POTENTIAL IMPACT OF A LOW EMISSION ZONE ON STREET-LEVEL AIR QUALITY IN BARCELONA CITY USING CALIOPE-URBAN MODEL

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> Introduction

This work is an initial step towards evaluating the impact of Barcelona Low Emission Zone (LEZ) on air quality using CALIOPE-Urban. Here we evaluate CALIOPE-Urban ability to simulate NO_2 concentrations and assess its sensitivity to structural reductions of NOx emissions.

> Methodology

CALIOPE-Urban

CALIOPE-Urban is a street-scale modelling system that couples CALIOPE air quality mesoscale modelling system (Baldasano et al., 2011) with R-LINE (Snyder et al., 2013). The CALIOPE system integrates WRF meteorological model, the BSC-CNS in-house HERMES for emissions, the photochemical model CMAQ and BSC-DREAM8b. The mesoscale system runs over Europe at a 12 km $\times$ 12 km horizontal resolution, Iberian Peninsula at 4 km $\times$ 4 km, and the Catalonia domain at 1 km $\times$ 1 km, including Barcelona.

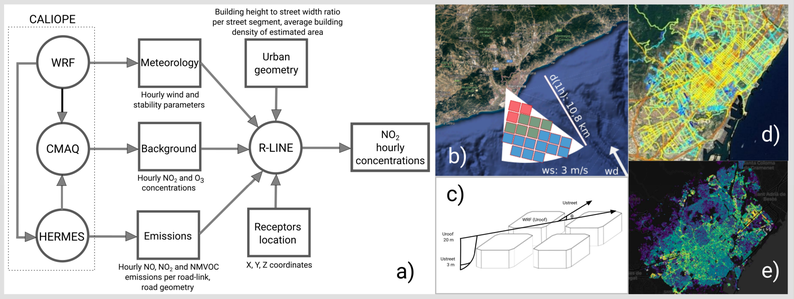

Figure 1: a) CALIOPE-Urban workflow: Models are represented by circles and data by rectangular shapes; b) upwind background scheme c) wind channelling; d) Barcelona traffic intensity in HERMES e) Barcelona building heights.

CALIOPE-Urban requires hourly emissions at road link level provided by HERMES, upwind CMAQ cell concentrations for background and WRF for meteorological inputs. WRF bottom layer over the street of interest is used as boundary conditions for R-LINE that estimates local meteorology at each street using urban geometrical parameters. Surface roughness is increased based on the average building height, building density, and the building height to street width ratio. The increase in surface roughness generally leads to a larger displacement height, u*, w*, and mixing height, deriving in less stable and more convective atmospheric conditions.

Observations

Ambient street-level pollutant measurements collected during a field study in April and May 2013 within the structured grid of Eixample neighborhood (Amato et al. 2014) are used to evaluate model performance in combination with fixed sites measurements. Mobile laboratories during the field study where located in street canyons with approx. 20 m building height and 20 m street width.

Figure 2: Monitoring sites location: Sites numbered 1 (Palau Reial), 2 (Eixample) and 3 (Gracia) are fixed sites and 4 (Industria Street 213), 5 (Valencia Street 445) and 6 (Industria Street 309) correspond to mobile laboratories located at street canyons.

> Methodology (con't)

Barcelona Low Emission Zone and sensitivity of CALIOPE-Urban to potential reductions of NO_x emissions

A 68% of Barcelona citizens were exposed in 2016 to NO_2 levels above the annual limit of 40 $\mu g/m^3$ (ASPB, 2017). To decrease the negative impact of air pollution on citizens health, Barcelona municipality implemented last December 2017 a Low Emission Zone (LEZ) that focus on its first stage on reducing NO_2 levels during air pollution episodes, banning the entrance of approx. 17,9% of the current circulating vehicle fleet (BR, 2017). Specifically, those produced before the entrance into force of EURO standards. This policy is planned to become permanent on December 2020.
To analyze the sensitivity of CALIOPE-Urban to potential reductions of NO_x emissions we use a mesoscale model run that incorporates the full emissions in the region and we force the street-scale model to use as input explicit emissions for each street segment for two different scenarios: base case (using full road traffic NO_x emissions) and R-15 (reduction of 15% in road traffic NO_x emissions). R-15 scenario represents an approximation of the potential impact of the LEZ, which is expected to ban the entrance of 17,9% vehicles.

Figure 3: Barcelona NO_2 concentration levels in 2008 (left) and delimited area for low emission zone (right).

> Results

Figure 4 scatter plots compare NO_2 concentrations estimated by CALIOPE and CALIOPE-Urban to observations at six sites described in Section Observations. CALIOPE-Urban more closely matches the observed NO_2 concentrations.

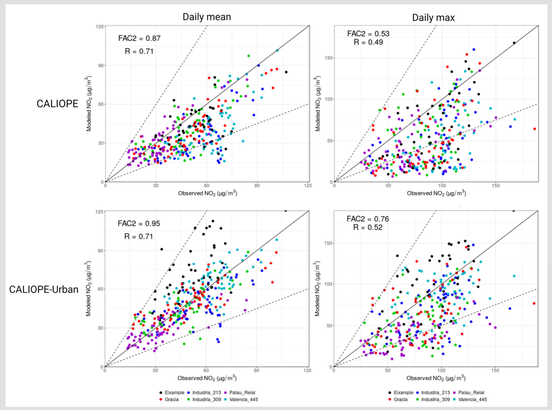

Figure 4: Scatter plot of daily mean (left) and daily maximum (right) modelled concentrations against observed concentrations with colors representing monitoring sites. Model statistics shown are for modelled mean daily concentrations for all sites (left) and modelled hourly concentrations at hour of observed maximum concentrations (right).

> References

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> Results (con't)

For daily means, similar correlation is given by both systems but CALIOPE-Urban produces more results within a factor of two of observations (FAC2 = 0.95 vs 0.87). The street scale system tends to overpredict daily means at Eixample site, in the area with highest traffic in the city (black dots), and to underpredict at the background site of Palau Reial (purple). For the daily maximum, CALIOPE underpredicts in general and CALIOPE-Urban decreases the bias mostly at sites closed to high traffic intensity (e.g. Valencia Street 445 and Eixample).

Scenario	Palau Reial	Eixample	Gracia	Valencia St. 445	Industria St. 309	Industria St. 213
CALIOPE-Urban base case	28.0	77.2	49.7	65.8	44.7	46.5
CALIOPE-Urban-R15	27.3	72.6	43.7	61.1	42.9	44.4

Table 1: 2-monthly mean NO_2 concentrations on an hourly basis in $\mu g/m^3$ at each site during April-May 2013 for CALIOPE-Urban base case (full NO_X road traffic emissions) and CALIOPE-Urban-R15 (reduced 15% NO_X road traffic emissions).

Impact of NO_X reduction at traffic sites is higher than at the background site of Palau Reial. The NO_2 concentrations decrease of 4.7 and 6 $\mu g/m^3$ in Valencia St. 445 and Gracia, which represent traffic sites where CALIOPE-Urban gives good performance, agrees with the scientific literature for LEZ impact caused by NO_X reductions. In Berlin a 14% reduction in NO_X emissions brought a decrease of 8 $\mu g/m^3$ NO_2 concentrations in the first year of LEZ operation (Lutz, 2009). A greater difference may be achieved in our modelling system results if mesoscale model incorporates the reduction in NO_X emissions in the model run.

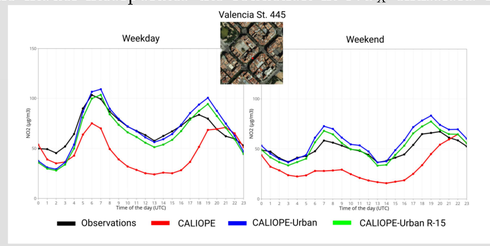

Figure 5: Diurnal averaged cycle at Valencia St. 445 site (street canyon with hight traffic intensity) during April and May 2013 for weekday and weekend.

In Figure 5 we can see a high difference in performance between mesoscale (red), tending to under predict, and CALIOPE-Urban with full NO_X emissions (blue) models compared to observations (black). Regarding impact of 15% NO_x emissions reduction scenario (green), NO_2 levels decrease following the same dynamics as the street-scale model with full NO_x emissions.

> Discussion and conclusion

We compare CALIOPE (mesoscale) and CALIOPE-Urban (street scale) NO_2 concentrations in Barcelona during April and May 2013. CALIOPE-Urban gives greater agreement with observations in trafficked areas. A 15% NO_X road traffic emissions reduction scenario, used as approximation of LEZ potential impact in Barcelona, is simulated using CALIOPE-Urban without reducing emissions in the photochemical model CMAQ. Reducing 15% NO_X road traffic emissions (Scenario R-15) has a small effect in NO_2 concentrations in April and May 2013. 2-monthly mean NO_2 concentrations on an hourly basis decrease approx. 4-6 $\mu g/m^3$ in traffic sites compared to CALIOPE-Urban base case (full NO_X road traffic emissions). These results, consistent with scientific literature, suggest that a greater effort should be done to reduce NO_2 concentrations below the legal annual mean limit of 40 $\mu g/m^3$. A policy more in line with Querol et al. (2012) recommendation of an overall 30% - 40% traffic reduction in Barcelona could help to comply with legal NO_2 concentration limits.

> On going work

Next steps are directed to decrease the emission uncertainties by integrating in the system new emission and traffic data that has been collected in Barcelona. Then, we will apply this new emission inventory to assess the potential impact on NO_2 concentration levels of the LEZ in Barcelona by simulating the effect of restricting the entrance to the ring-road to the banned vehicles integrating the emissions in both the mesoscale and the local scale model runs.

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