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FORECAST OF THE IMPACT BY LOCAL EMISSIONS AT AN URBAN MICRO SCALE BY THE COMBINATION OF LAGRANGIAN MODELLING AND LOW COST SENSING TECHNOLOGY: THE TRAFAIR PROJECT

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Abstract: Within the framework of the CEF-TELECOM programme 2017, the TRAFAIR project has been funded: the project focuses on air quality forecast at urban 'micro' scale by coupling lagrangian particle dispersion modelling, space- and time-resolved gas monitoring by lower cost gas sensors and realistic traffic flow rates by dynamic traffic model based on real time traffic data. Test cities of TRAFAIR are Modena, Florence, Pisa, Livorno, Zaragoza and Santiago de Compostela, with Modena partners being the forerunner of the consortium for their longer experience in air quality research.
In Modena two dispersion models will be used over the same domain and their output will be compared: Parallel Micro Swift Spray (PMSS, Arianet srl, Italy and Aria Technologies, France) and GRAL (The Graz Lagrangian Model). The domain, covering the whole urban area, is 6 km x 6 km, with a horizontal resolution of 4 m. On a first basis only traffic emissions will be considered. The models will be used to produce forecast maps of primary NO_x and CO for the following day using local weather forecasts. A set of 12 portable sensor units will be deployed across town; each unit will mount 4 electrochemical cells to provide time-resolved estimate of NO, NO_2, CO and O_3. These units, along with the air quality regulatory stations, will allow to test and validate the two models at multiple sites.

Key words: lagrangian dispersion modelling, low cost sensors, urban air quality, traffic emissions

INTRODUCTION

Road traffic is one of the strongest emission source of atmospheric pollutants in urban areas of Europe, along with domestic heating and representing a threat for public health (WHO, 2016). The rising awareness of citizens regarding air quality is leading to a demand for lower atmospheric pollution levels and for better information about air quality conditions inside urban areas, where the largest part of the worldwide population lives. Several initiatives are pursued in Europe to meet these needs: e.g. the definition of Low Emission Zones (Holman et al., 2015), or a service of simulated air quality maps both in analysis and in forecast provided by several Public Environmental Agencies. However this type of maps are suitable for local domains, but are not able to take into account the complexity of the urban areas and fail in describing realistically the dispersion of low level emissions within the urban context.

Particle lagrangian dispersion models are a suitable tool for simulating the effect of buildings on the dispersion of emissions and have been proved to reliably estimate the impact of urban emissions on local air quality, whenever fed with data having sufficient quality (Ghermandi et al., 2015; Ghermandi et al., 2019).
Another promising approach to meet the expectations of the population is the collection of spatially distributed air quality data by air quality sensors: the lower cost of this type of sensors allows the setup of a network of sensors within the urban area, integrating the sparse network of regulatory air quality monitoring stations. Low-cost sensing technology exhibited highly alternate results, both encouraging (e.g. in Bigi et al., 2018) and discouraging (Fonollosa et al., 2016), leading to some cautionary notes to appear in the literature (Lewis and Edwards, 2016) and more recently, to an official position by WMO (2018).
The TRAFAIR project, funded by the Innovation and Networks Executive Agency within the CEF TELECOM instrument, was started with the aim to respond to the needs of the citizens and to set up an innovative tool for air quality management by local policymakers by combining pollution maps in forecast by lagrangian dispersion modelling with low cost sensor networks, along with traffic flow modelling.

METHODS

TRAFAIR project gathers 4 research institutes, i.e. University of Modena and Reggio Emilia, University of Zaragoza, University of Florence and University of Santiago de Compostela, 3 public administrations, i.e. Municipality of Modena, Tuscany regional administration, Municipality of Santiago de Compostela, The public Supercomputing Centre of Galicia (CESGA) and Lepida SpA, an investee company of Municipalities and Public Authorities of the Emilia Romagna. The University of Modena and Reggio Emilia is the leading partner.
TRAFAIR activities will be applied to 6 test cities: Modena, Firenze, Pisa, Livorno, Zaragoza and Santiago de Compostela, although the present study will focus on Modena.

Simulation of atmospheric dispersion

The contribution of traffic to atmospheric levels of primary NO_x and CO in the urban area of Modena will be estimated by the use of two Lagrangian Particle Dispersion Models: the Parallelized Micro-Swift Spray (PMSS, Arianet srl, Italy and Aria Technologies, France; Oldrini et al., 2017) and the Graz Lagrangian Model (Oettl, 2015). The domain, of 6 km x 6 km, covers most of the urban area of Modena, including the main ring road and has a horizontal grid of 4 metres (square cells). The simulation will account for buildings of the urban area, which are described by 25 600 polygons contained in the ESRI shapefile provided by Geoportale Regione Emilia-Romagna. Estimate of traffic emissions will be based upon the most recent details of fleet composition for the municipality, including the vehicle type, fuel, engine capacity, load displacement, Euro emission standard. These data will be combined with the road network, described by ~1100 sections with a total length of 210 km and featured by slope of the road and average travelling speed.
In Modena, as in all project cities, vehicle fluxes will be based upon traffic reconstruction by a traffic flow model. This latter model will be based upon traffic data collected by induction loops across town and it will allow to better constrain traffic emissions in the dispersion modelling phase by tailoring vehicle fluxes to weekday and season simulated by the dispersion model.
NOx emissions for each road segment in terms of pollutant mass per trip unit will be estimated by the means of the R package VEIN (v0.5.2) (Ibarra-Espinosa et al. 2018), although the latest emission factors by Ntziachristos and Samaras (2016) will be applied instead of the package-default ones.
The meteorological fields used to estimate the meteorological variable for the two dispersion models will be provided by the Emilia Romagna Regional Environmental Agency ARPAE as COSMO-5M grib files, i.e. COSMO fields with 5 km horizontal resolution over the Emilia Romagna region.
GRAL will be the main lagrangian dispersion model used within TRAFAIR, although in Modena selected periods will be simulated also by PMSS for comparison between the two model in terms of simulated output and computation performance. After a preliminary setup of GRAL on analysis of past conditions, it will be setup on a daily forecast service of dispersion maps for primary NO_x and CO by traffic emissions for the following 48 hrs.

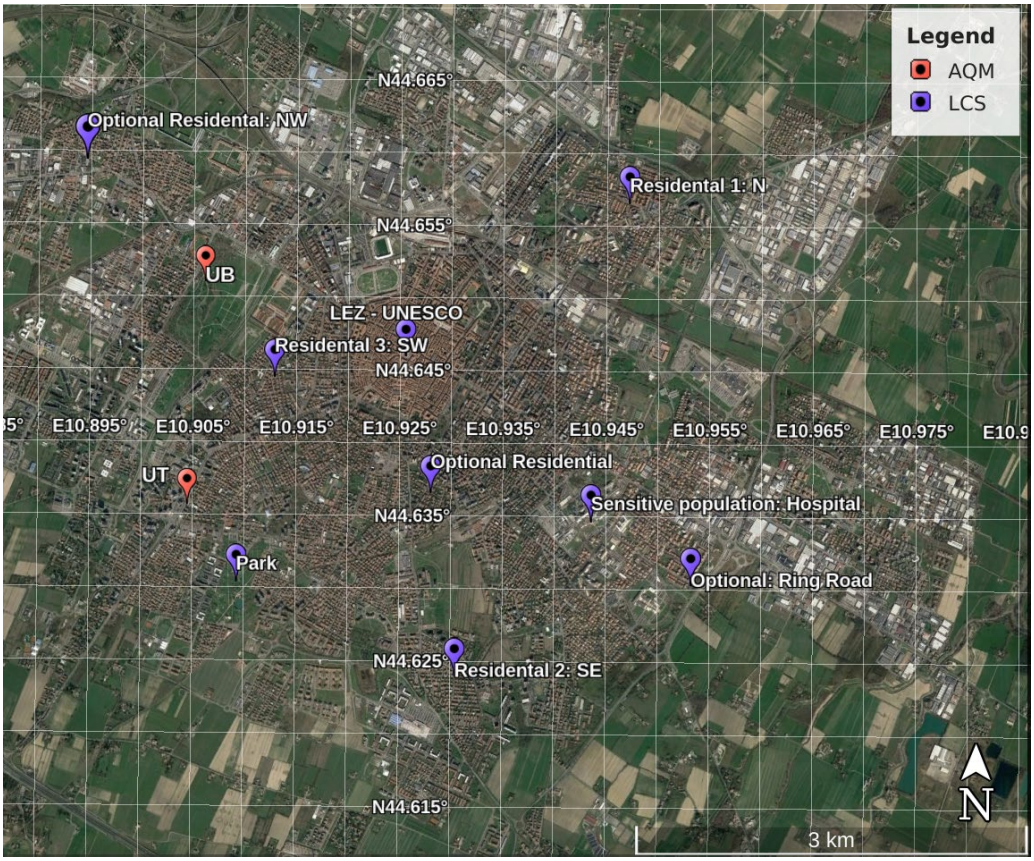

Figure 1. Preliminary map of the low-cost sensor network for Modena. AQM red marks indicate regulatory Air Quality Monitoring stations. LCS purple marks indicate the location of the low cost sensors.

Low-cost sensor network

A network of low-cost sensors will be deployed in each TRAFAIR city. In Modena 12 Aircubes (Decentlab GmbH, Duebendorf, Switzerland) will be installed. Each sensor unit will host 4 electrochemical cells for detecting NO, NO_2, CO and O_x (i.e O_3 + NO_2) and one RH/T sensor. 1 minute resolution data will be transmitted to a central database exploiting a LoRaWAN network which was set up in town within the TRAFAIR project. Calibration protocol will be mainly based upon Bigi et al. (2018): the 12 units will be co-located for 1 – 2 weeks at one of the two urban sites for the regulatory air quality monitoring, then a group of units will be deployed across town for up to 80 – 100 days for air quality monitoring, while another group will stay at the regulatory sites. This latter group will allow to partially to represent mean sensor ageing and to collect data useful for their specific calibration. At the latest after 80 – 100 days the two groups will be swapped to update the calibration of the former group. Within the deployment across town, one unit will be placed in the second regulatory monitoring site to assess the overall uncertainty of the calibration+sensor system and this will provide a general benchmark for the uncertainty of its group.

24-hour statistics of atmospheric concentration provided by the units and the regulatory sites will be compared on a daily basis, along with their Spearman rank correlation. This will be used to eventually flag sensor data and to highlight severe sensor drifting or malfunctioning.

Sensor location is based upon expected pollution levels, the fraction of residents and according to a priority list for exposure and sensitive population. A preliminary map of sensor location for Modena is Figure 1 and includes the main hospital, the pedestrian area of the UNESCO heritage site, a large park and several residential areas.

The goal of sensors monitoring will be twofold: publishing semi-real time maps of air quality by using concentration bins and improving the dispersion model results. Moreover, this data will be used also to develop more sophisticated calibration protocols and improved QA/QC management procedures.

CONCLUSIONS

The TRAFAIR project, funded by the CEF TELECOM, was started. The project gathers several research institutes and public bodies in Italy and Spain. In Modena, one of the six test cities of TRAFAIR, two particle lagrangian dispersion models will be set up, GRAL and PMSS, and the former will be used to provide a service of daily forecast of pollution map by primary NOx and CO from traffic emissions. Also 12 sensor units each one enclosing 4 low-cost electrochemical cells for monitoring NO, NO_2, CO and O_3. These units will be used to publish semi-real time map air quality and to improve the dispersion model results. TRAFAIR will provide a valuable tool to the local policymakers, will provide useful information to the citizens and finally will allow further developments in the calibration and QA/QC management of low cost sensors.

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