Real-time mapping of air quality in cities for improved exposure estimation

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Photo: ETH Zurich, OpenSense project

Motivation

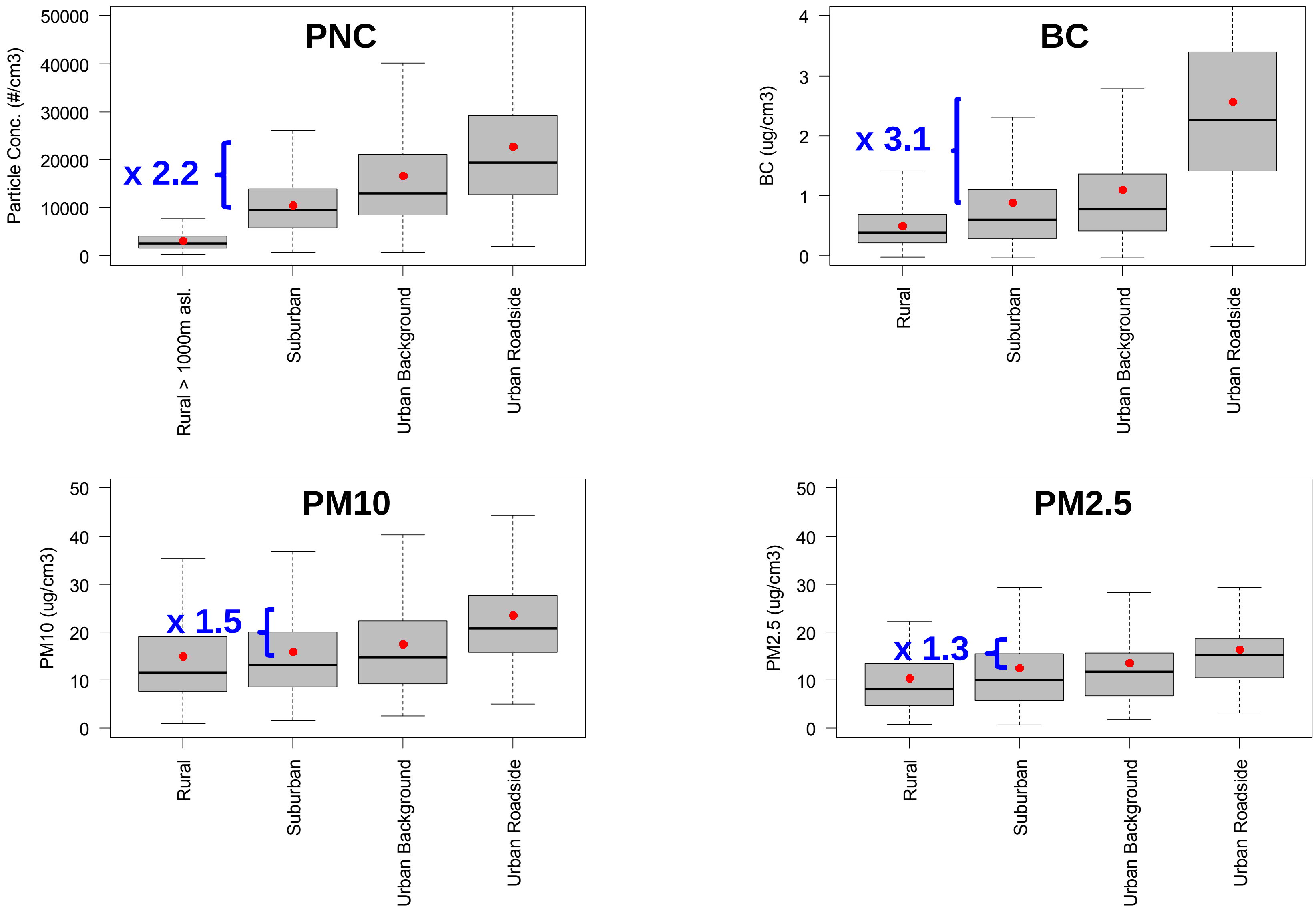
“ There is **increasing, though as yet limited, epidemiological evidence** on the association between short-term exposures to ultrafine (<0.1 μm) particles and cardiorespiratory health as well as the central nervous system. Clinical and toxicological studies have shown that ultrafine particles in part act through mechanisms not shared with larger particles that dominate mass-based metrics such as PM2.5 or PM10.”

“Although there is considerable evidence that ultrafine particles can contribute to the health effects of particulate matter, for ultrafine particles, measured by the number of particles, **the data on concentration-effect functions are too scarce to evaluate and recommend an AQG.**”

Review of health aspects of air pollution – REVIHAAP project, first results (WHO, 2013)

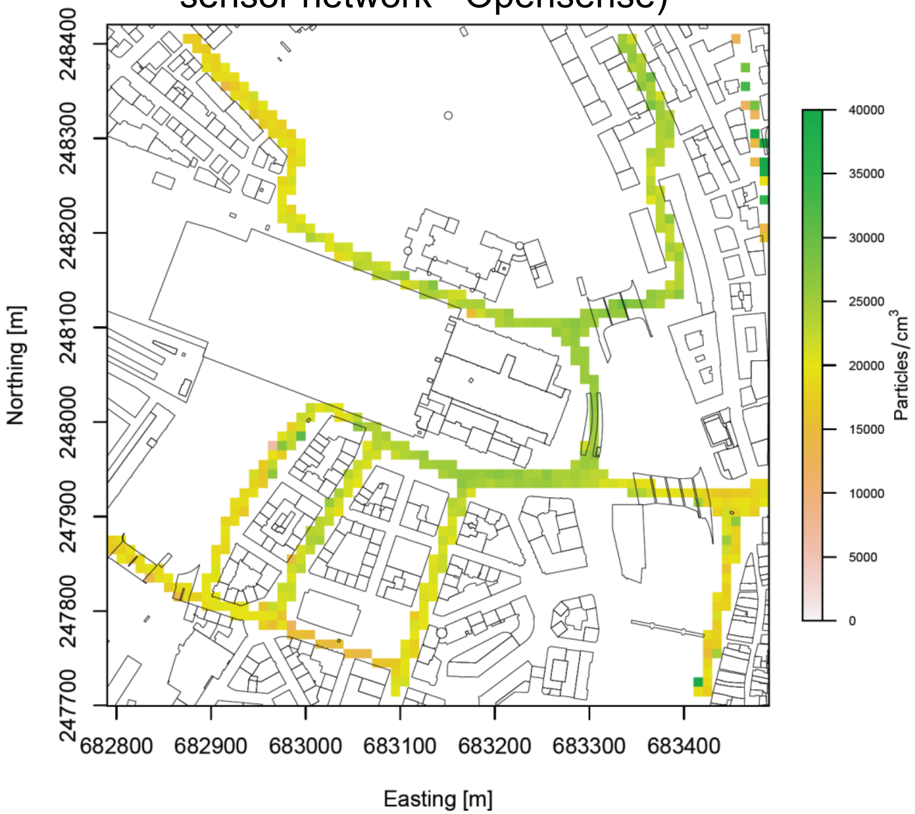
Why is it so difficult to find epidemiological evidence for health effects of ultrafine particles – UFPs?

Differences between Swiss sites (NABEL, data from 2012)

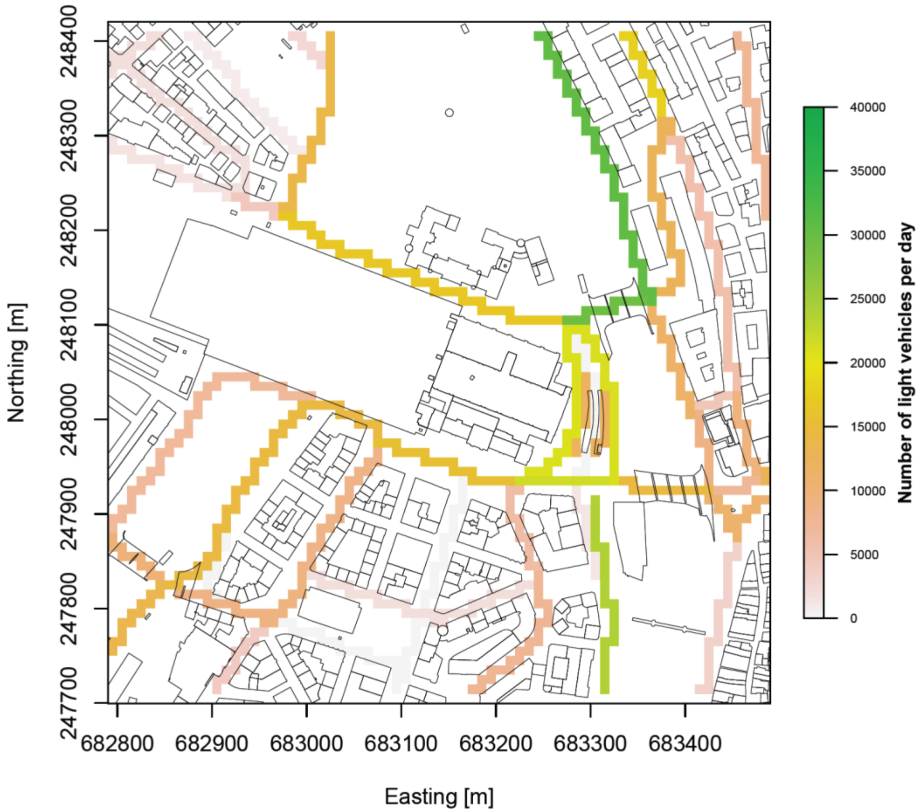


Small-scale (urban scale) variability of UFP

PNC near Zurich HB
(Feb.-Mar. 2013, data from tram based mobile sensor network - Opensense)



Traffic activity near Zurich HB



Small-scale spatial and temporal variability of air pollutants such as UFPs, BC, NO_2 is difficult to capture

Lack of epidemiological evidence might (partially) be due to insufficient information about spatial variability and thus inaccurate exposure estimates

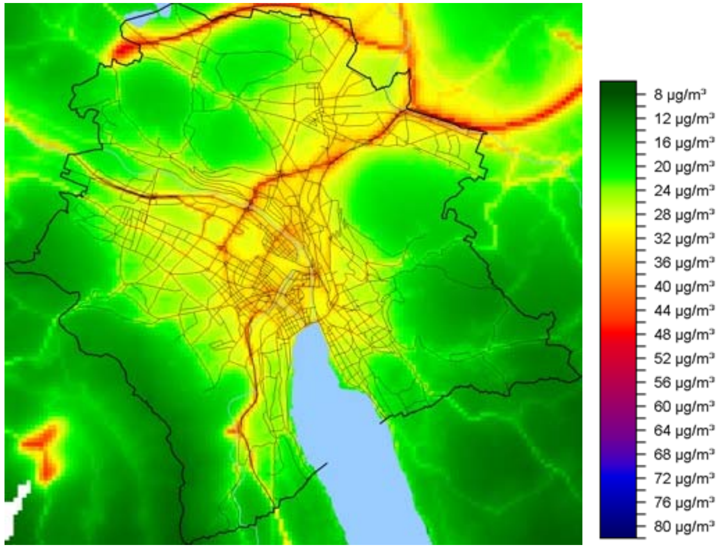
Approaches for improvement

1. Personal monitoring
2. Air pollution maps
   (high spatial and temporal resolution)

   a. Dispersion models

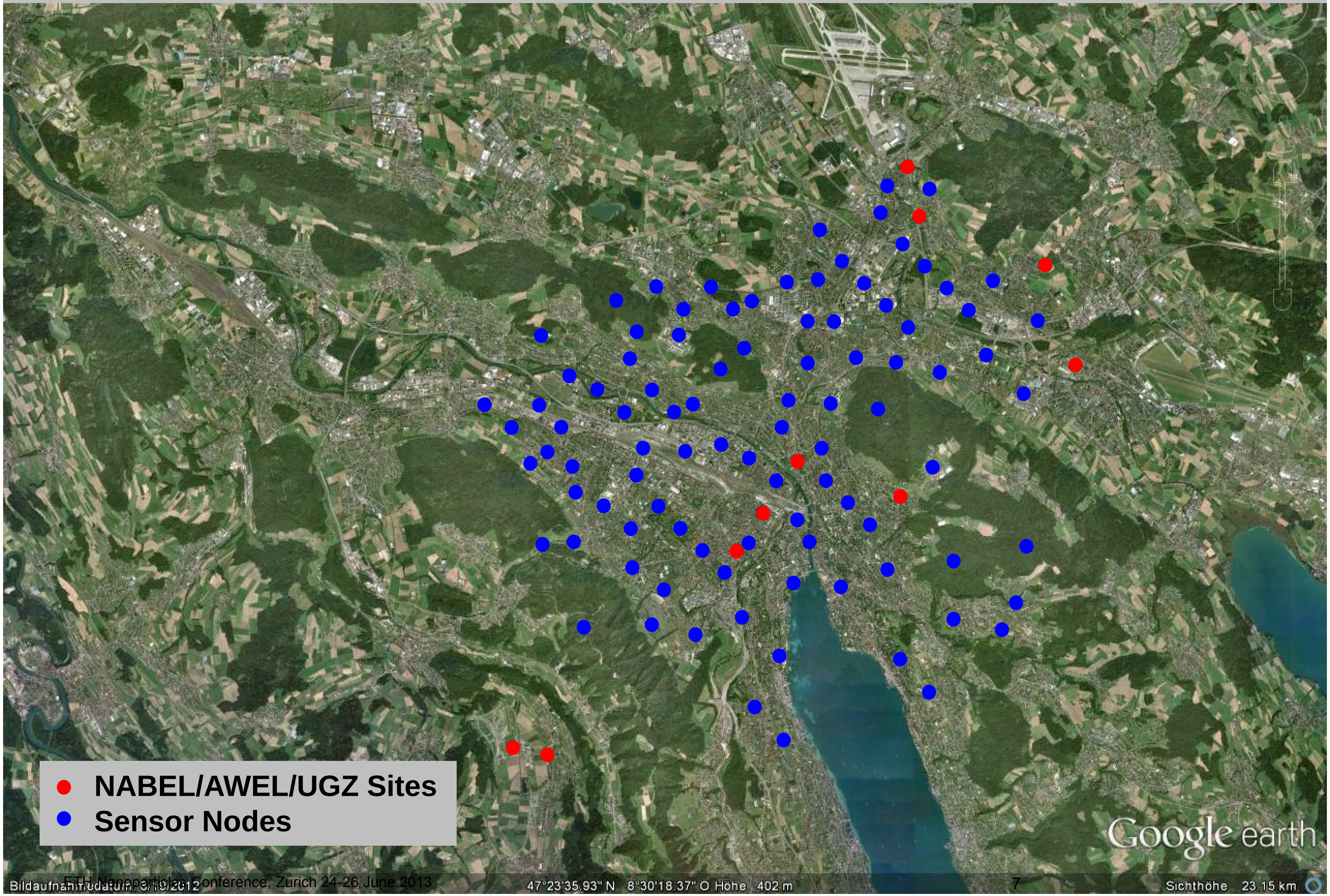
   b. Sensor networks & statistical models

Modelled annual NO_2 surface concentration (2011)



from http://www.stadt-zuerich.ch/content/gud/de/index/umwelt/luft

Hypothetical air quality sensor network in Zurich



Parallel measurements using low-cost sensor and reference instruments

Opensense mobile sensor network in Zurich

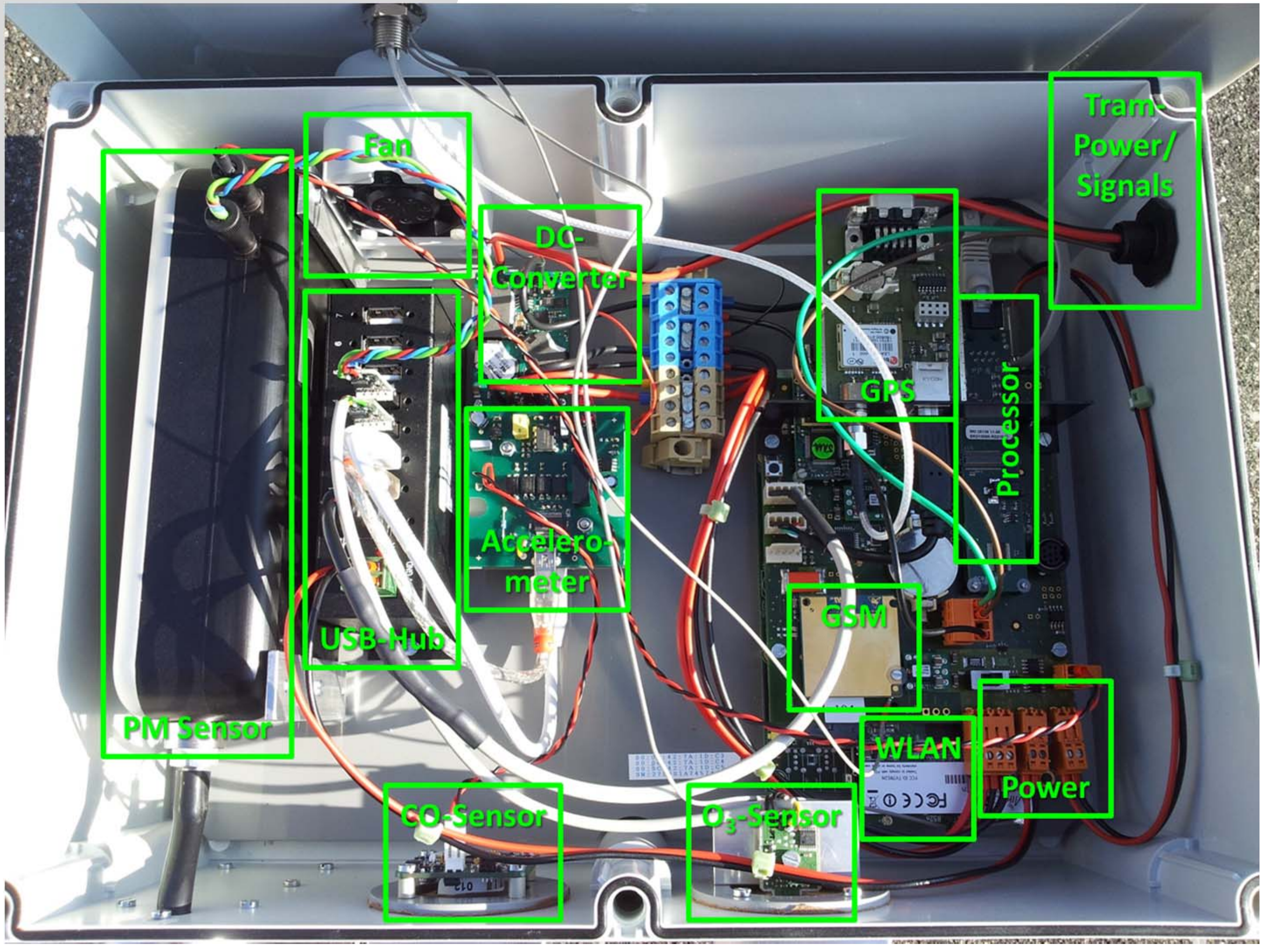
Open SENSE

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

opensense.ethz.ch

Opensense sensors nodes

- Currently 10 nodes
- Sensors: O_3, CO, PNC, temperature, humidity, accelerometer
- GPS
- Communication: WLAN and GSM
- External power supply



Sensors for air quality measurements – issues to address

- How good are available sensors (performance characteristics) ?
- How to operate sensor networks (calibration, QA/QC in general) ?
- How to derive *spatial information* from a sensor network (air pollution maps with ***high spatial and temporal resolution***) ?
- …

Statistical modelling

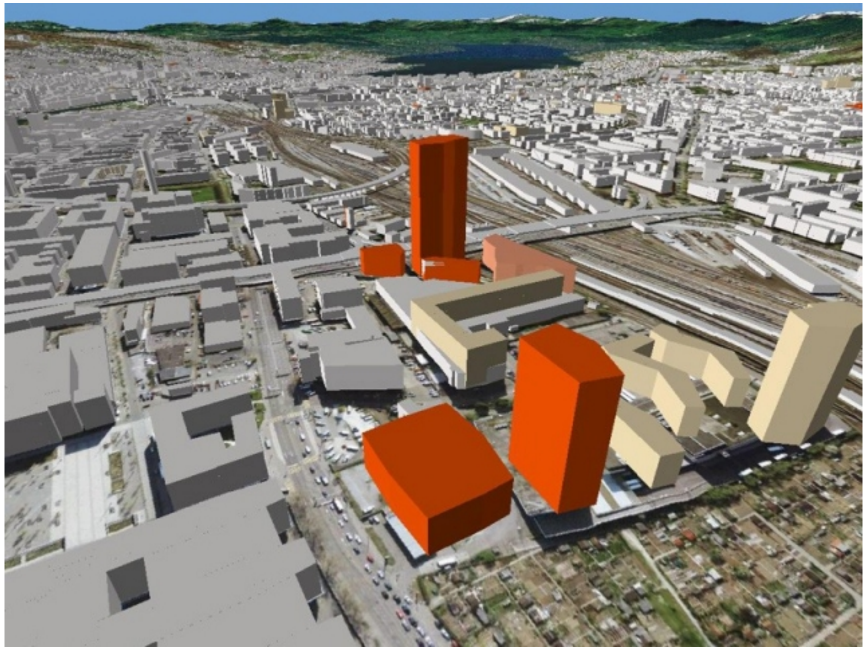
- Model association between air pollutant concentration and land use information (Land use regression - LUR)

e.g. $$Y_i = f(geo_{i1}) + g(geo_{i2}) + h(geo_{i3}) + \cdots + meteo + E$$

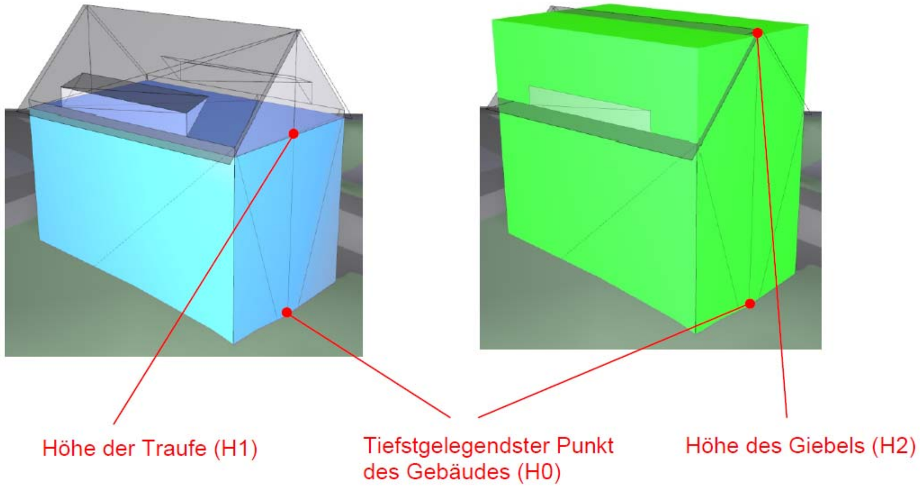
Y_i	air pollutant concentration at location i
f, *g*, *h*, etc.	smooth non-parametric functions (Generalized Additive Model, GAM)
geo_{ij}	road traffic (road network) rail traffic built environment, buildings, street configuration heating systems used industries topography …
meteo	meteorological variable(s)

- Use model for prediction of air pollutant concentration in each grid cell of modeling domain

3D – city model for Zurich

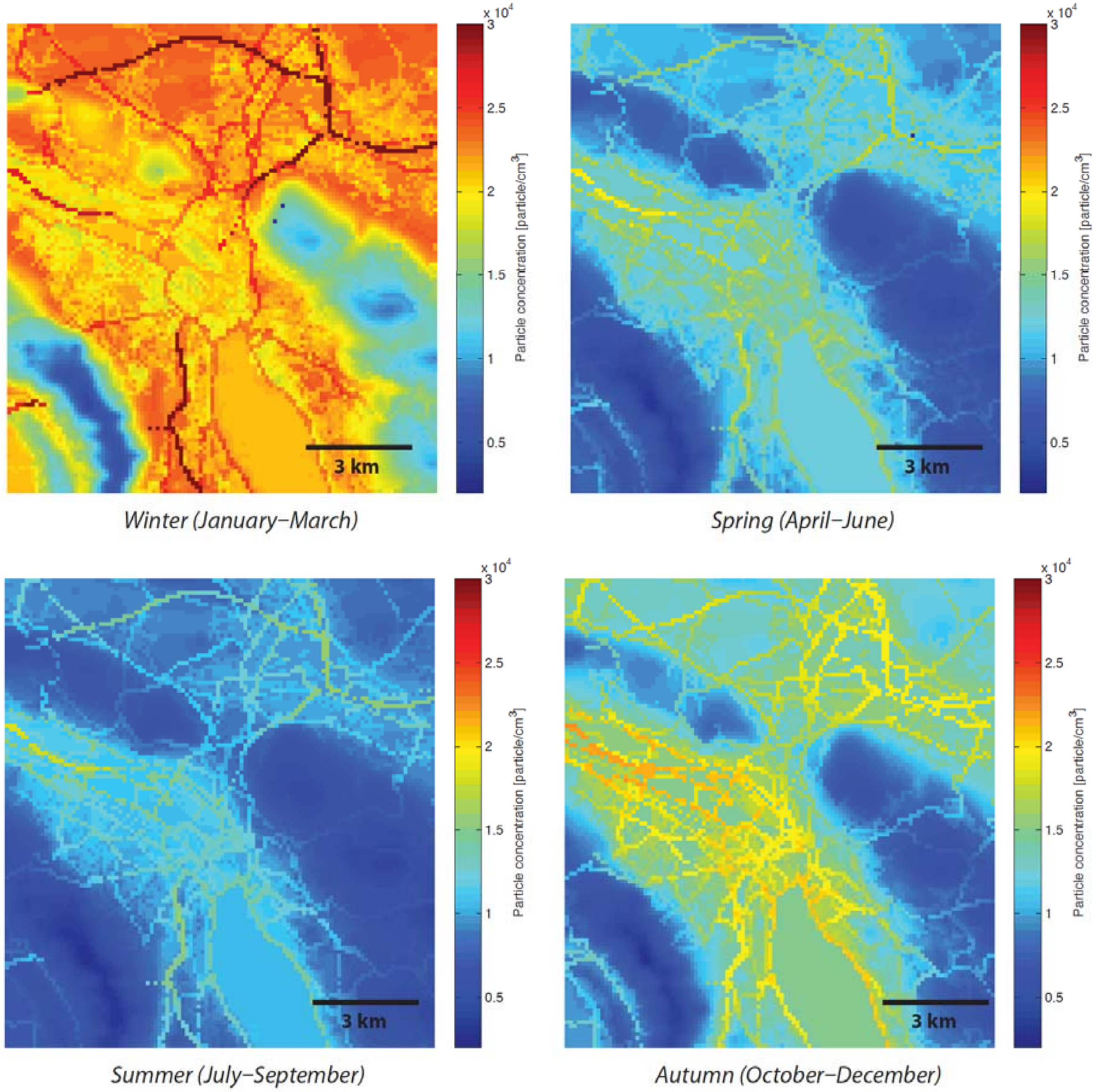


accuracy: x/y = ±10-15cm; z = ±50cm



Seasonal PNC maps for Zurich (100m x 100m)

Data from the mobile sensor network in Zurich (modeling by D. Hasenfratz, ETHZ)



Estimation of 14-day NO_2-pollution maps

2008, 100m x 100m resolution

Barmpadimos & Hueglin, ES&T, in review

EMPA Materials Science & Technology

Summary

- It is currently difficult to find epidemiological evidence linking spatially highly variable air pollutants with health effects
- This is especially relevant in the urban environment which inherently combines dense population and high variablity of air pollutants
- Sensor networks offer new opportunities for the mapping of air pollutant concentrations in cities (combining sensor data and geo-referenced information)
- Operation of sensor networks? – Sensors need to be linked in a smart way to reference site(s)

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