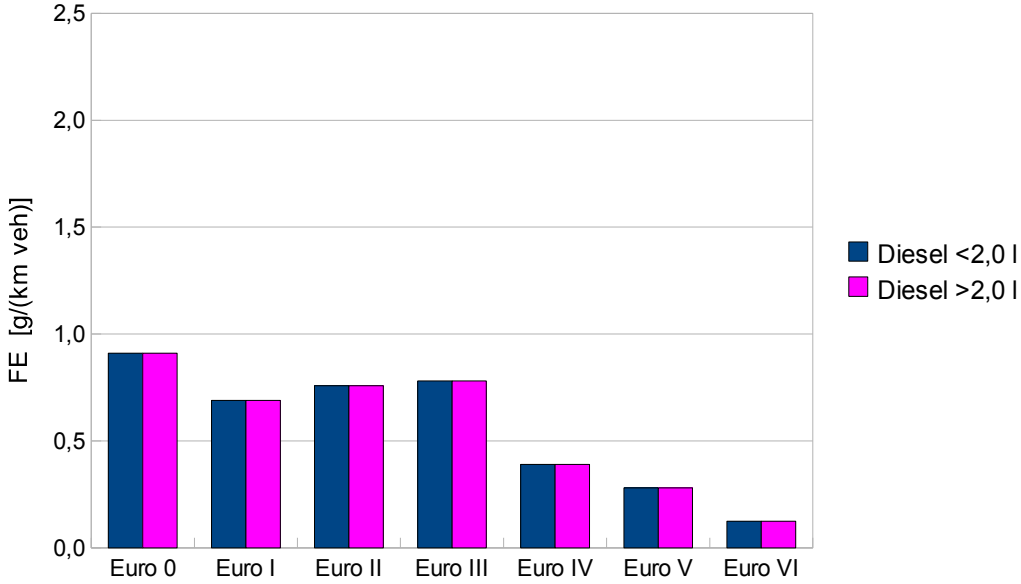


Emission factors

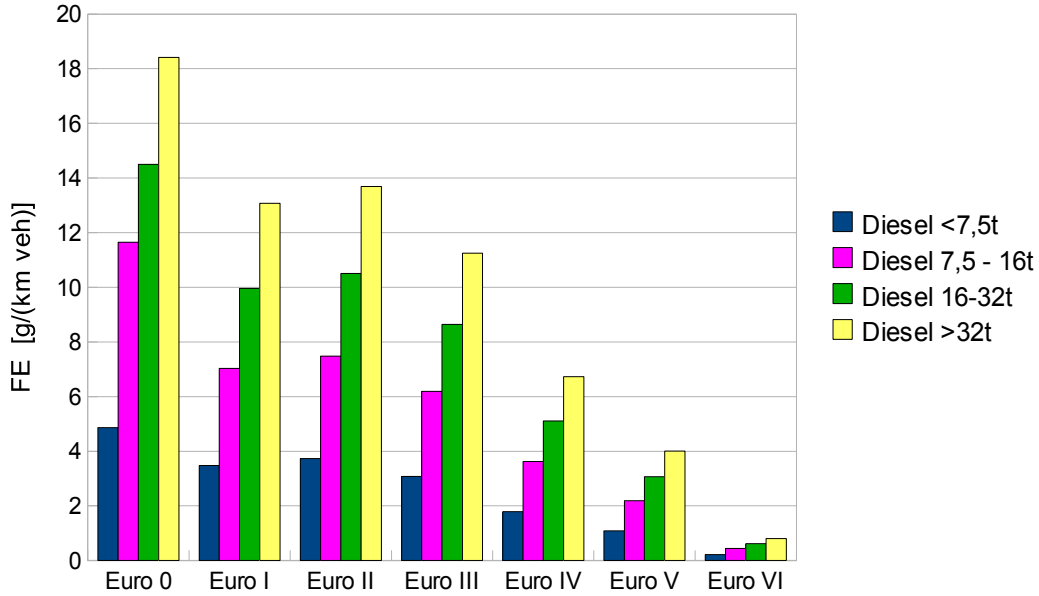
Emission factors – Gasoline passenger cars



Emission factors – Diesel passenger cars



Emission factors – Light Duty Vehicles



COPERT algorithm (1/2)

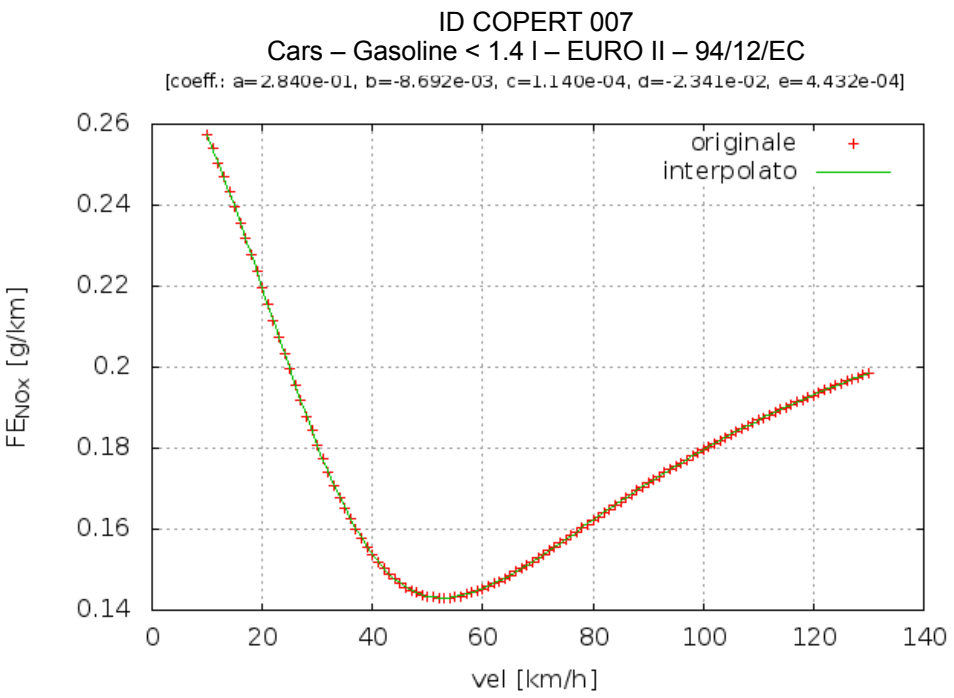
COPERT formulation was adapted to be general and to deliver results with acceptable calculation time → can also be used in real-time application

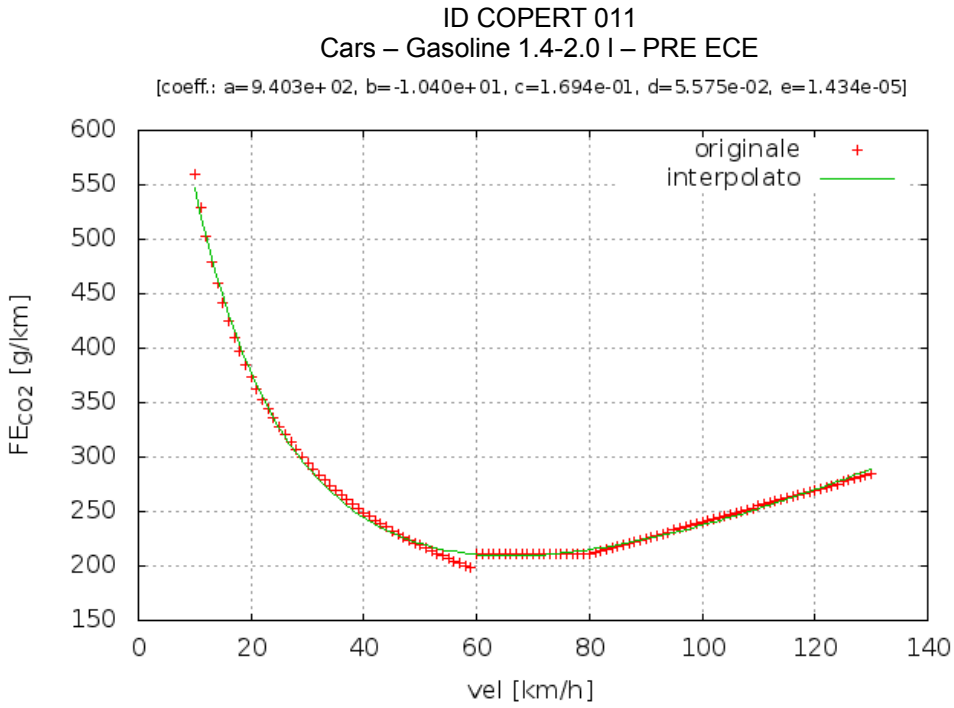
All the emissions are expressed in the generalized version with a simple formula

$$EF = (A+B*v+C*v^2)/(1+D*v+E*v^2)$$

EF [g/(km*veh)] emission factor
v [km/h] mean vehicle speed on the road stretch

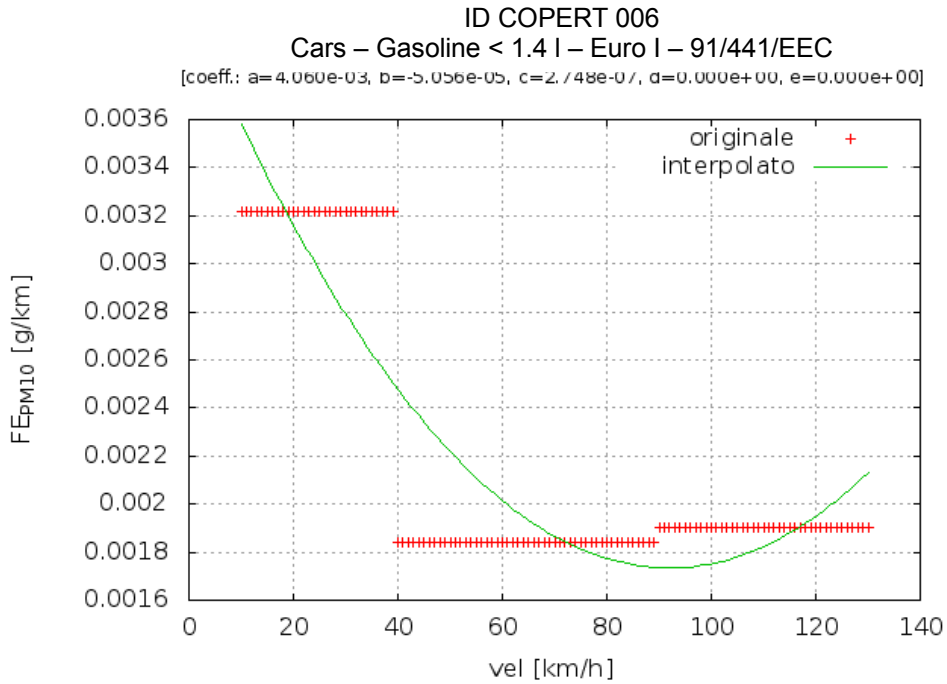
COPERT algorithm (2/2)





2 types of original “EF” curves:
- continuous formulation → OK
- not continuous or step-wise formulas → problems if we want to derive continuous (smooth) results

The interpolation solves and simplifies the issue and in most cases the difference with respect to the original formulation is negligible



Calculation method

The emission calculation procedure is split into 2 phases

1. Derivation of continuous curves through min-square adaptation (146 vehicle classes x 11 pollutants = 1606 formulas)
Done only once and saved in the DB as precalculated coeffs

2. Creation of a calculus software taking advantage of the derived EF database, in different versions.
The main target is:

- a full database version intended to be used in *real-time application*, based on Postgresql + Python scripting

Moreover, two additional versions are provided:

- a “stand-alone” software able to read / write files in industry standard SHP+DBF, which can be used in a common GIS environment (es. Arcview)
- an excel/openoffice compatible spreadsheet, intended for quick calculation of overall emissions

Pollutants

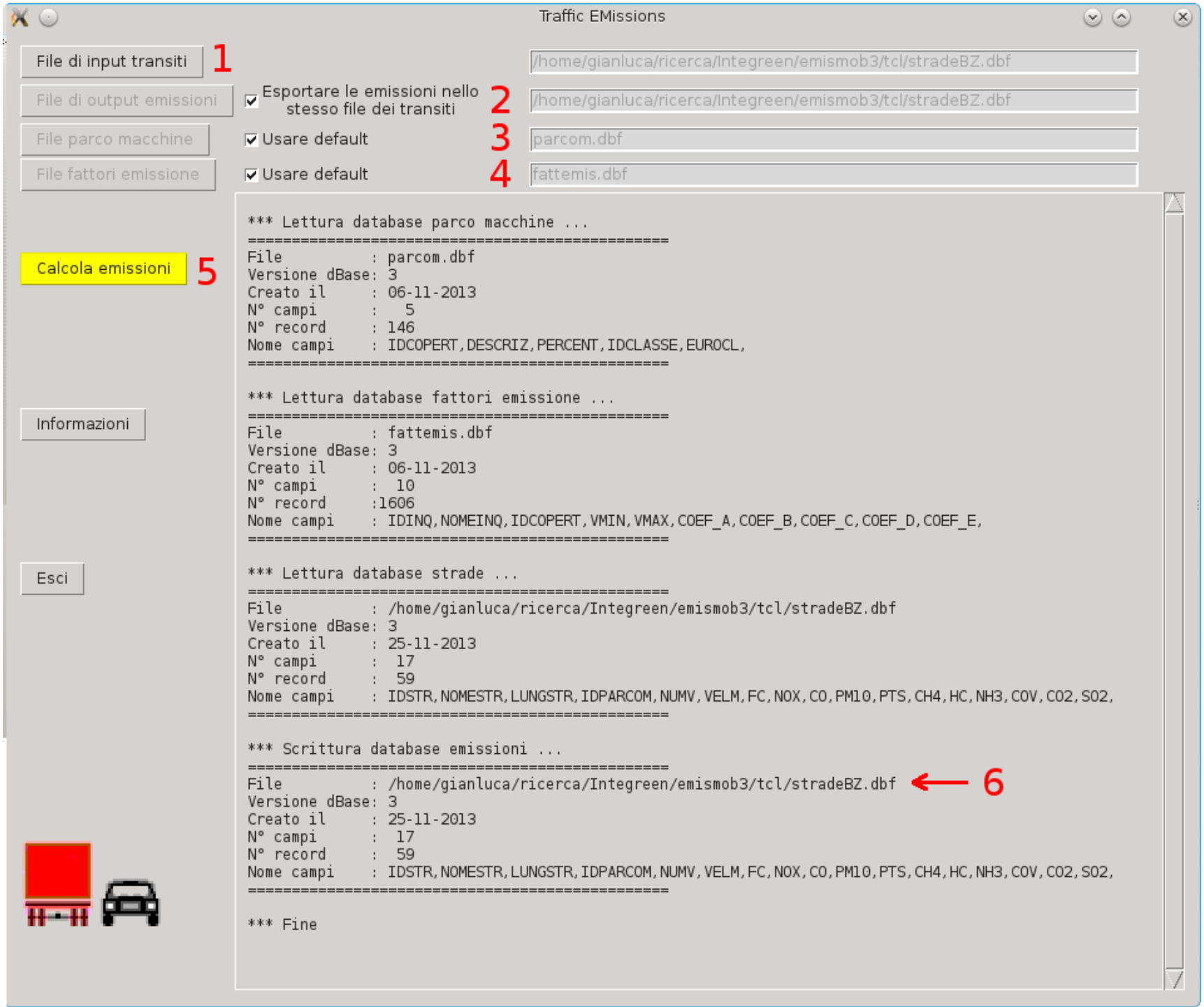
Considered pollutants:

NOx (nitrogen oxides), CO (carbon monoxide), VOC (volatile carbon organic compounds), NH3 (ammonia), **PM10 (fine particulate matter)**, TSP (total suspended particulate matter), SO2 (sulphur dioxide), CH4 (methane), HC (unburnt hydrocarbons)

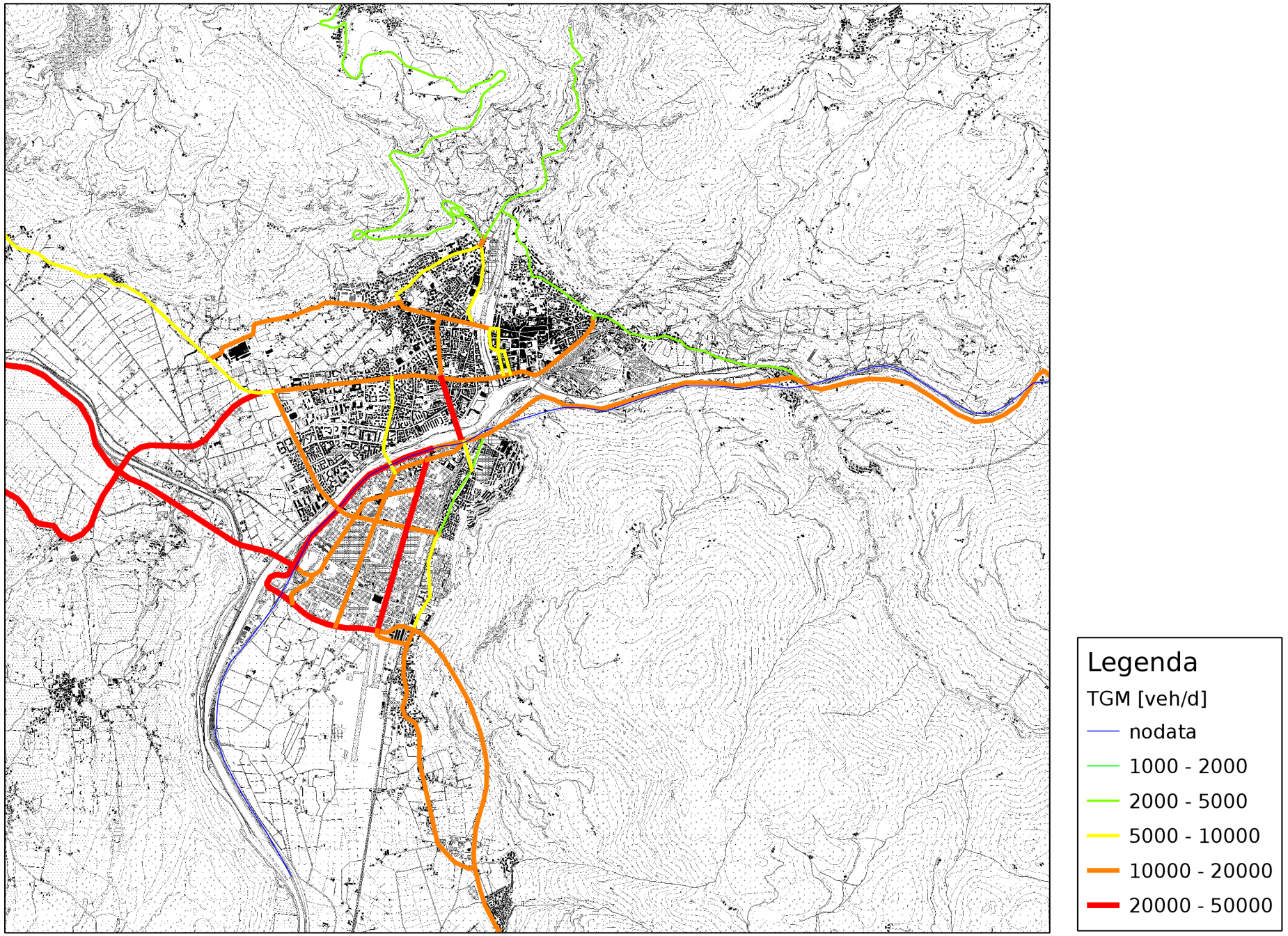
And moreover:

CO2 (carbon dioxide) & FC (fuel consumption) which are directly bound to each other

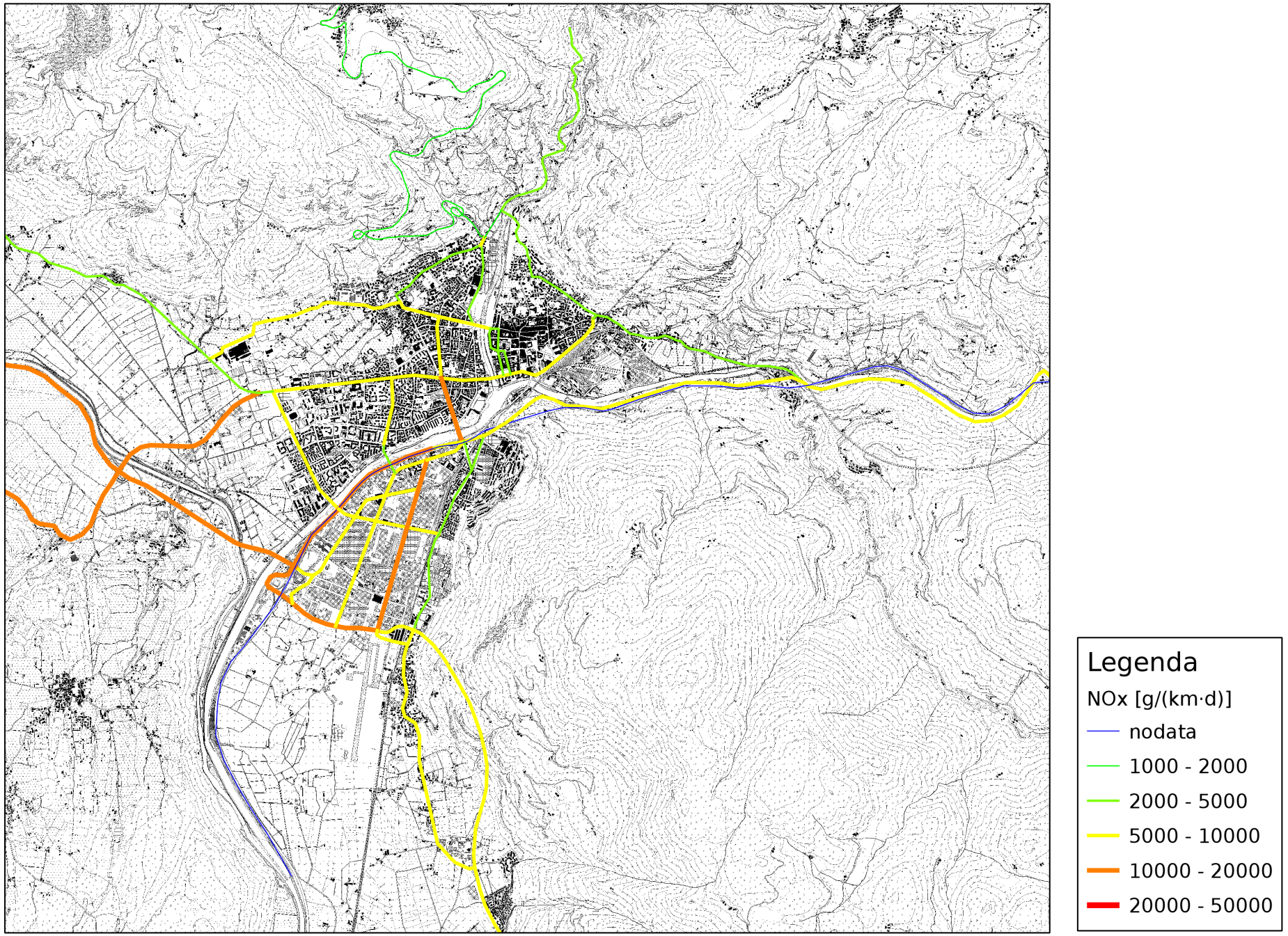
TEM: “stand-alone” version



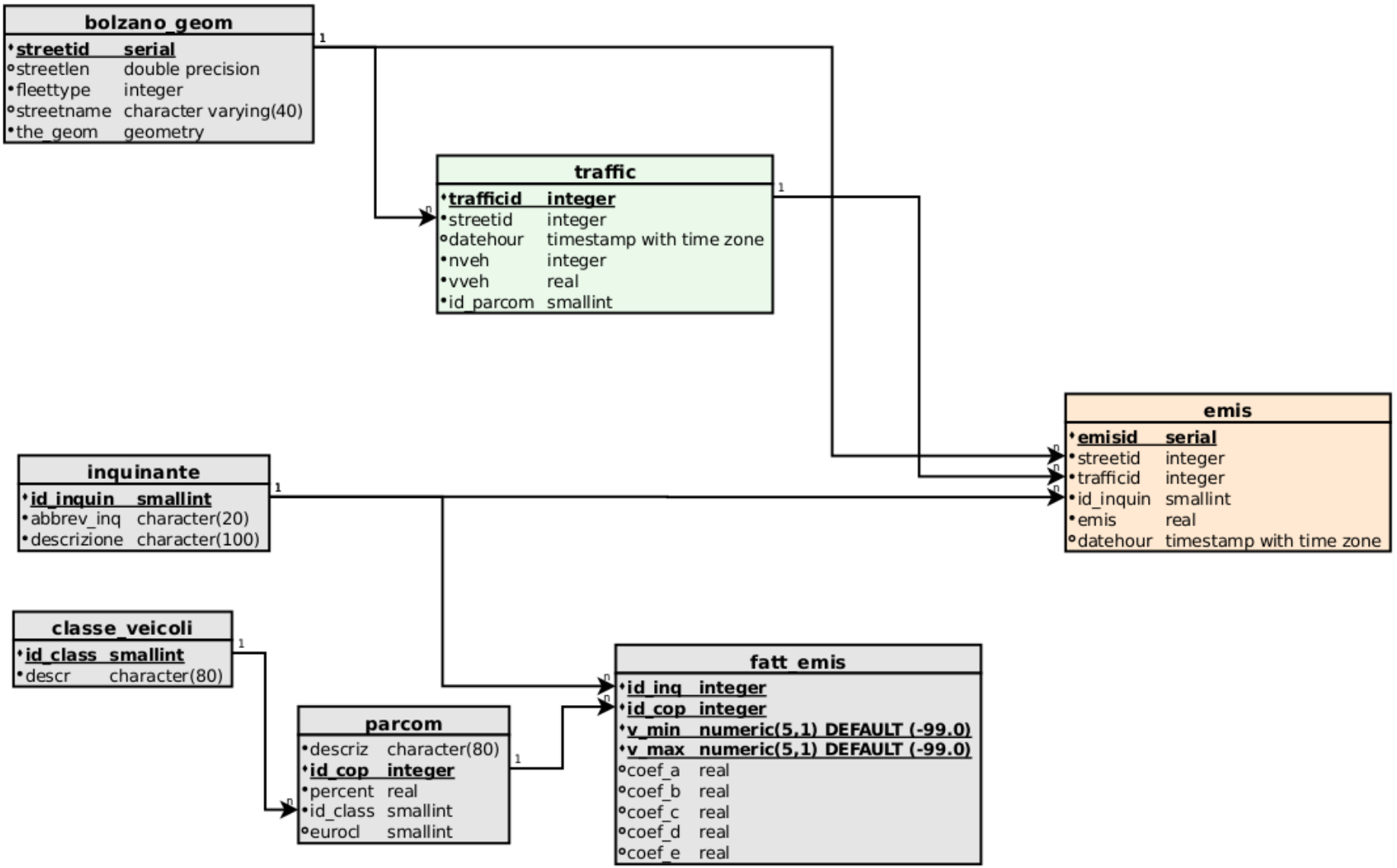
Example: traffic data (input)



Example: emission data (results)



TEM : database version



Input data

How do we ingest traffic data in Traffic Emission software?

When using TEM in *real-time mode* traffic assignment on the basis of measured data at traffic station should be ingested. There are some possibilities:

- Use a scaling coefficient to derive the number of vehicle transit on each road stretch with reference to the nearest traffic station – needs to be calibrated at least once (present simplified method)
- Adopt simple traffic model based on traffic data to be run “on-the-fly” before the emission estimate
- Use a complete traffic data (to be verified if this is feasible in a real-time environment)
- Feed the emission software with direct measurements from Bluetooth gates and traffic counters (loops)

Air pollution dispersion model

The traffic emissions module (TEM) has been coupled with a dispersion model in order to deliver quasi-real time maps of pollutant concentrations at the urban scale with a grid resolution of 50 m

Input data:
- emission data from TEM
- meteorological data from weather station
- morphological data

Two dispersion models have been tested:
- AUSTAL
  - a dispersion model developed according to Germany's air pollution control regulation TALuft (available at website http://www.austal2000.de/de/downloads.html)
  - Lagrangian particle tracking air dispersion model
  - contains its own diagnostic wind field (TALdia)
  - takes into account the influence of topography on the wind field and therefore on the dispersion

- CALINE  **Selected model**
  - a traffic dispersion model recommended by the U.S. EPA (available at website http://www.epa.gov/ttn/scram/dispersion_prefrec.htm)
  - simplified and flexible, can also be adapted to peculiar situations such as emissions in “urban canyon”, over bridge, in parking lots, etc...
- good performance in terms of computational time and accuracy

Dispersion model from traffic emissions

The CALINE software has been heavily modified in order to adapt it to the global computational structure

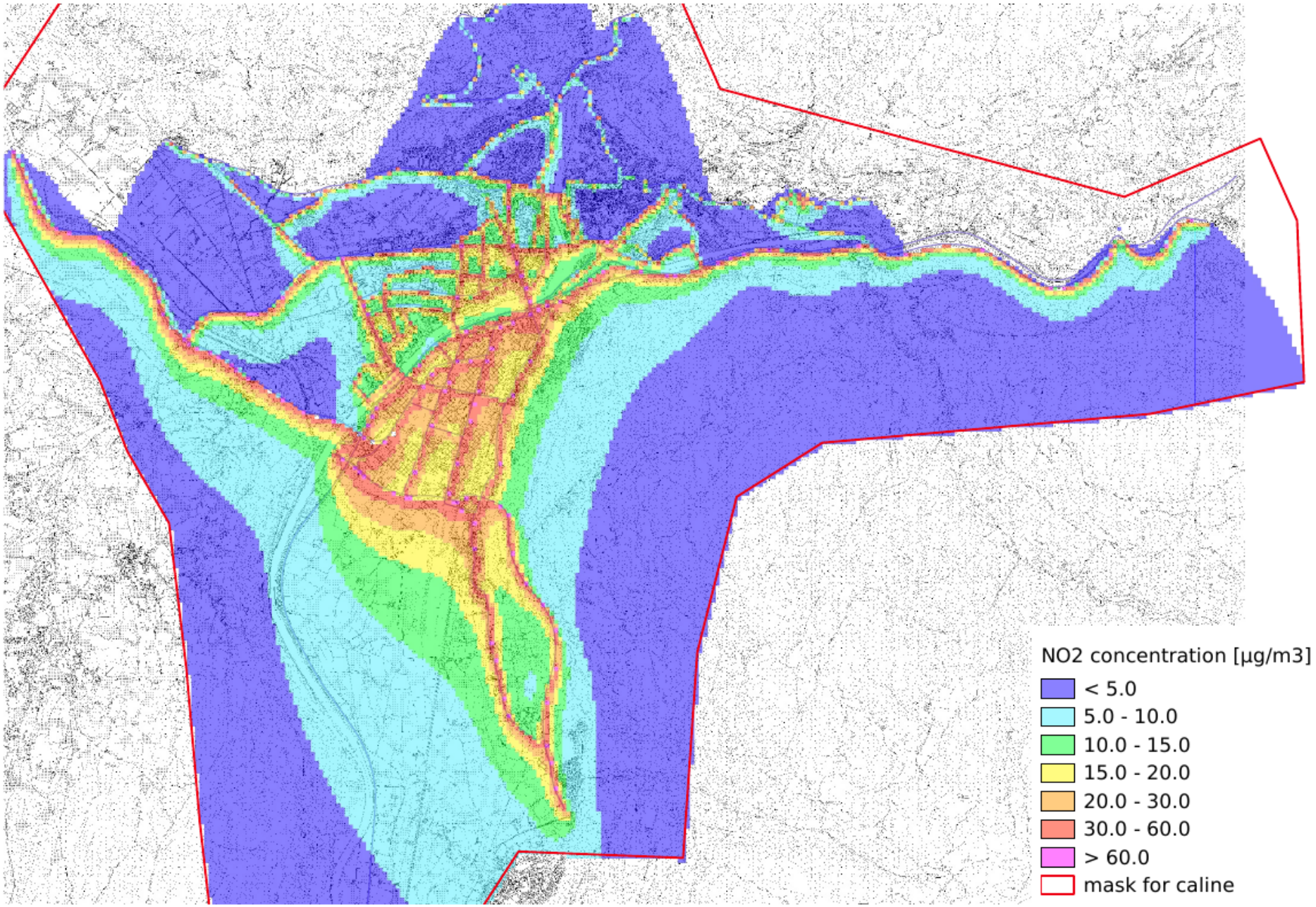
Main improvements:

- Input and Output have been completely rewritten
- Restrictions on the maximum number of computational grid cells and of the line sources have been removed
- A mask has been applied in order to avoid dispersion computation away from emission sources
- The Romberg formula has been implemented in order to obtain NO_2 from NO_X concentrations

A Postgresql + Python script has been written to integrate the dispersion calculation module into the INTEGREEN system.

Traffic dispersion model – Results

Example of hourly average NO_2 concentration map



Traffic dispersion model – Results

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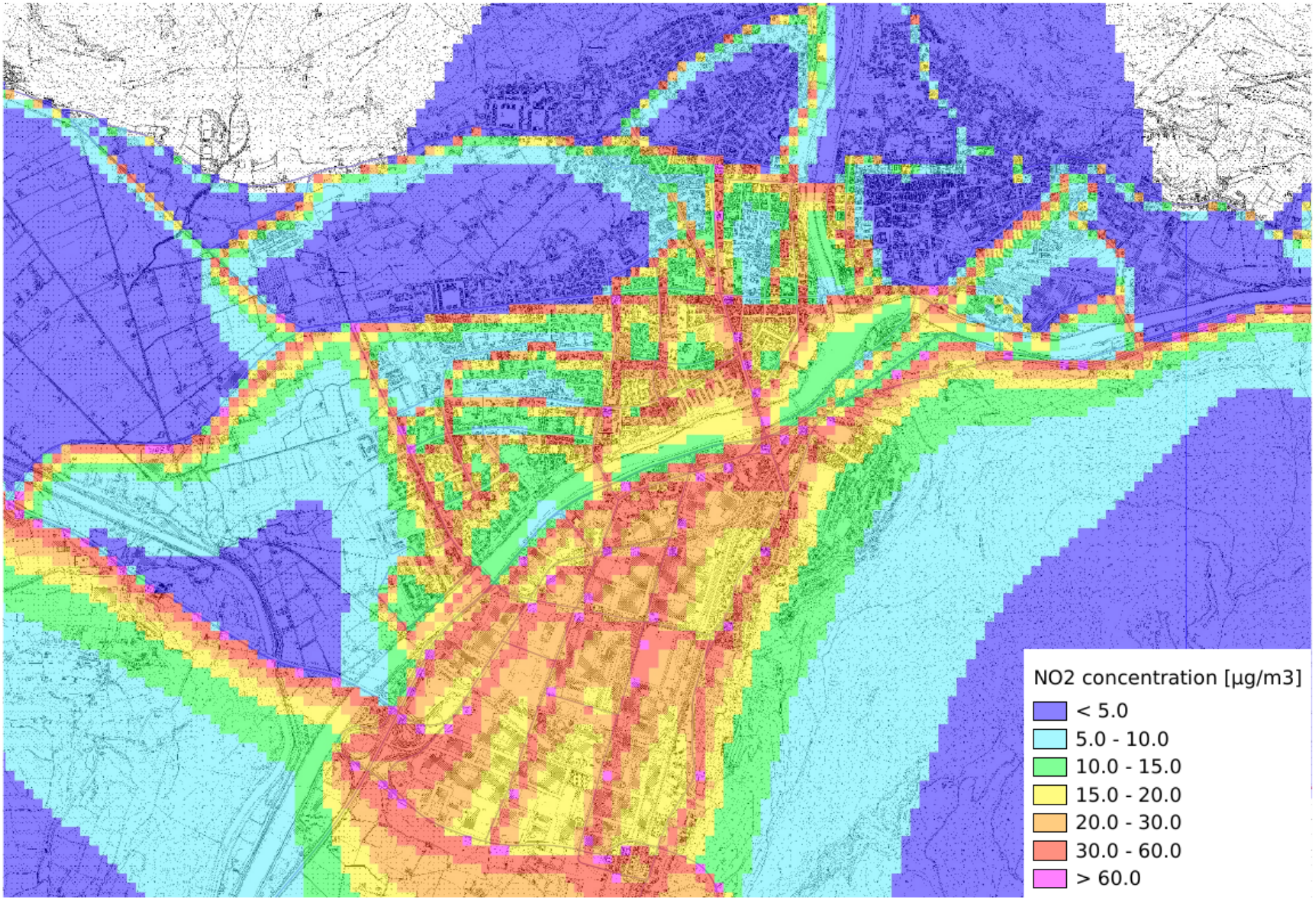

Concluding remarks

- This system is focused on the municipality of Bolzano
- It can be adopted in a larger scale municipality, but with some limitations (smaller than a regional scale)
- It should be adjusted in order to be used in a different context, because it has been developed to fulfill the requirements and the characteristics of the municipality of Bolzano
- It requires a large amount of traffic data (directly measured or derived from a complete traffic model). This is a necessary condition for the applicability of the entire system to another town.
- The system allows to perform **real-time** traffic/environmental estimations that can encourage the adoption of eco-friendly traffic management policies

Thanks for your attention