Mobile measurements of number concentrations of ultrafine particles in different Swiss cities with the miniDiSC

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Mobile measurements can help considerably in obtaining a more precise overview of ambient air pollution within cities. Particularly, particle number concentrations can vary within small distances and are therefore highly location dependent. Concentration levels are influenced by traffic densities, urban conditions (street canyons, green areas) and industrial sites. Both, citizens and official authorities can profit from pollution maps based on mobile measurements to avoid highly polluted areas in everyday life and to formulate mitigation strategies. The calculation of such pollution maps can be done most accurately the more data points are available and the higher the spatial coverage is.

With the here presented two research projects we followed two different approaches for monitoring air pollution within cities:

Firstly, a long-term research project was established in the city of Zürich to measure particle number concentration as well as CO and O_3 concentrations. In cooperation with the OpenSense project (NanoTera, Computer Engineering and Networks Laboratory of ETH (TIK), Aberer, 2010) boxes with miniDiSCs, CO and O_3 sensors were installed on the roof of five trams in September 2011 (1 box) and early 2012 (4 boxes). The miniDiSC is a handheld instrument that was developed at the IAST (Fierz, 2010) and measures the particle number concentration, the average particle diameter and the lung deposited surface area with a time resolution of 1 second. The measurement boxes are equipped with GPS and GSM antennas and a WLAN internet connection to enable data transmission to our database, online data control and continuous data download from our webpage: https://datalogger.cs.technik.fhnw.ch/feinstaubmessnetz/. Data can also be viewed on the PermaSense webpage (http://data.permasense.ch/science.html#science) together with the data of the other sensors. There are different possibilities to display the data points, such as time series projected on a Google earth map, or a color-coded animation of the varying concentrations which are moving along the tram lines on a Google earth map.

To obtain a most complete coverage of the city, the choice of trams was optimized with calculations performed by TIK, ETH. Continuous measurements performed throughout one year will lead to a differentiated analysis of data according to diurnal and weekday variation and seasons of the year. Additionally, different weather conditions can be studied in detail. As expected, a clear diurnal variation is visible in the particle number concentration data, with two peaks during the morning and the evening rush hours. In contrast, the average particle size has two minima during these rush hours, indicating that traffic generated combustion particles have a smaller average size.

Eventually the collected particle number concentration data will be used together with the coordinates obtained from the GPS measurements for interpolations with the geo-statistical Kriging Algorithm (Pebesma, 2004) to obtain a pollution map of the city of Zürich. Other methods such as land use regression including information on streets, buildings and green areas can also be explored to reach a better prediction of pollution levels in areas where the sensor coverage is low (especially in the outskirts of the city).

In addition to these long term measurements in Zürich, random walks in eight Swiss cities were performed by the Verkehrs-Club der Schweiz (VCS) and the Vereinigung Ärzte und Ärztinnen für Umweltschutz (AefU). They were initiated to obtain snapshots of ambient air pollution exposure scenarios of pedestrians in everyday situations in the following cities: Basel, Bern, Biel, Chiasso, Geneva, Lausanne, Lucerne and Lugano. The test-parcours were designed such that different areas of the city were chosen, both quite residential areas as well as highly trafficked street crossings. The miniDiSC was equipped with a GPS/GPRS extension which allows for tracking the mobile measurements. Furthermore, a PersonalDustMonit was employed by the VCS in these walks to measure the particle mass concentrations PM_{10}, $PM_{2.5}$ and PM_1. The walks were made at different times of the day and different weather conditions, so that a comparison of the results within the different cities is not possible.
As was expected, particle number concentrations showed a high variability, but also PM concentrations were highly variable, which most probably has to be attributed to re-suspended road dust while measuring directly on busy streets in a height of less than 2m. Due to this, these pedestrian walks through different cities are snapshots which cannot be extrapolated to generate a general conclusion.

We believe that particle number concentration and the lung deposited surface area (LDSA) represent two measurement parameters that are more relevant for health effects than particulate matter. With the here presented approaches we try to complement the point-wise measurements taken by fixed monitoring station and try to help in obtaining a better understanding of distribution of ambient air pollution within the city of Zürich.

References:

Fierz, M., Houle, C., Steigmeier, P., and Burtscher, H. (2011) Design, Calibration and Field Performance of a Miniature Diffusion Size Classifier, Aerosol Science and Technology, 45, 1-10.

Aberer, K., Sathe, S., Chakraborty, D., Martinoli, A., Barrenetxea, G., Faltings, B., and Thiele, L. (2010) OpenSense: Open Community Driven Sensing of Environment, IWGS ’10, November 2, 2010, San Jose, CA, USA.

Pebesma, E.J. (2004) Multivariable geostatistics in S: the gstat package. Computers and Geosciences 30, 683–691.

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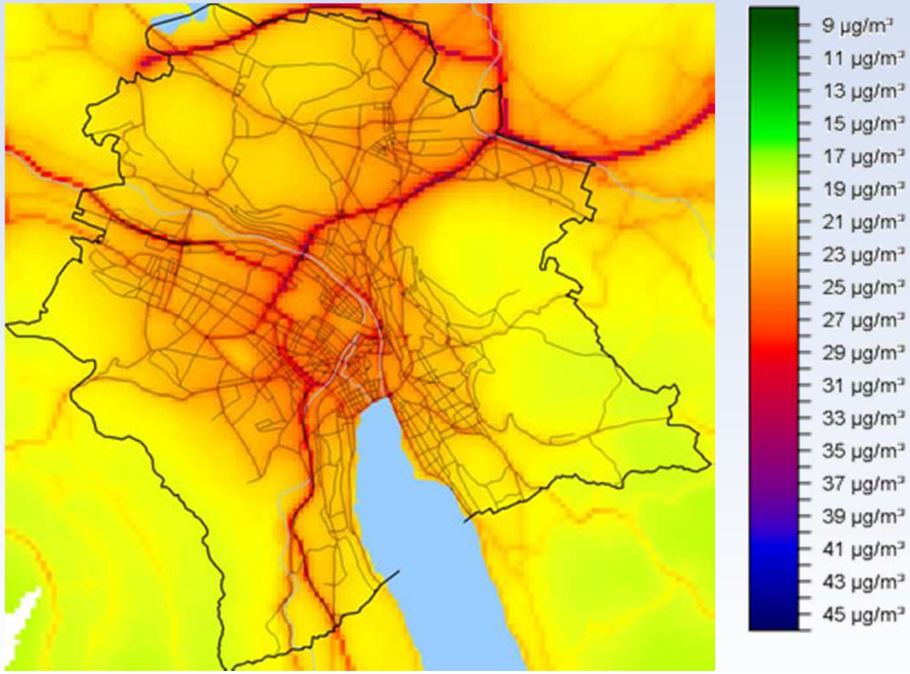
Motivation

- Mobile measurements
- Alternative measures to particle mass: particle number (PN) & lung deposited surface area (LDSA) which might be more relevant for health effects
- From snapshots to monitoring PN throughout a year
- Generate a „pollution map“ of the city of Zürich to enable a choice of the least „polluted path“
- Seasonal and diurnal variation / variation due to meteo conditions
- Split the city of Zürich in zones of different pollution exposure (GIS info)

Air pollution monitoring

Air pollution is highly location-dependent

- traffic density
- distribution of buildings (street canyons)
- industry



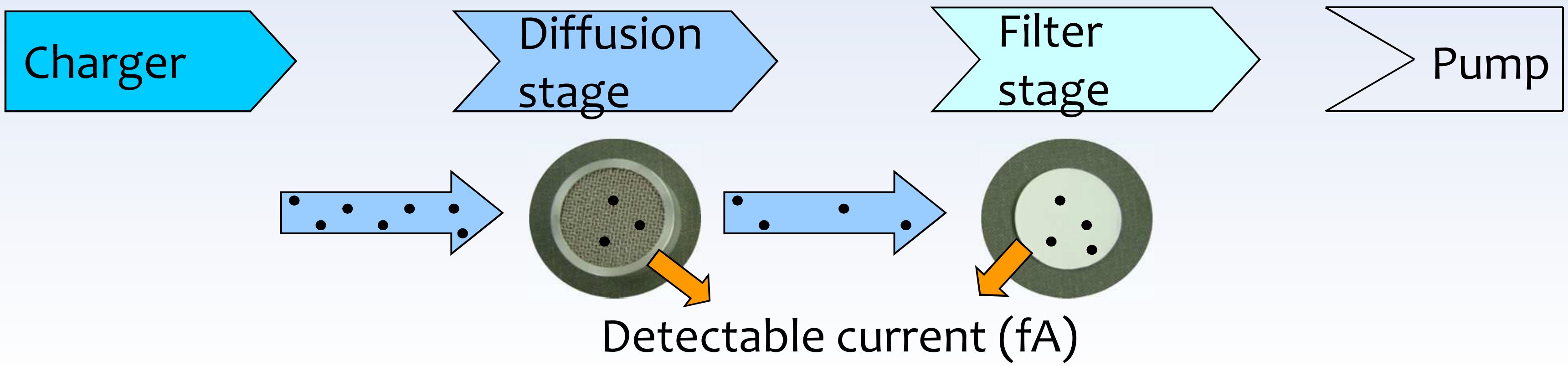
Expand system of fixed monitoring networks (NABEL, OstLuft, UGZ,…) with mobile measurements (<u>location-dependent, real-time</u>)

- Official uses
  - location of pollution sources
  - incentives to reduce environmental footprint
  - public health studies
- Citizen uses
  - advice for outside activities
  - assessment of long-term exposure
  - pollution maps

PM map, source: http://www.stadt-zuerich.ch

miniDiSC (miniature diffusion size classifier)

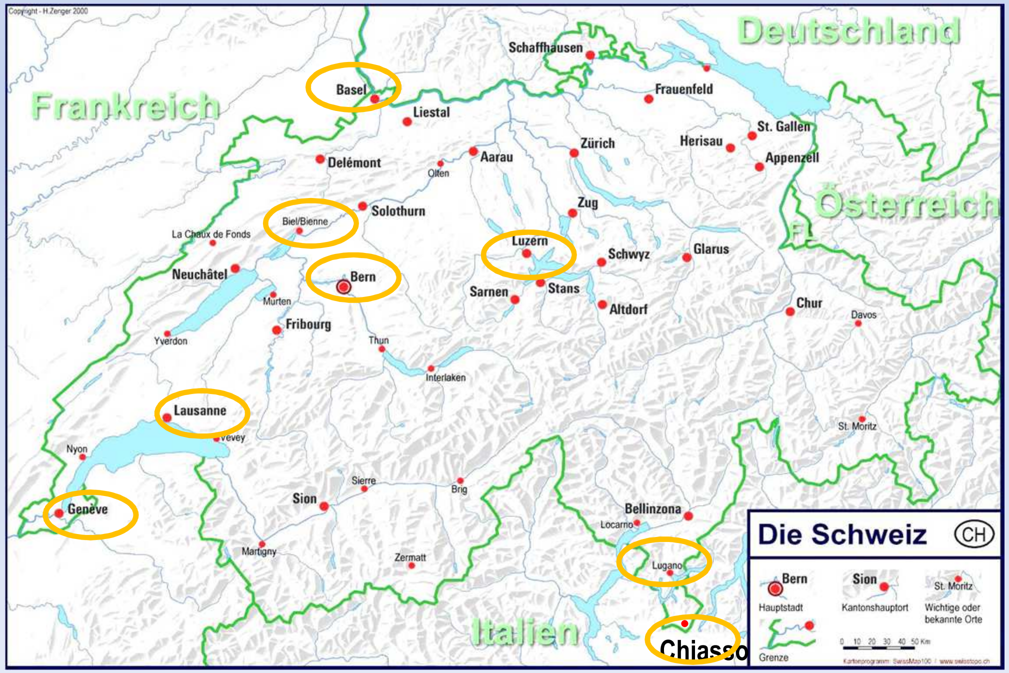
- Particle number concentration, average particle size and lung deposited surface area (LDSA)
- Particle size: 10 – 300 nm
- Time resolution: 1 sec
- Developed at IAST/FHNW
- *New:* GPS/GPRS extension



Testparcours VCS/AefU

Project idea:

- «Snapshots» of everyday situations
- Measurement of UFP with miniDiSC (10-300 nm; /1 sec)
- Measurement of PM with PersonalDustMonit ($PM_{10, 2.5, 1}$; /1 min)

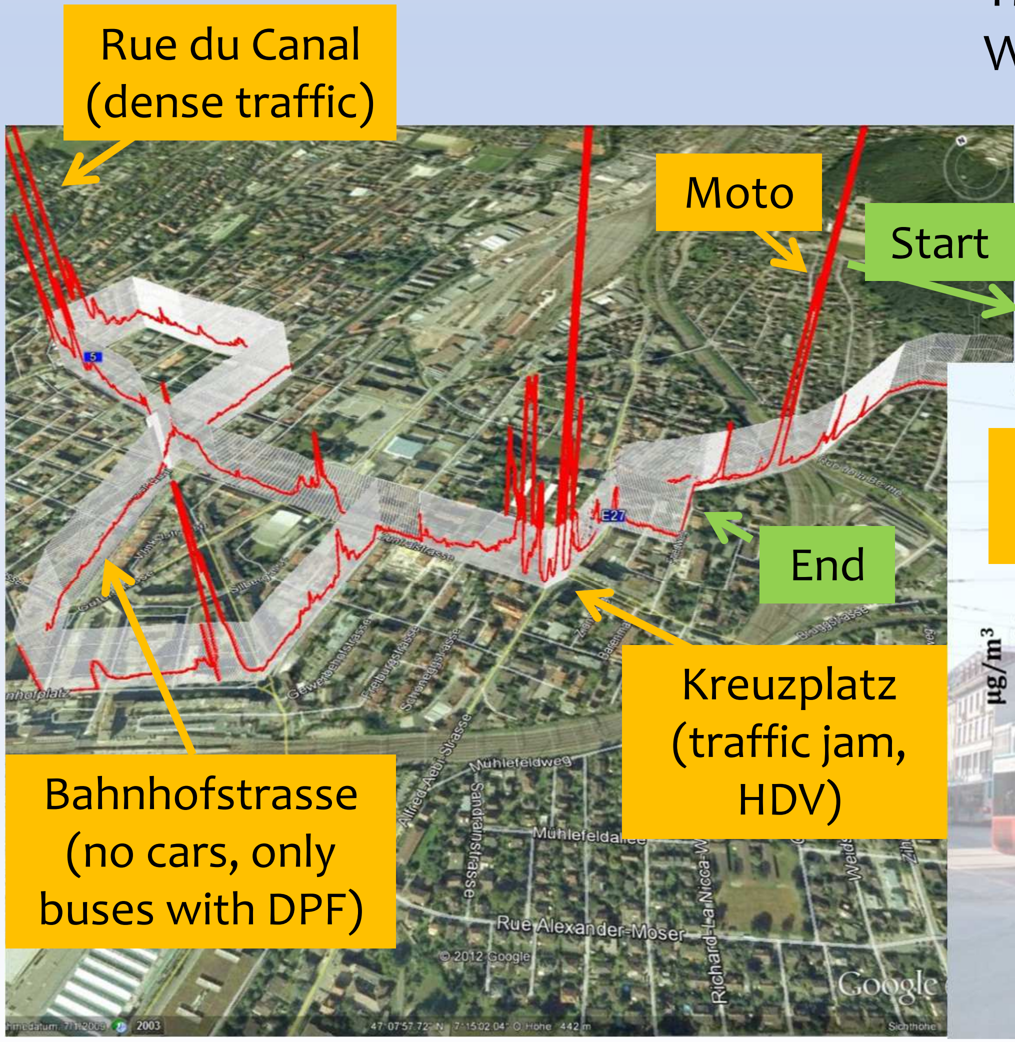


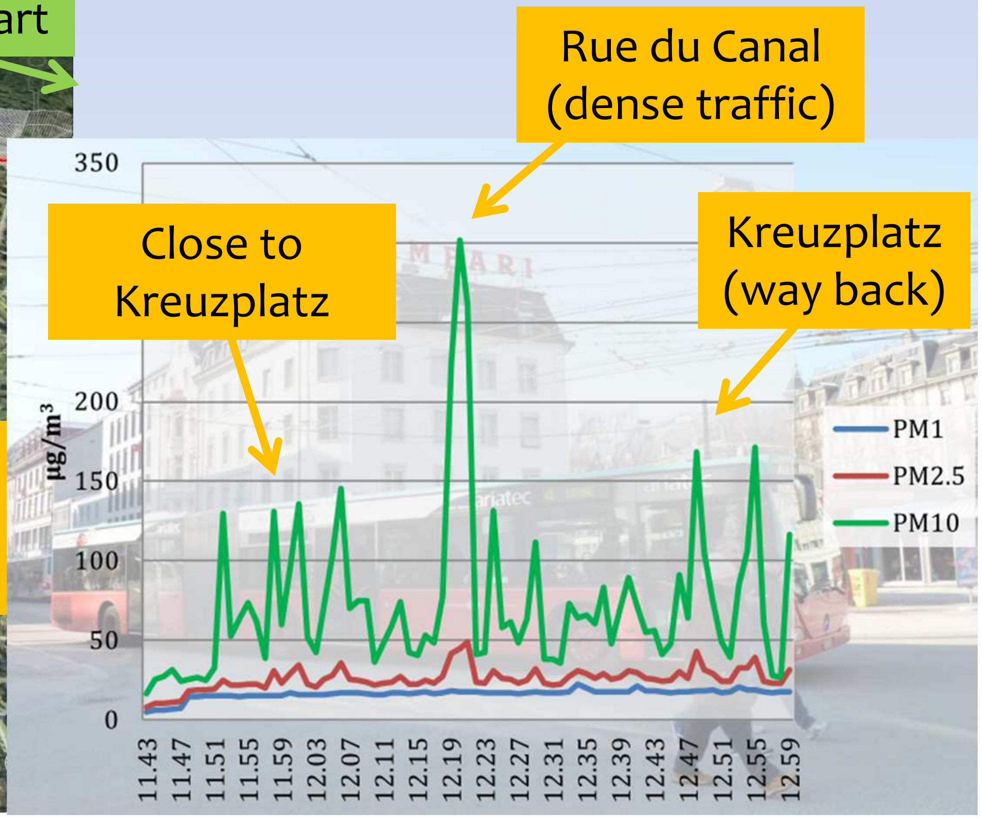
Limitations:

- Comparability of cities is not given: different meteo conditions / time of day / urban conditions / traffic densities
- PM data showed unexpectedly high variation

Example: city of Biel

Date: 3. March 2012
Time: 9:30 – 12:30
Weather: sunny, strong West wind, -7°C





PM data: VCS, PersonalDustMonit

OpenSense boxes on Trams

5 boxes (July/Aug 2012: **10** boxes)

- Sensors: **particle number concentration (miniDiSC), O_3, CO, temperature, humidity, accelerometer**
- GPS
- Communication: WLAN, Ethernet and GSM

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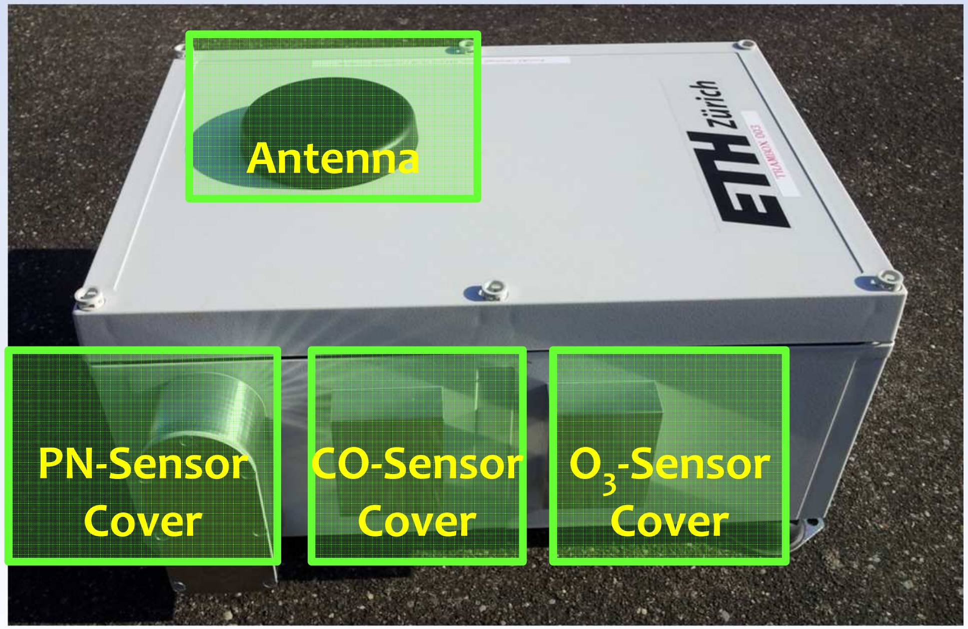
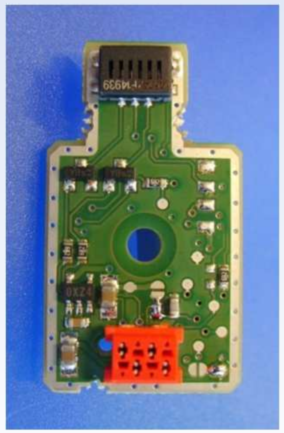
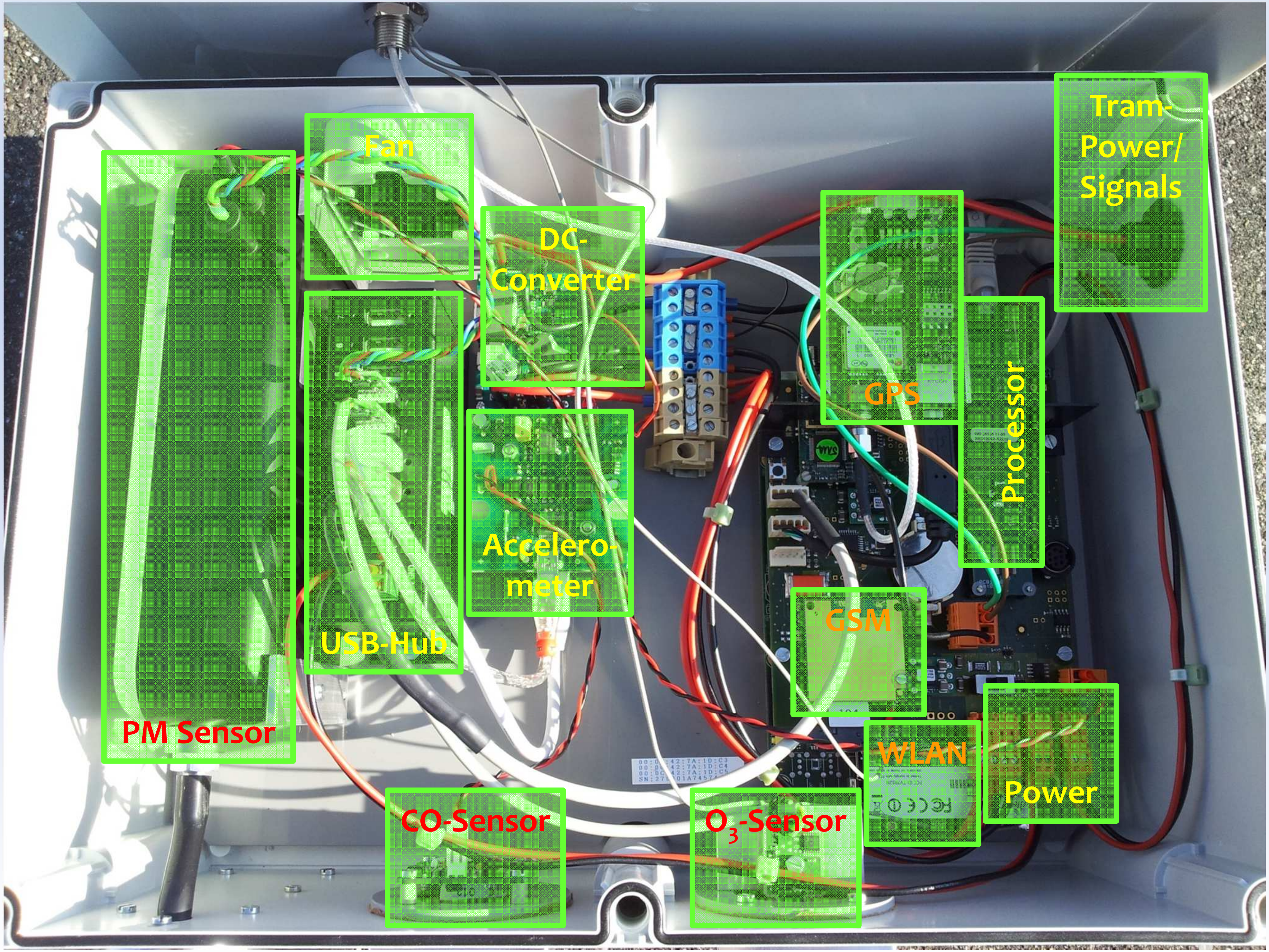
VBZ Züri Linie



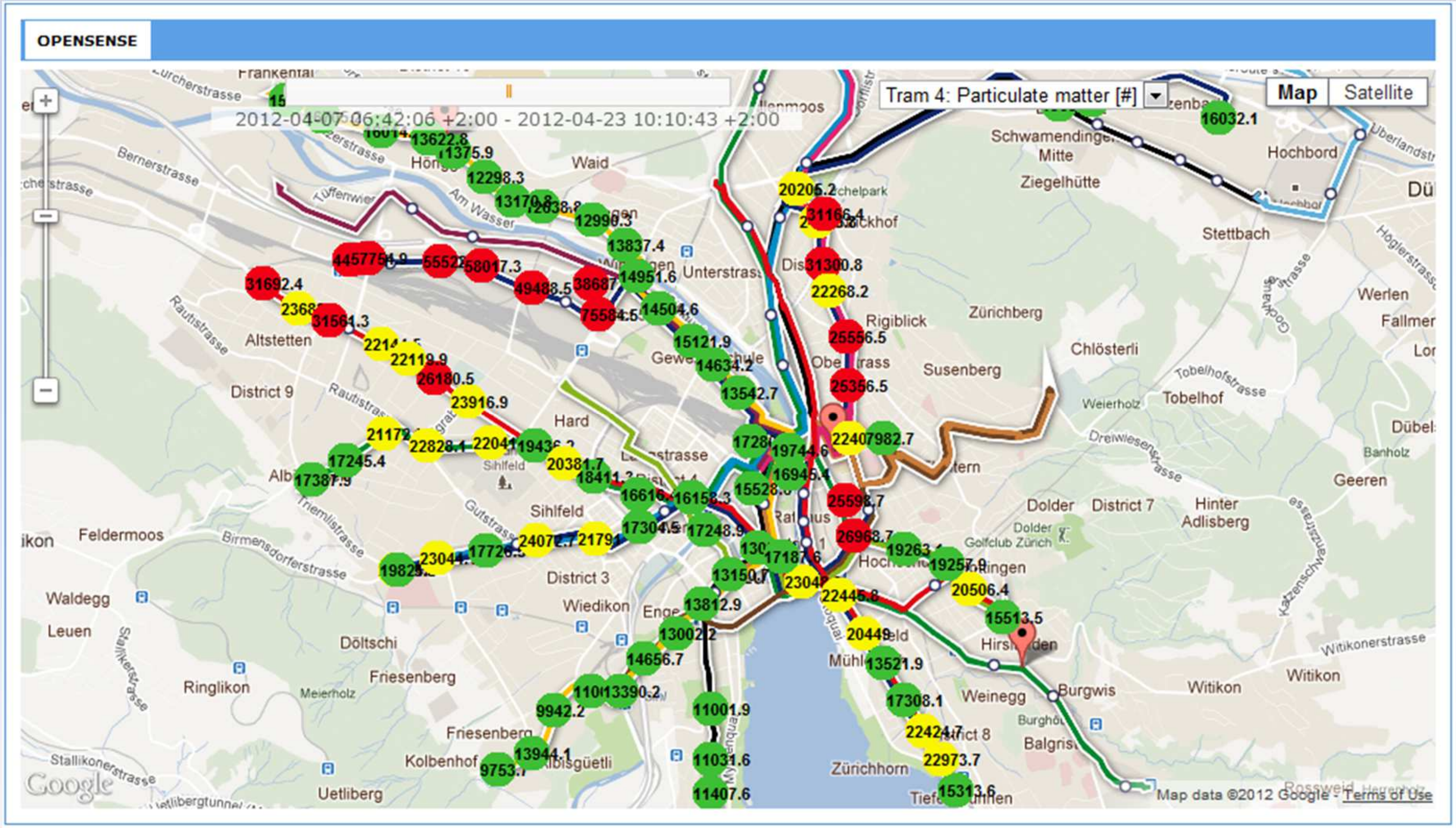


Courtesy of TIK/ETH



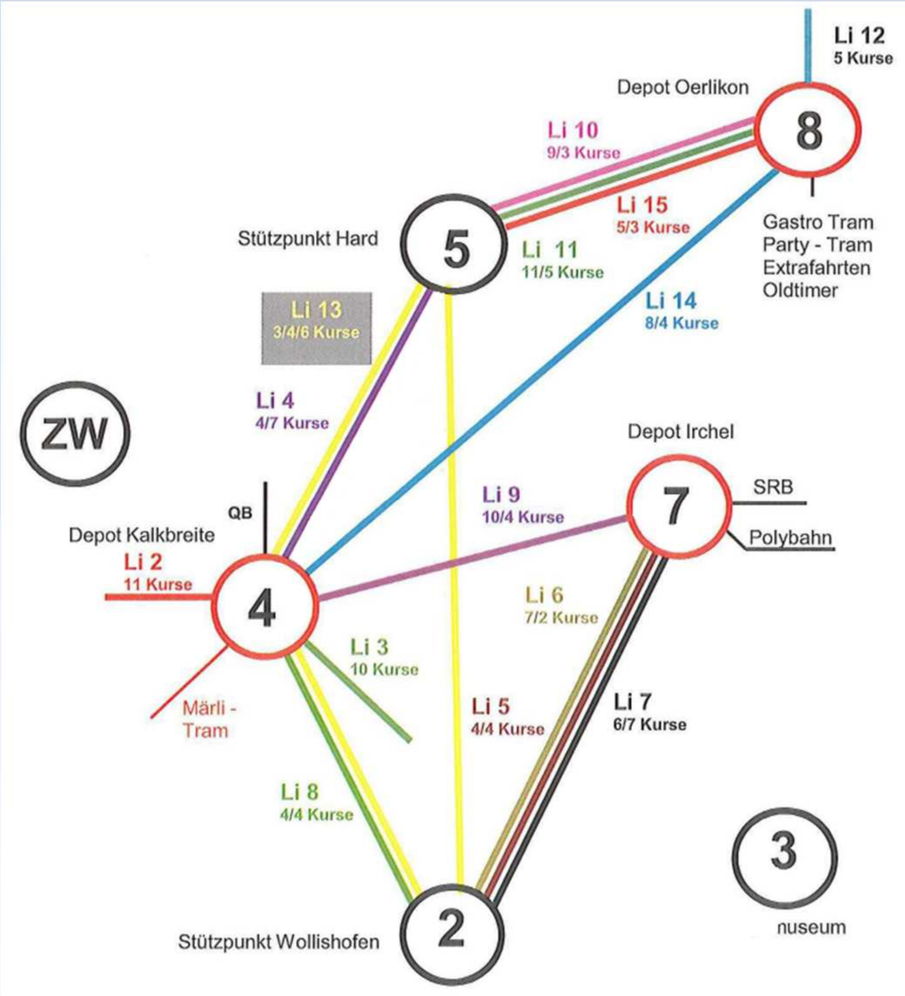
Courtesy of TIK/ETH

City scale coverage

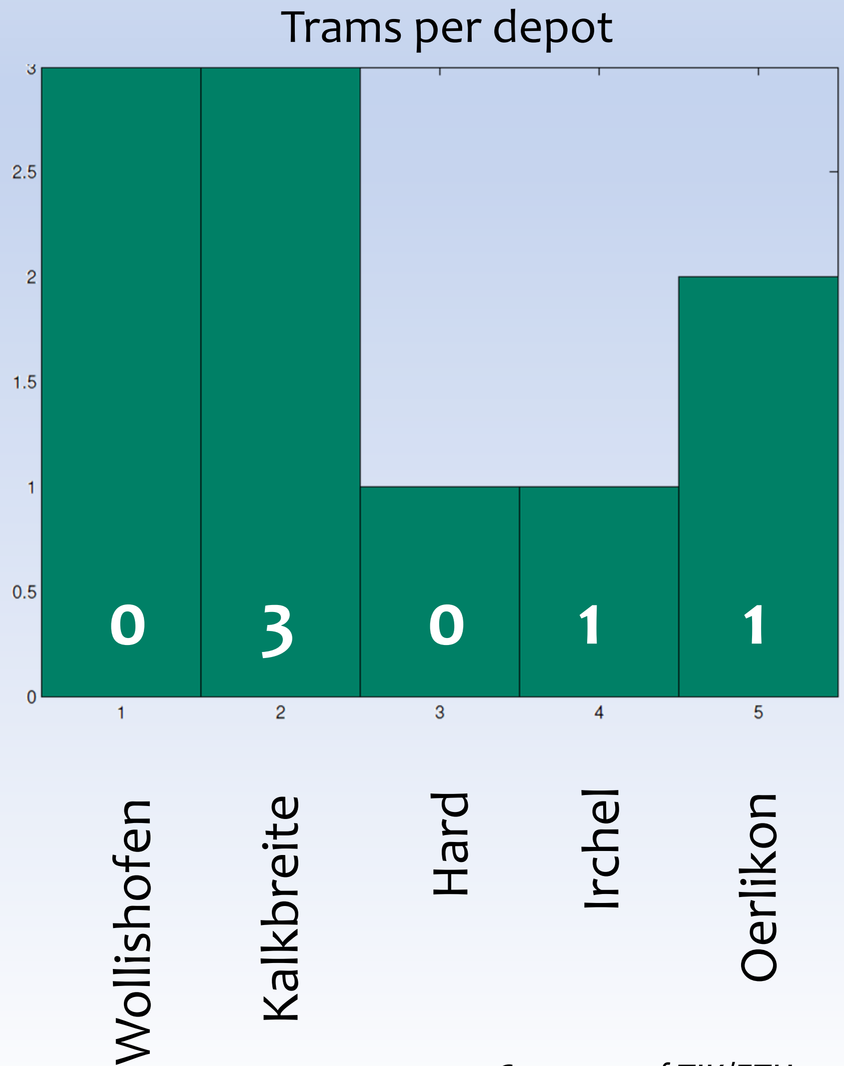


Which routes to pick for installation of OpenSense nodes to cover the city well?

Choice of trams: optimization results



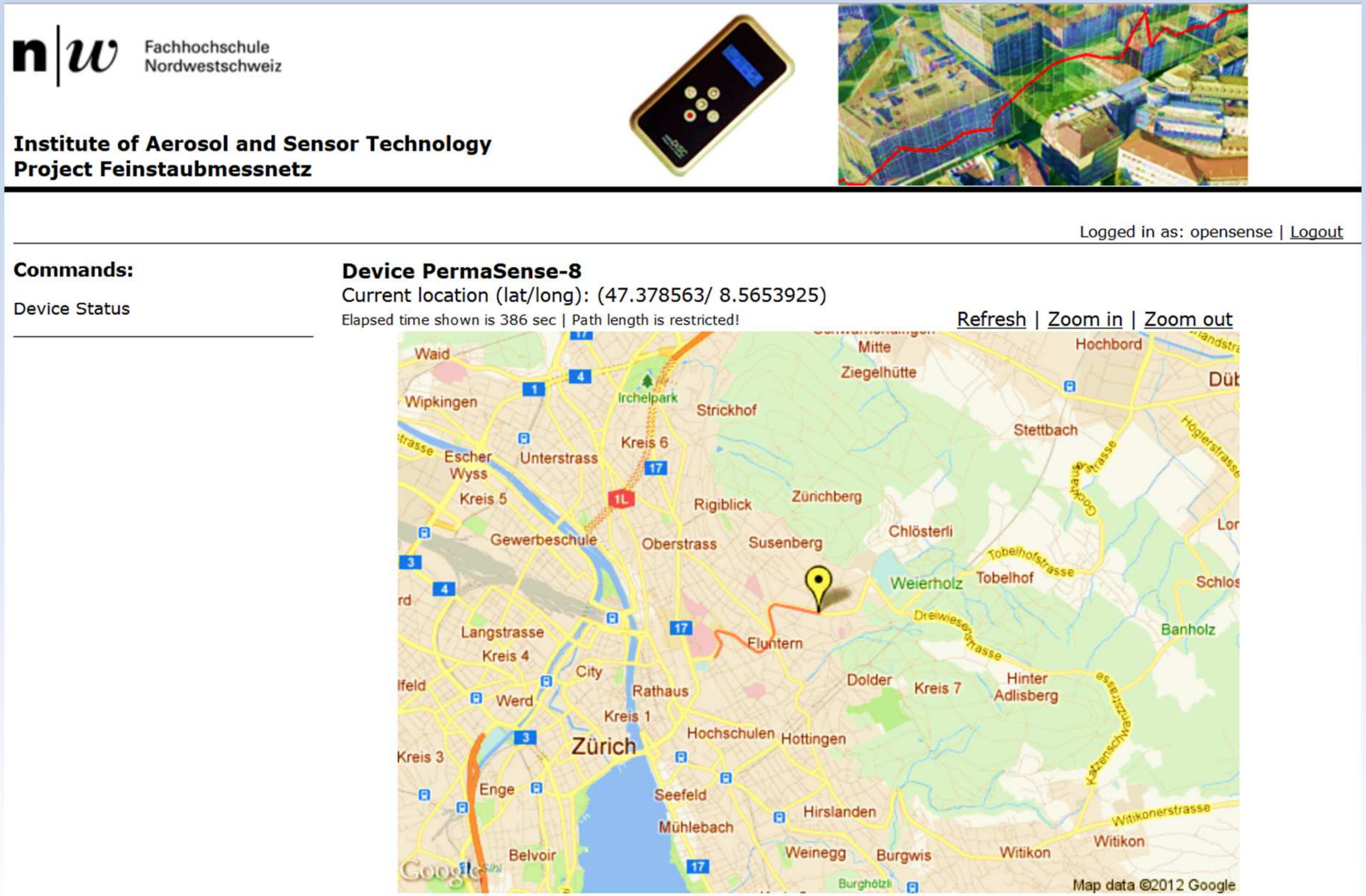
Optimally selected 10 trams

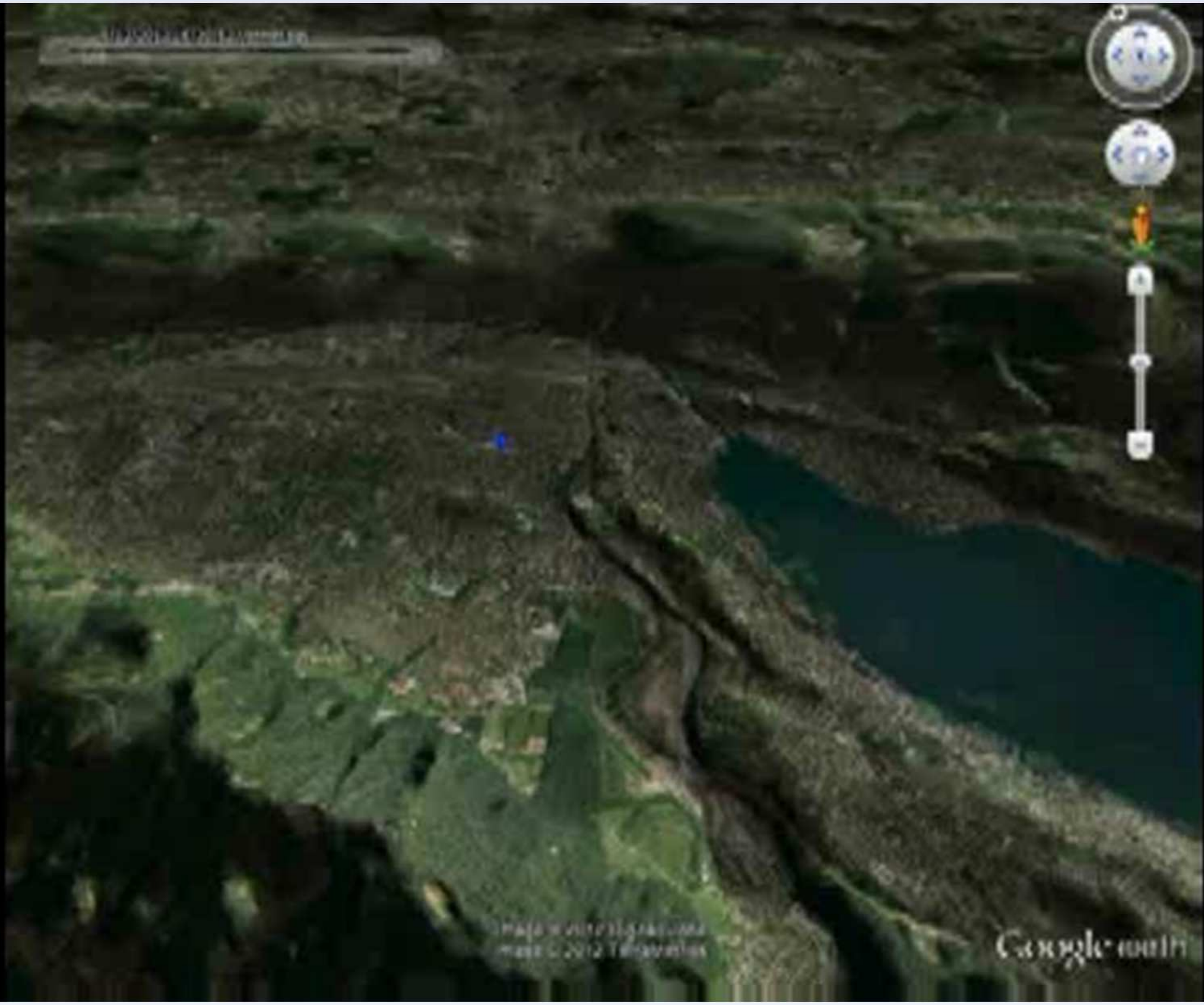


Courtesy of TIK/ETH

Webpage

https://datalogger.cs.technik.fhnw.ch/feinstaubmessnetz/



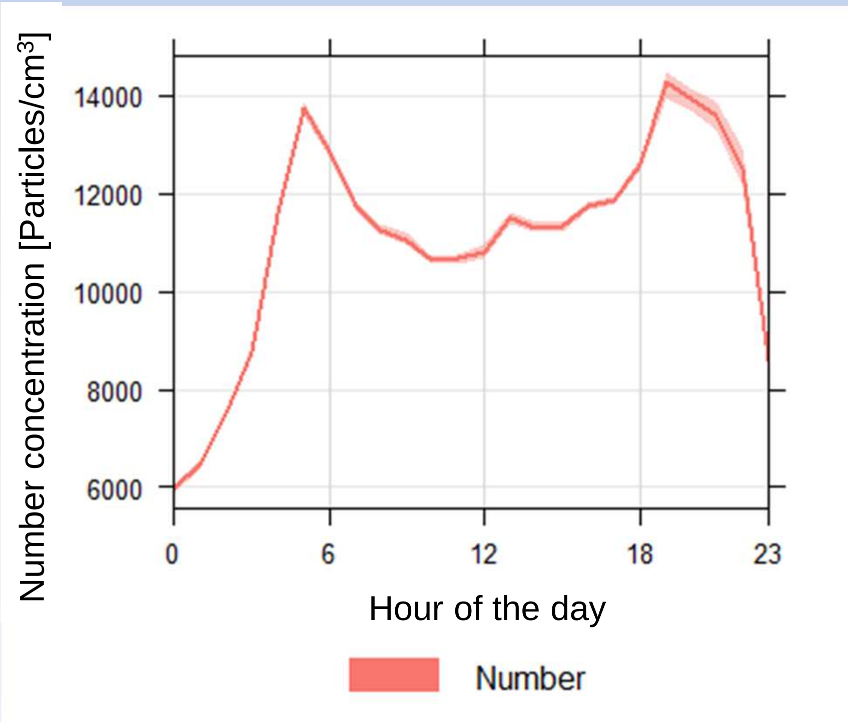


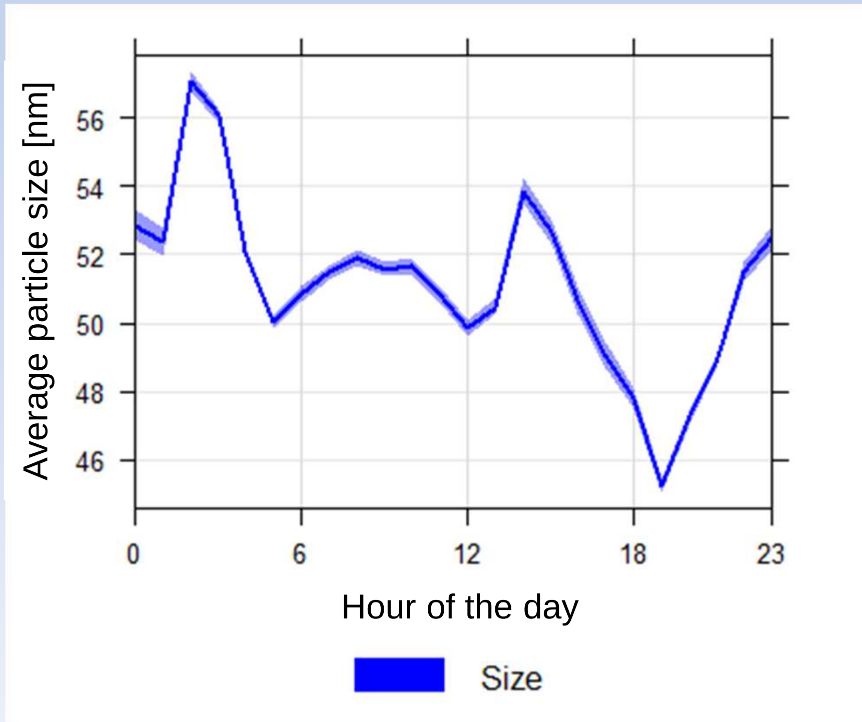
< 1000 3000 10'000 30'000 >100'000

Particles / cm^3

Programmed by Martin Fierz

Diurnal variations

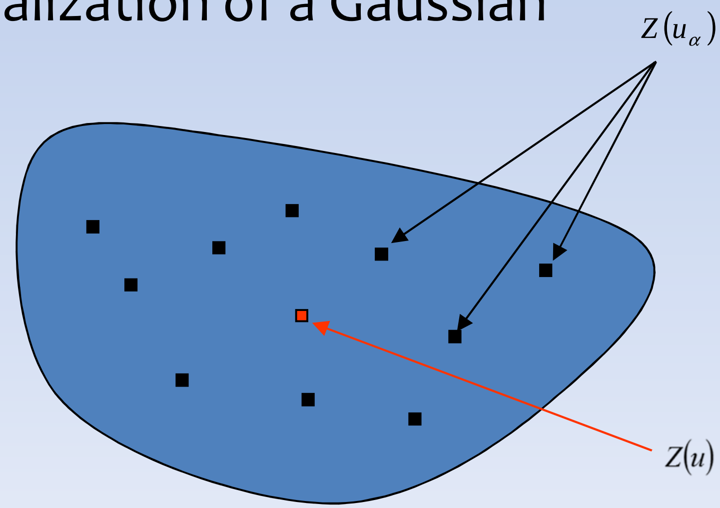




=> Traffic rush hours visibile (time = UTC)...

Gridding (Kriging)

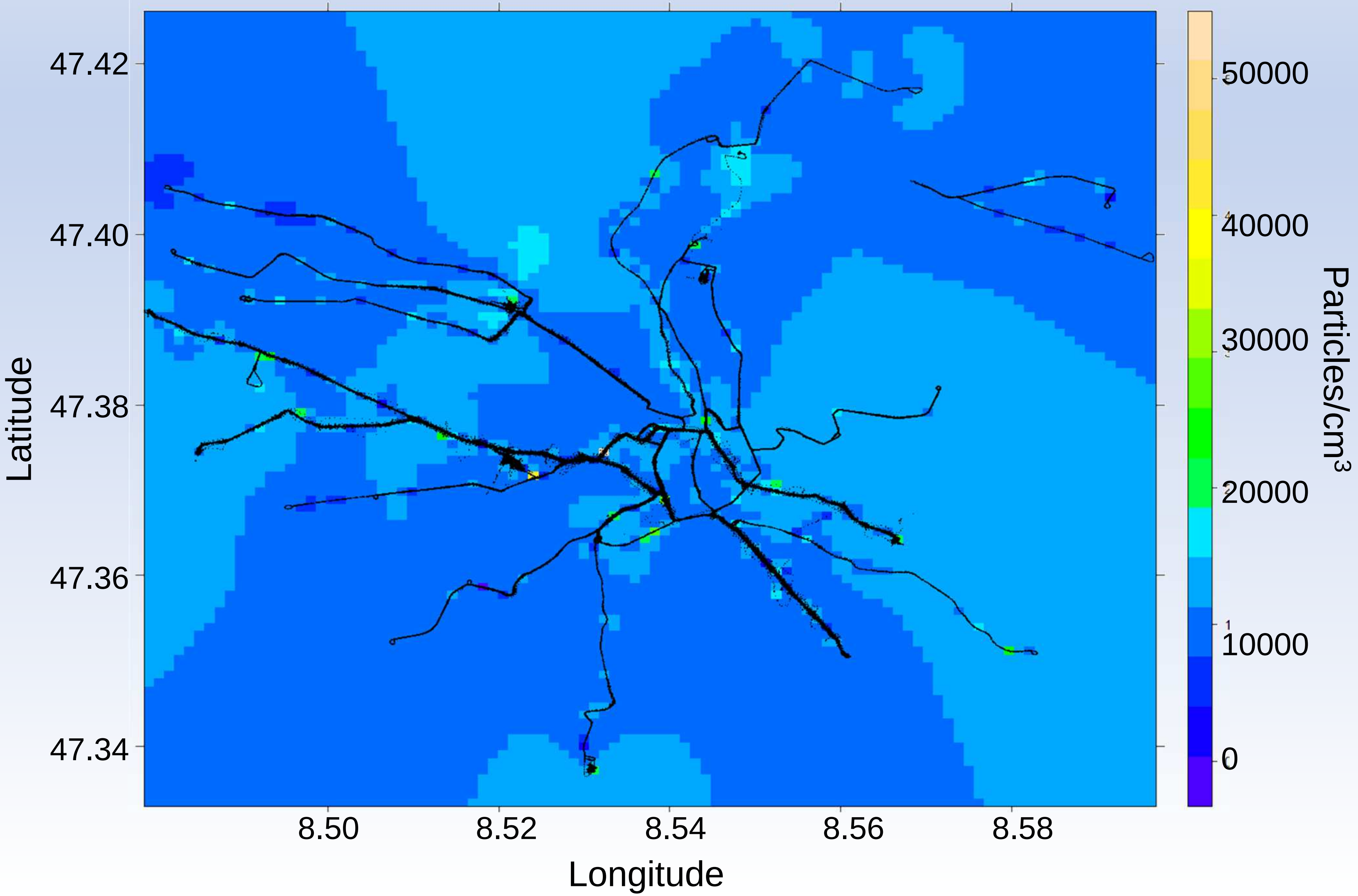
- Geo-statistical method to determine most probable value at each grid node based on statistical analysis of entire data set
- Assumes that unknown function is a realization of a Gaussian random spatial processes



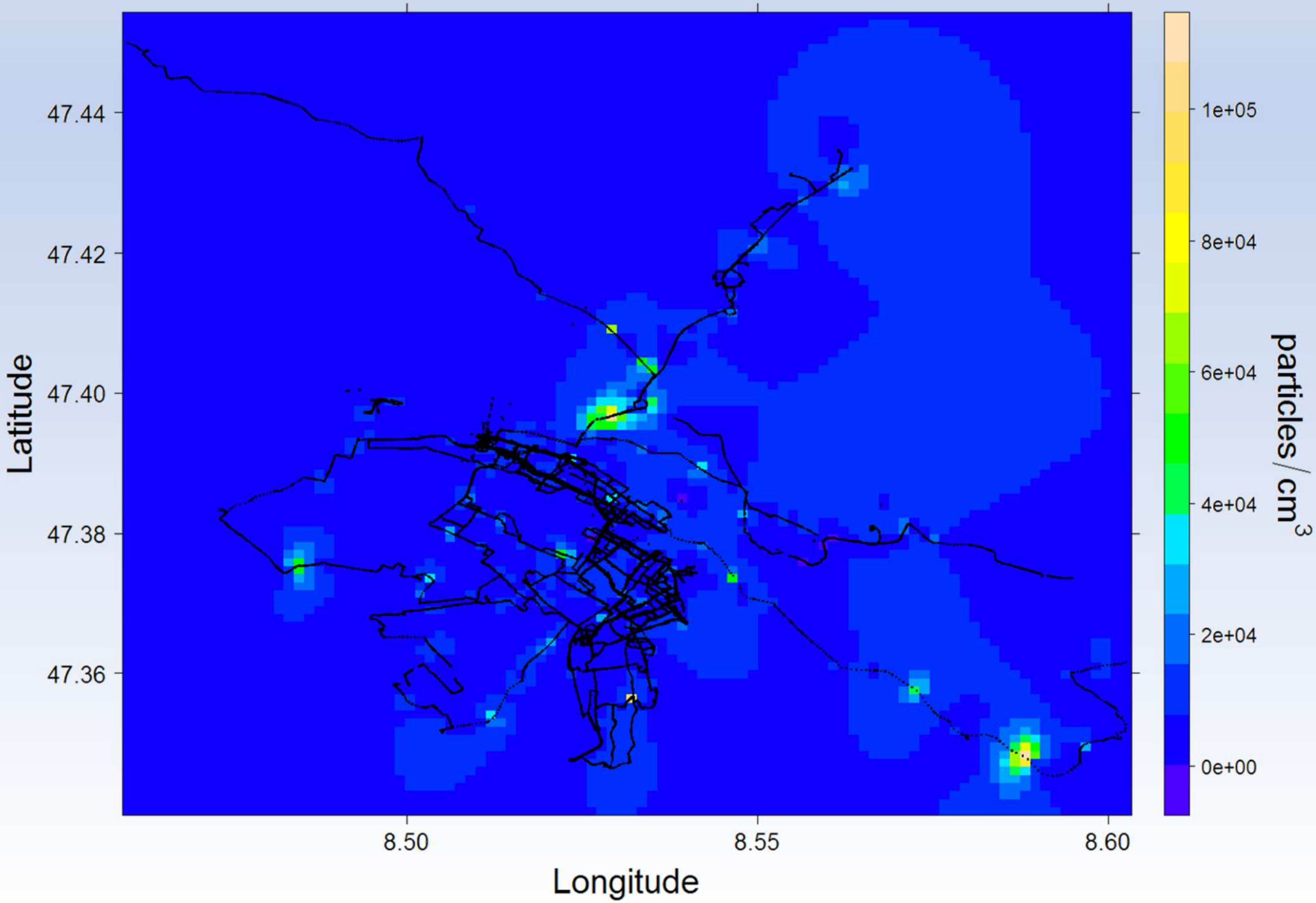
Challenges:

- Trams are not uniformly distributed in Zürich/Grid not evenly dense => quality of gridding / errors
- Geospatial information should be included
- Reduced data set (1min averages, median values for a grid with smaller density)

First Kriging results (trams)



First Kriging results (bicycle)



Conclusion & Outlook

- High variability in data
- Repetetive measurements are needed

- Land-use regression (include other variables such as traffic and population density, landuse: percentage of buildings, number of floors of buildings, type of heating used in buildings...)
- Order by:
  - hour of day
  - day of week
  - Seasons
  - meteo conditions, ...
- Use data for other calculations

Thank you very much for your attention!

Links:

LUNGE ZÜRICH

http://www.lungenliga-zh.ch/

Open SENSE

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

opensense.ethz.ch

data.opensense.ethz.ch

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