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High-resolution air pollution modeling for urban environments

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The nested air pollution modeling system **GRAMM/GRAL** is used to simulate the **NO_X distribution** in the city of **Lausanne**, Switzerland, at **5m** of resolution by taking into account the **topography**, **land use** and 3-dimensionnal **building structure**.

1. Motivations & background

- Air pollution in cities has very **high spatial** and **temporal variability**
- **High density** of **measurements needed** but accurate sensors are costly
- Deployment of **low-cost mobile sensors** in Lausanne in addition to reference monitoring sites
- **High-resolution model** required to extend observation coverage towards the whole city

2. Modeling system

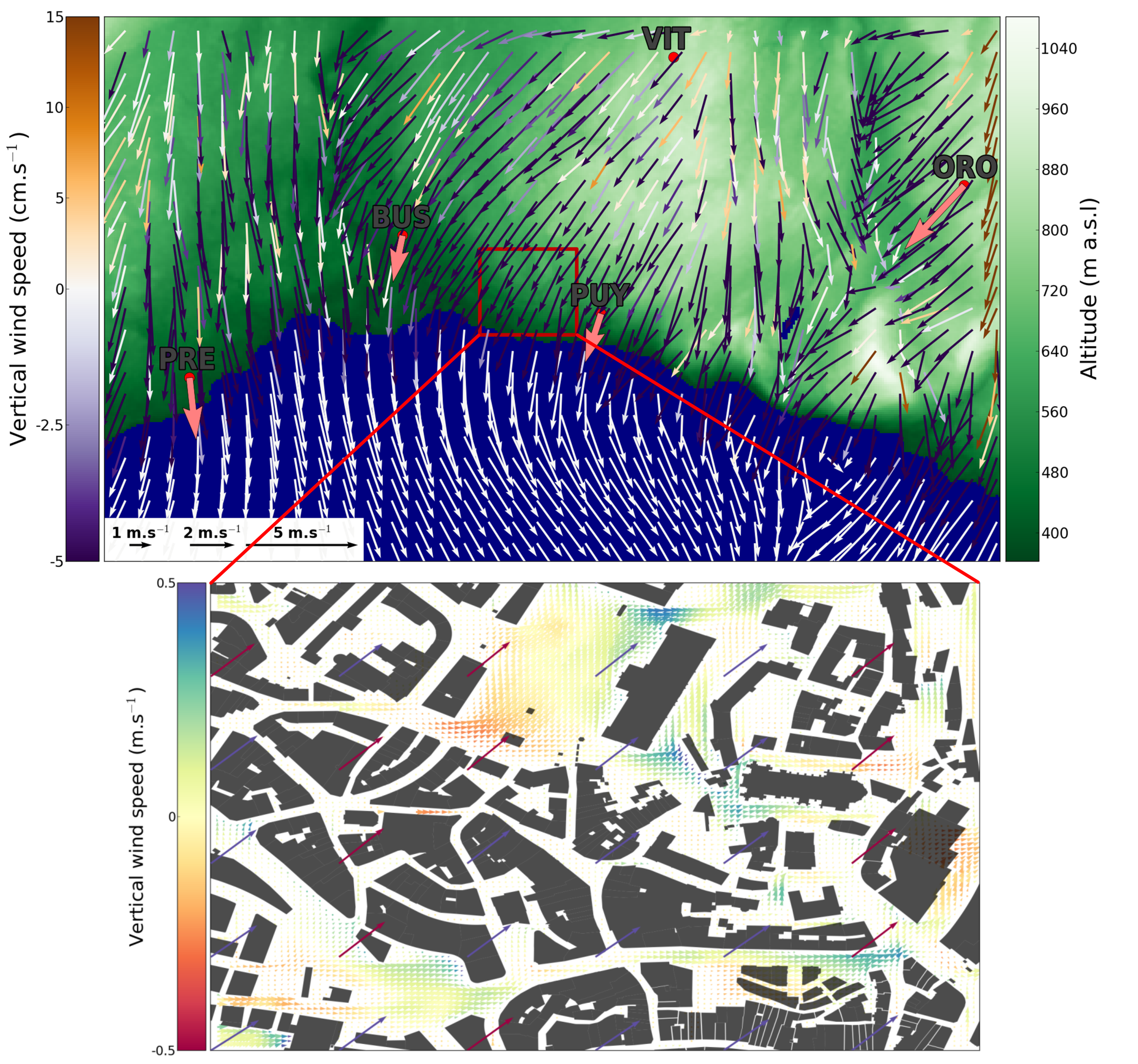
a. GRAMM: Graz Meso-scale Model [1]

- **Possible states** of atmospheric flow and mixing can be described by a **limited library** of **reference** states.
- Computation at **100m** of resolution of reference states by taking into account topography, land-use, forcing wind direction and speed, and stability classes.
- Selection of **hourly states** according to **in-situ** meteorological **observations**

b. GRAL: Graz Lagrangian Model [2]

- **Nested** computation of **building-resolving** flow at **5 m** resolution with GRAMM meteorological fields as initial and boundary forcings
- Computation of reference concentration fields at **5m** of resolution from **NO_x emission inventories** (by sector, with temporal daily and seosonal profile)
- **Background** level from a **rural** site
- Conversion of NO_x to NO_2 with average parameterisation [3]

Figure 1: (top) *Wind fields computed by GRAMM for very stable conditions (23/06/2012 midnight). Arrow colours represent vertical velocity. In-situ observations are super-imposed to modeled winds. Red square shows the location of nested GRAL domain.* ***(bottom)*** *Nested computation of high-resolution winds by GRAL from GRAMM forcing fields. Big arrows represent GRAMM fields, while smaller ones depicts high-resolution computations accounting for buildings.*



c. Observations

- **Continuous** accurate measurements at a **NABEL** air quality monitoring site close to a busy road; NO, NO_2 measured; strong concentration gradients at this site in between a busy polluted street and a pretty clean square and park)
- Rural NABEL site 45 km away of Lausanne as background
- **39 passive NO_2 sensors** at different locations in the city; **monthly** analysis of the samples

3. Spatial distribution

- **Strong gradients** between busy streets and background areas **reproduced** in the model
- 50% resp. (80%) passive sensors well simulated with obs:simu ratio deviation from reference ratio within 20% (resp. factor 1.5)
- Remaining diverging sensors due to systematic simulation over-estimation in green (resp. under-estimation in orange)

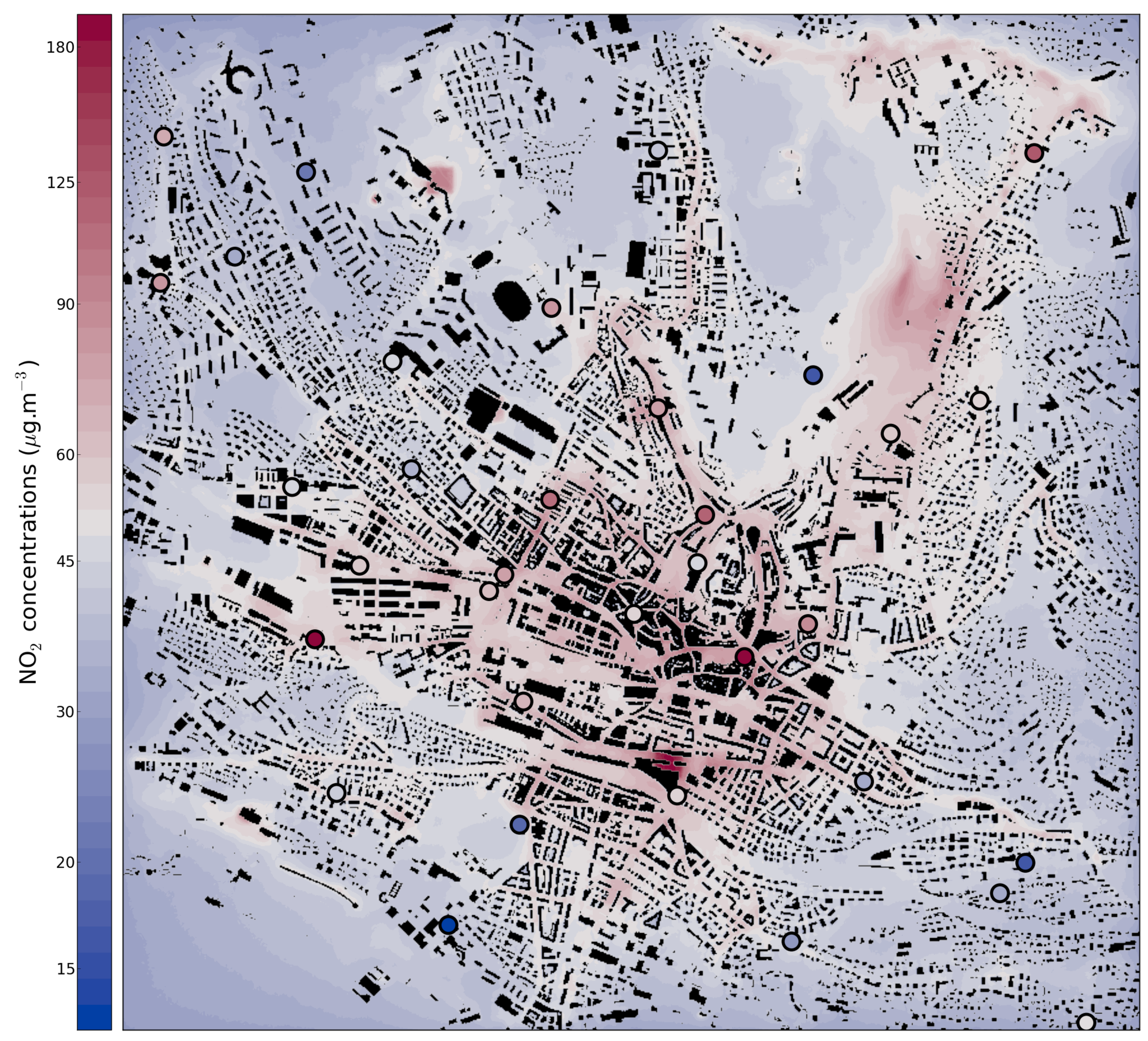
✔ Consistent representation of the very high spatial variability of air pollution at the city scale

✘ Still difficulties for specific locations when sensor locally influenced by pollution not reproduced in the model and reversely

✘ Required improvements in emission data base and possibly in turbulence and buildind representation

✘ Coarse NO_x to NO_2 chemical conversion must be improved

Figure 4: *Average simulated NO_2 concentrations (shaded area). Observation to simulation ratio at passive sensor sites for monthly means. Green sensors are systematically over-estimated by the model.*



4. Temporal variability

- Good match with **diurnal cycle** and **day-to-day variability** of NO_x according to traffic profiles and other emission variability
- Better temporal observation-simulation correlation for busy **week-days** than for week ends
- Better simulations in **summer** with correlation > 0.6-0.7
- Very good temporal agreement at passive sensor sites for monthly means (r > 0.9 for most sites)

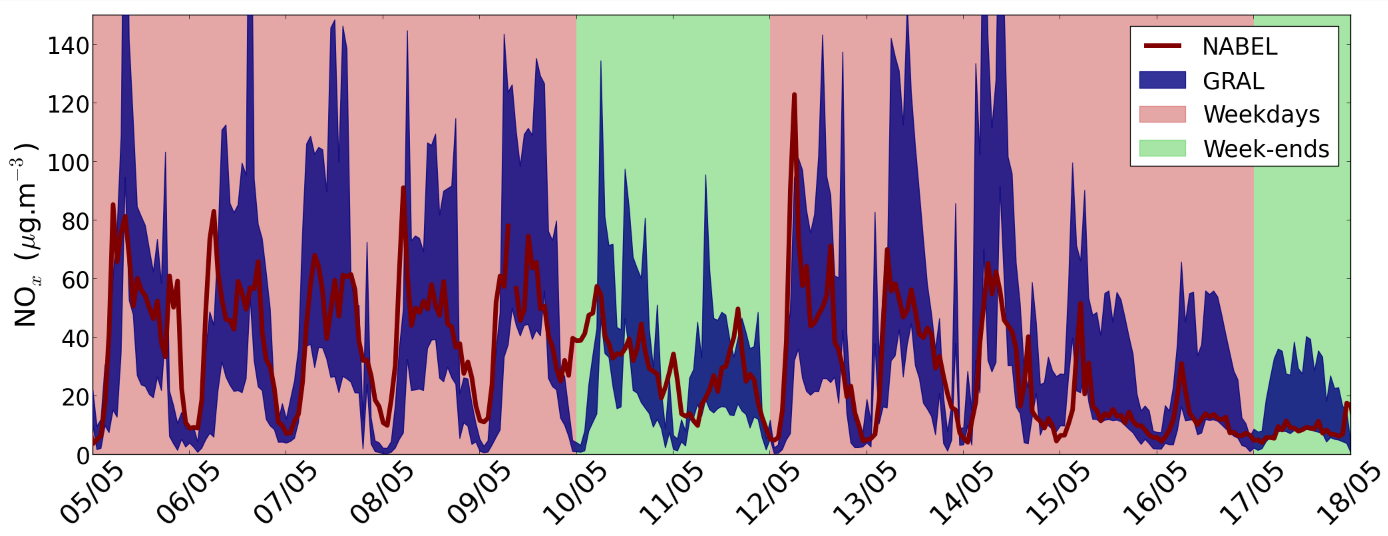


Figure 3: *Observed (red) and simulated time (blue) series of NO_x concentrations at a continuous high quality monitoring site. The blue shaded area depicts the uncertainties in the model computed as the simulated concentrations in a radius of 50m around the site.*

✔ Consistent influence of weather situations on concentration variability

✘ Reasonable temporal profile in the emissions, but still potential for improvements for traffic peaks and human activity

5. Conclusions & Further steps

✔ Consistent simulation of air pollution temporal and spatial variability at 5m hourly resolution taking into account meteorological and emission variations

► Implementation of GRAL-C chemistry module for modeling NO:NO_2:O_3 chemical reactions

► Improving emission inventories and temporal profiles by systematic assimilation of in-situ observations

► Multi-species simulations and comparison to observations

References:

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[2] Almbauer el al.: Simulation of the air quality during a field study for the city of Graz, *Atmos. Env.*, 34 (27), 4581-4594, 2000.
[3] Düring et al.: A new simplified NO/NO_2 conversion model under consideration of direct NO_2-emissions, *Meteorol. Z.*, 20, 67–73, 2011.

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