ICOS Talks Cities

City emission inventories – state of the art and challenges

Speakers: Ingrid Super (TNO), Olivier Perrussel (Airparif), Dominik Brunner (EMPA)

SCHEDULE

9.00-9.05 am
ICOS Cities Talk – short introduction

9.05-9.35 am
ICOS Cities Talk: City emission inventories

9.35-9.50 am
Q&A

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PRACTICAL INSTRUCTIONS

- The session will be recorded
- Keep your camera turned off during the presentations, if you do not wish to risk being included in the recording.
- Please keep your microphone muted while the speakers are presenting
- Type your questions in the chat
- Use the "raise hand" option for urgent/immediate questions/problems or during the discussion
- Turn your microphone and camera on to ask questions during the hands-on and QA sessions

UPCOMING TALKS – sign up now!

- *24 November 2021 at 9 am CET*
  Oslo's climate budget - a tool to achieve ambitious climate goals
  Speaker: Astrid Ståledotter Landstad, Climate Agency, City of Oslo

  8 December 2021 at 3 pm CET
  Seeing the tree for the forest: New ways to use eddy covariance to map landscape fluxes
  Speaker: Ankur Desai, University of Wisconsin-Madison

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UPCOMING TALKS – sign up now!

- *15 December 2021 at 9 am CET*
  Surveying attitudes towards climate change and energy preferences
  Speaker: Diana Zavala-Rojas and Rory Fitzgerald, ESS

  19 January 2022 at 9 am CET
  Productive online meetings
  Speaker: Jonas Rajanto, Grape People

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ICOS Talks Cities

City emission inventories – state of the art and challenges

Speaker: Ingrid Super (TNO)

CITY EMISSION INVENTORIES

STATE OF THE ART AND CHALLENGES

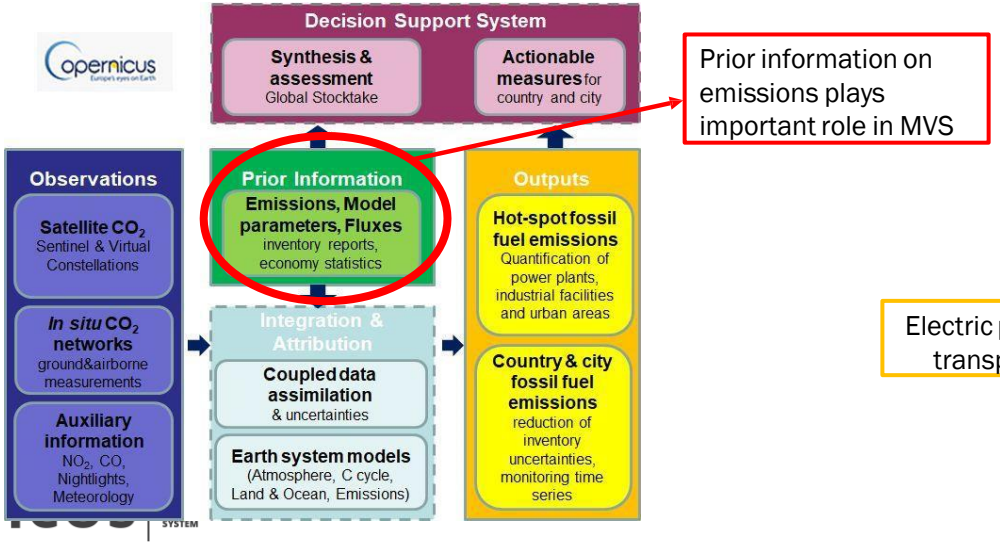
| *INGRID SUPER, OLIVIER PERRUSSEL, DOMINIK BRUNNER*

INTRODUCTION

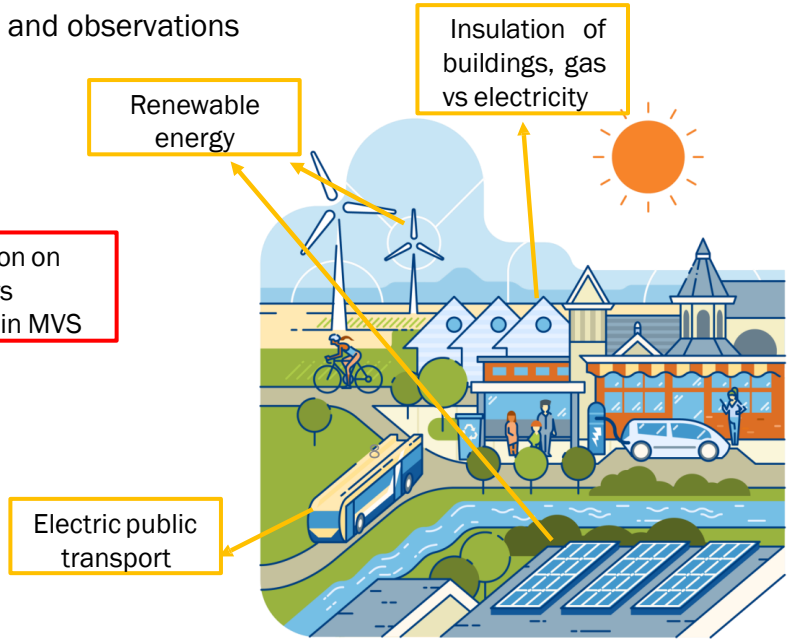
CITY EMISSION INVENTORIES EXPLAINED

A city emission inventory contains information on the emission landscape of an urban area: how much is being emitted, from which source sectors, where and when?

- Support independent verification of emissions through models and observations
- Provide information needed to set climate ambitions



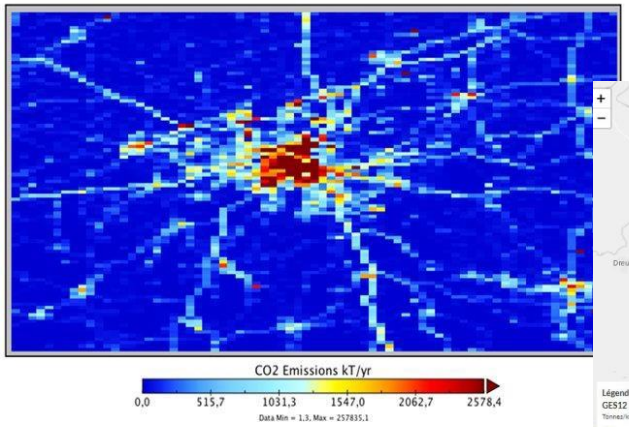
Prior information on emissions plays important role in MVS



INTRODUCTION

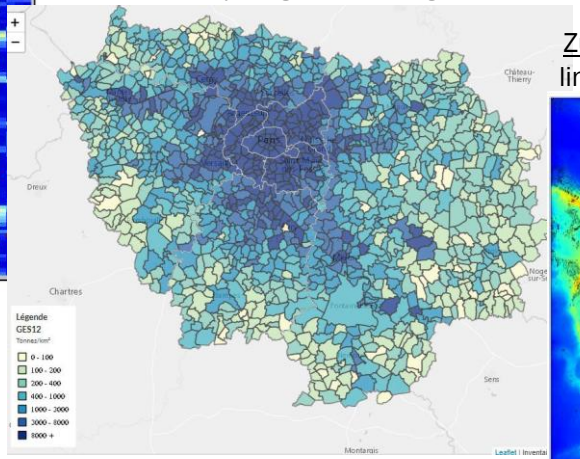
THIS PRESENTATION

Munich city-level data is available, but no spatially explicit city inventory yet



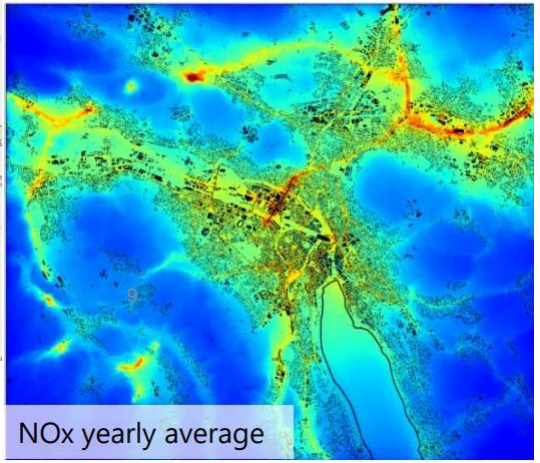
Dealing with uncertainties in emission inventories

Paris local data used for spatially explicit city inventory for greenhouse gases



Acquiring local data

Zurich city emission data is projected onto line, point and area sources (vector-based)



Temporal downscaling

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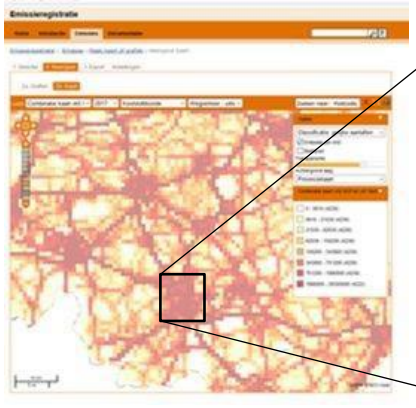
BUILDING A STATE-OF-THE-ART CITY INVENTORY FOR MUNICH

APPROACH 1: DOWNSCALING REGIONAL EMISSION DATA

Officially reported road transport emissions at 1x1 km²



Downscaled road transport emissions at 25x25 m²

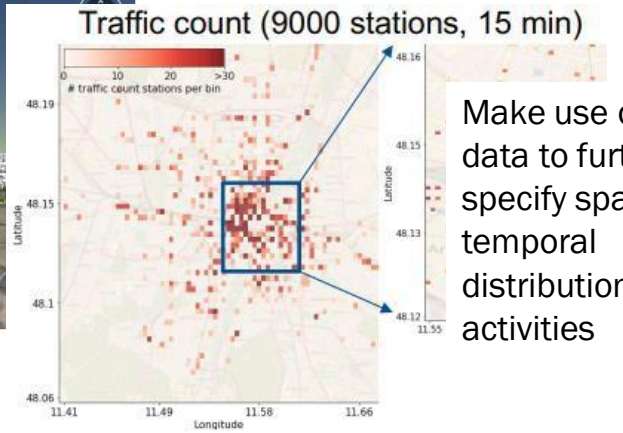
Make use of information on buildings to distribute residential heating emissions to 25x25 m² resolution

- Advantages
  - Serves as blueprint for other cities using whatever data is available
  - Consistent with national reported emissions and regional inventory outside city boundaries (easy nesting)
- Limitations
  - Quality could be improved if local data are used
  - Data are still gridded, no line/point sources

BUILDING A STATE-OF-THE-ART CITY INVENTORY FOR MUNICH

APPROACH 2: VECTOR-BASED DISTRIBUTION

3D city model: map emissions onto line, point and area sources



Make use of local data to further specify spatial and temporal distribution in activities

- Advantages
  - Makes use of local knowledge
  - Higher level of detail and improved quality
  - Aggregate to e.g. 100x100 m^2 resolution
- Limitations
  - Data may not be available for all source sectors
  - More difficult to assess uncertainties
  - No consistency with country-level emissions

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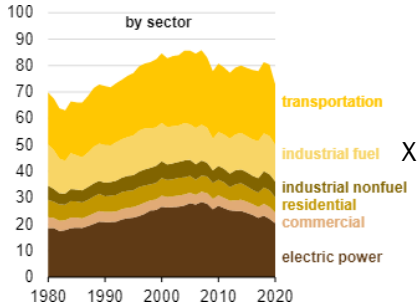
DEALING WITH UNCERTAINTIES

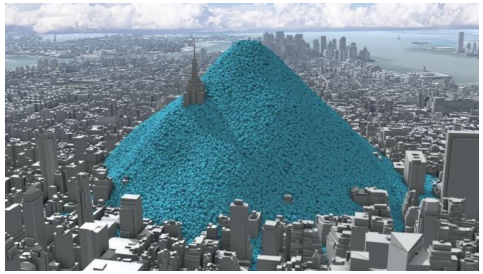
SOURCES OF UNCERTAINTY

Input data, e.g. fuel statistics



X emission factor →

Total emissions for city



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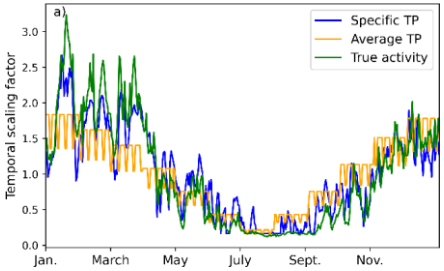
Temporal downscaling



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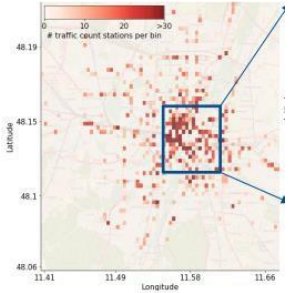
Spatial downscaling



- Uncertainties matter, because:
  - A good estimate of prior uncertainties is needed for MVS
  - They help to estimate the range of possible outcomes from climate actions

- For downscaling often proxies are used:
  - How is relationship between proxies and activity?
  - How accurate is the proxy value?

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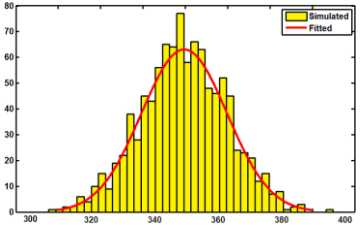
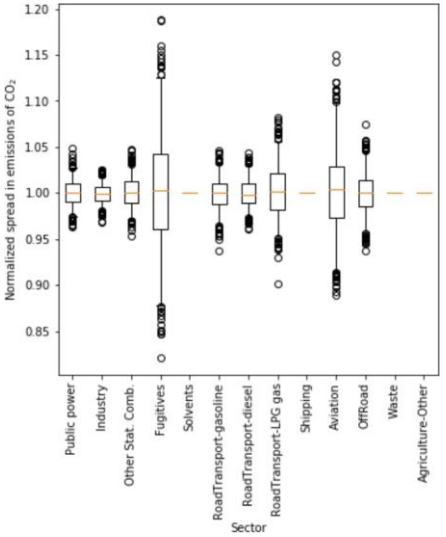
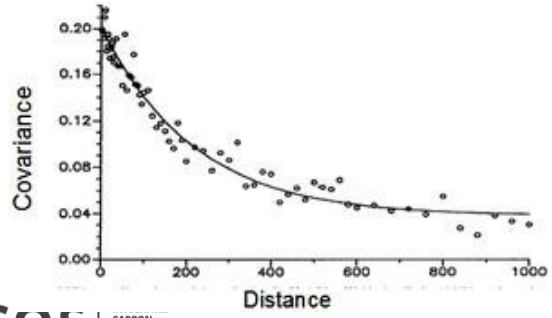
DEALING WITH UNCERTAINTIES

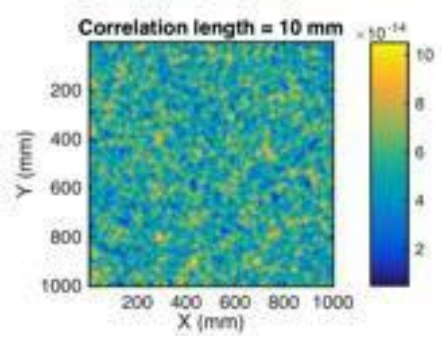
QUANTIFYING UNCERTAINTIES

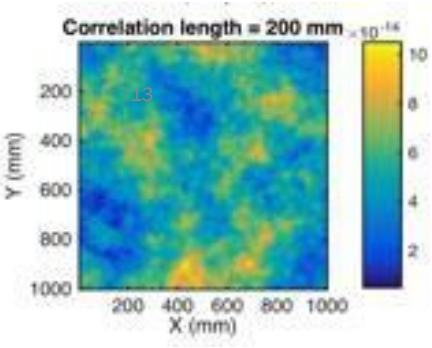




- Monte Carlo simulation:
  - Advantage: Robust method
  - Requires knowledge on uncertainty distribution input data
  - Good approach to estimate city-scale uncertainties
- How to deal with spatial and temporal correlations in data and uncertainties?
  - Error correlation decreases with distance/time
  - Important for MVS studies: pixels contain information on neighbouring pixels







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THANK YOU FOR
YOUR TIME

CONTACT: INGRID.SUPER@TNO.NL

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ICOS Talks Cities

City emission inventories – state of the art and challenges

Speaker: Olivier Perrussel (Airparif)

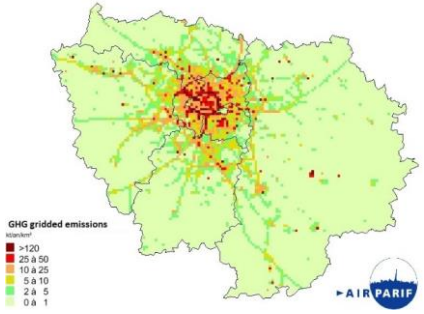
AIRPARIF

L'Observatoire de l'air en Île-de-France

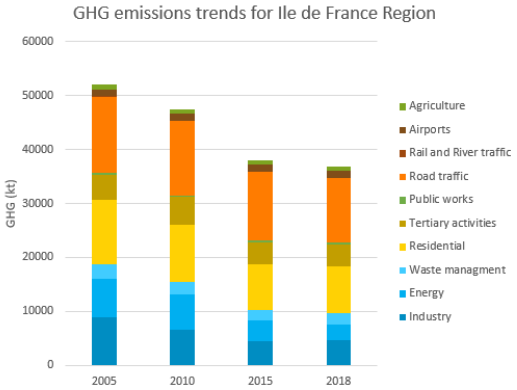
Cities Emissions Inventories
State of the art and challenges
Case of Paris

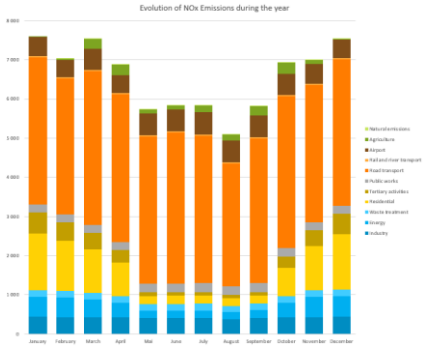
Airparif's EI : 15 years of work !

High resolution GHG and AQ pollutants EI for Ile-de-France Region



1 km²
resolution
1300 cities
40 pollutants





Use of temporal profiles

Bottom up approach with lots of local data !

More infos : https://www.airparif.asso.fr/en/monitor-pollution/emissions

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Use of local energy consumption data (1/2)

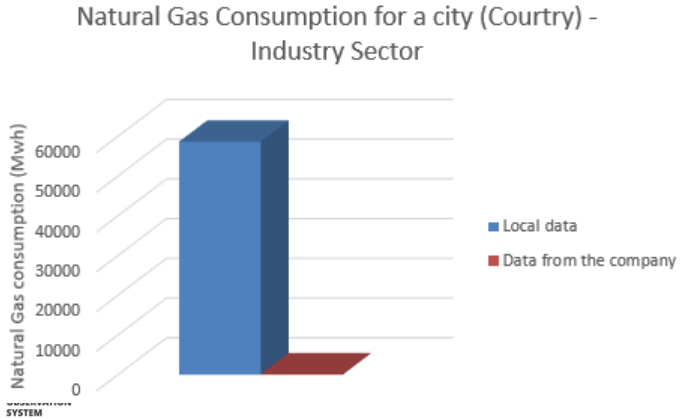
Energy consumption data provided by **energy suppliers**

Spatial resolution	Activities included	Energy sources
City scale (each of the 20 arrondissements for Paris)	Residential, Industry, Agriculture, Tertiary Activities	Natural Gas, Electricity, Urban heat

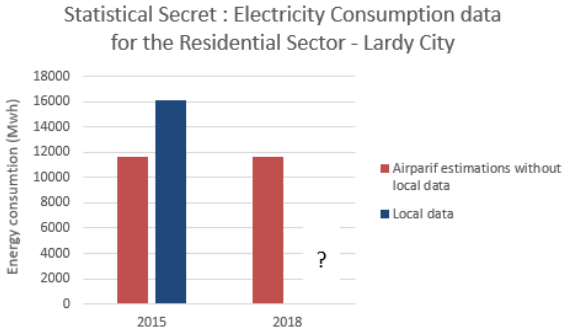
Available from 2011 (2012 Natural Gas) until N-2

A very interesting source of local data with some challenges to overcome :

Incompatibility with other data sources



Dealing with statistical secret



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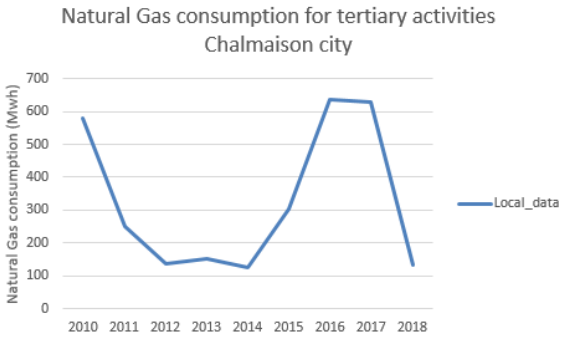
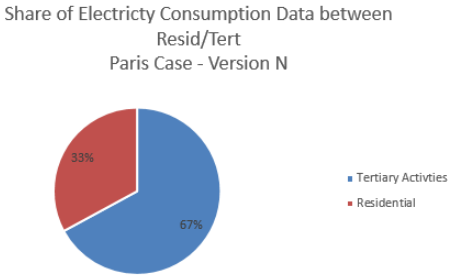
Use of local energy consumption data (2/2)

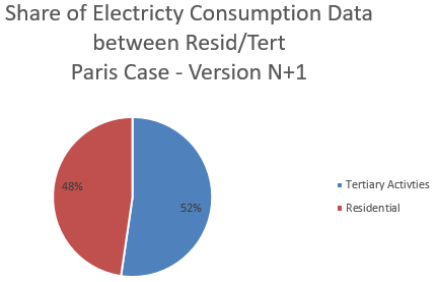
Challenges for validating historical data



Is it valid or not ?
What kind of validation elements can we have ?

Change in sector scope from one version of data to the next





Small office space at the bottom of a residential building was counted « tertiary activities » in the N version

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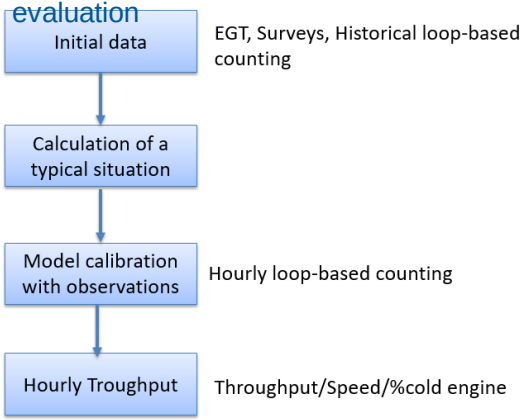
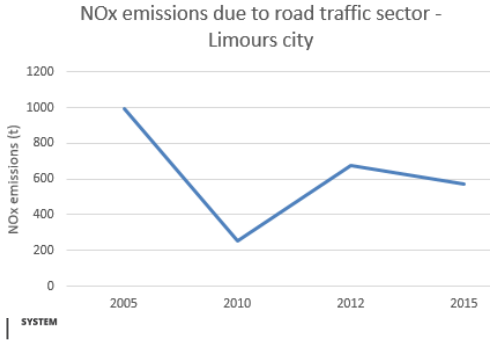
Use of local data for the road traffic sector

Challenges regarding the consistance of historical road traffic emissions

Process of road traffic emissions evaluation





Avaibility of traffic loops near the study area

	2005	2010	2012	2015
MIR91H	Bad	Good	Good	Good
MIR91A	Medium	Good	Good	Good
MIR91E	Medium	Bad	Good	Good
MIR78I	Medium	Good	Good	Bad

Lack of constistance for road traffic emissions due to perturbations concerning the traffic loops avaibility

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Use of local data for the tertiary activities

The tertiary sector includes many different activities
The number of employees or students (for the education sector) are used for the spatialization of emissions from this sector.

Sub Sector	Database for nbr of employees /sudents	Comments
Community housing	SIRENE (INSEE) : a very complete BDD (for the present) but very expensive and with no past data. CLAP : recently stopped ASTREE : same as CLAP, recently stopped UNISTATIS : uncomplete database	ACOSS, a new database related to employees seems to be a relevant source combining completeness and coherent historical data.
Health and Social		
Offices		
Shops		
Bars, hotels and restaurants		
Transport establishments		
Sports and leisure facilities		
Education	Opensource for education ministry : incomplete For each department : Academic Rectorate Academic inspection	

Challenges :

- Difficulties in achieving comprehensiveness (namely for the education sector)
- Compilation of number of employees depends a lot on database
- Having a coherent evolution of employees for each city is a big challenge

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ICOS Talks Cities

City emission inventories – state of the art and challenges

Speakers: Dominik Brunner (EMPA)

The emission inventory of the city of Zurich

Dominik Brunner

Laboratory for Air Pollution and Environmental Technology

Empa, Swiss Federal Laboratories for Materials Science and Technology

Empa Materials Science and Technology

Stadt Zürich Umwelt- und Gesundheitsschutz

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- Public vote in 2008 to reduce energy consumption per citizen to 2000 Watts and 1 t CO_2 yr^{-1} by 2050
- Net zero by 2040 for direct emissions (in city)
- -30% by 2040 for indirect emissions (outside city)
- Net zero by 2035 for city administration

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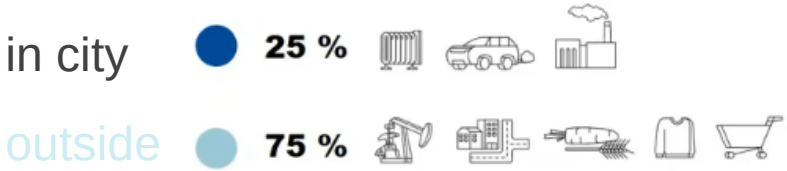
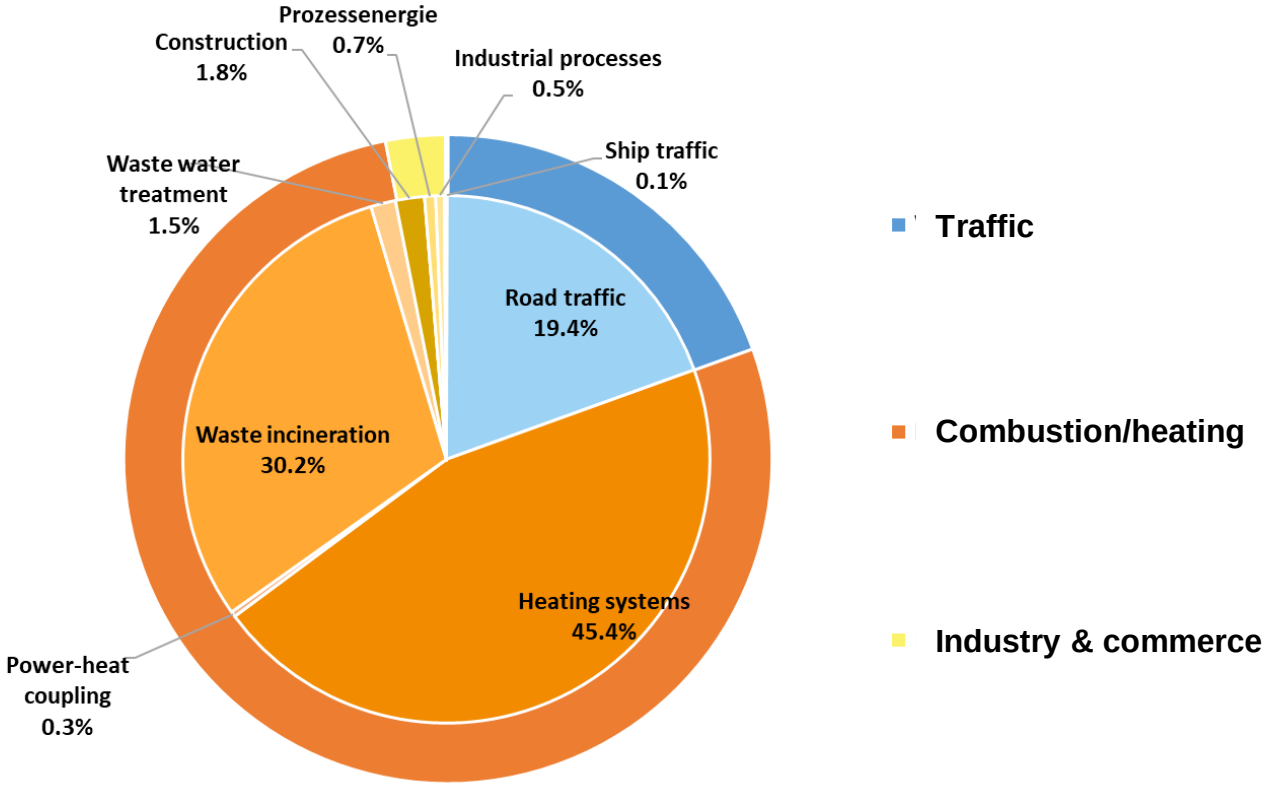
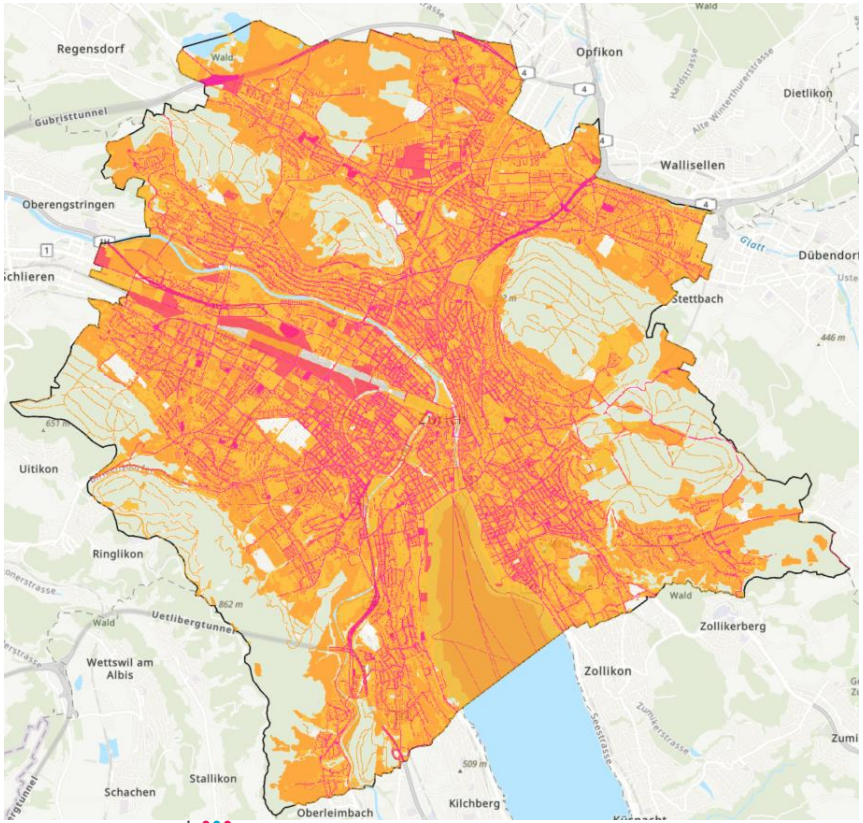
Action plan with 57 actions

- Buildings
- Energy supply
- Mobility
- Spatial planning
- Consumption




Prozessenergie
0.7%
Construction
1.8%
Industrial processes
0.5%
Ship traffic
0.1%
Waste water
treatment
1.5%
Road traffic
19.4%
Waste incineration
30.2%
Heating systems
45.4%
Power-heat
coupling
0.3%
Traffic
Combustion/heating
Industry & commerce



- Every 5 years: 2010, 2015, 2020
  Possibly every 2 years in future
- Only direct emissions within city boundary (Scope 1)
- Important policy tool for air quality and greenhouse gas management
- Spatial resolution (at least 10m x 10m)

CO2 Gesamtemissionen [kg/a]

- 0
- 0 - 1
- 1 - 50
- 50 - 100
- 100 - 500
- 500 - 1'000
- 1'000 - 10'000
- 10'000 - 100'000
- 100'000 - 500'000
- 500'000 - 5'000'000
- 5'000'000 - 280'000'000

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- **9 air pollutants**: PM_{10}, $PM_{2.5}$, NO_x, CO, SO_2 NH_3, VOCs, soot, benzene
- **3 greenhouse gases**: CO_2, CH_4, N_2O

65 detailed source categories as line, point or area sources

		Wichtigste Datengrundlage	Bottom-up	Top-down
Verkehr	Schiffsverkehr	EF BAFU, eigene Aktivitätsdaten (Fahrplan)	✓	
	Schienenverkehr	EF, eigene Aktivitätsdaten (Fahrplan)	✓	
	Strassenverkehr	EF BAFU, eigene Aktivitätsdaten	✓	
Feuerungen	Öl-/Gas-/Holzheizungen, BHKW	EF BAFU, eigene Aktivitätsdaten (FETA)	✓	
	Kehrichtheizkraftwerke	gemessene Emissionsfrachten	✓	
Industrie & Gewerbe	Baustellen	EF BAFU, eigene Aktivitätsdaten	✓	✓
	Notstromanlagen	EF BAFU, eigene Aktivitätsdaten (FETA)	✓	
	Prozessenergie	EF BAFU, eigene Aktivitätsdaten	✓	
	industrielle und gewerbliche Prozesse	unterschiedlich	✓	
	Lösemittel	Umlegung CH-Daten		✓
Land- & Forstwirtschaft	Forstwirtschaftliche Fahrzeuge	EF BAFU, eigene Aktivitätsdaten (GSZ)	✓	
	Landwirtschaftliche Fahrzeuge	Umlegung BAFU-Jahresfrachten		✓
	Nutzflächen	Umlegung BAFU-Jahresfrachten		✓
	Nutztierhaltung	EF BAFU, eigene Aktivitätsdaten (GSZ)	✓	
Haushalt	Reinigungsmittel, Lösemittel, Spraydosen	Umlegung BAFU-Jahresfrachten		✓
	Kleingärten (Grünabfall, Holzöfen)	EF Nussbaumer, eigene Aktivitätsdaten	✓	
	Abfallverbrennung in Hausfeuerungen	EF BAFU, eigene Aktivitätsdaten	✓	
	Haustiere, Zoo- und Zirkustiere	Umlegung BAFU-Jahresfrachten		✓
	Feuerwerke	Umlegung BAFU-Jahresfrachten		✓
	Brand Feuerschäden	EF BAFU, eigene Aktivitätsdaten	✓	
Natürliche Emissionen	Biogene Emissionen	EF BAFU, eigene Aktivitätsdaten	✓	

Traffic

Heating

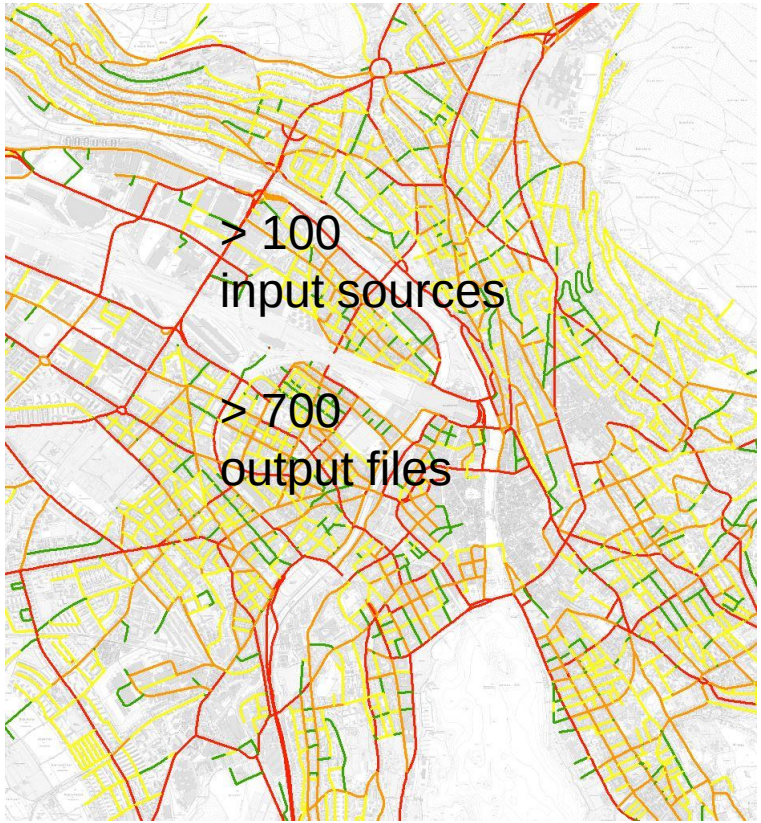
Industry & commerce

Agriculture & Forestry

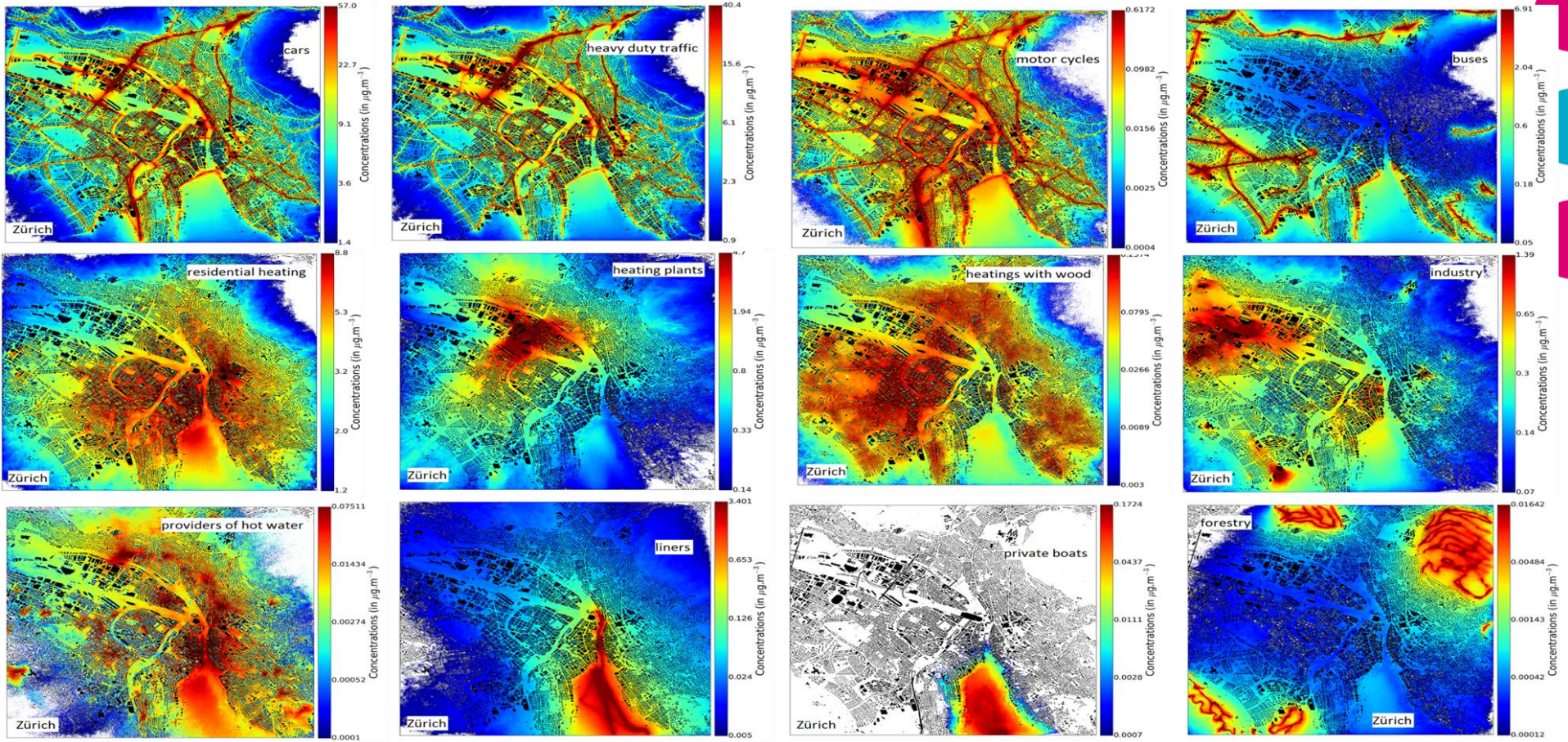
Natural emissions

Household, hobby, garden

car traffic



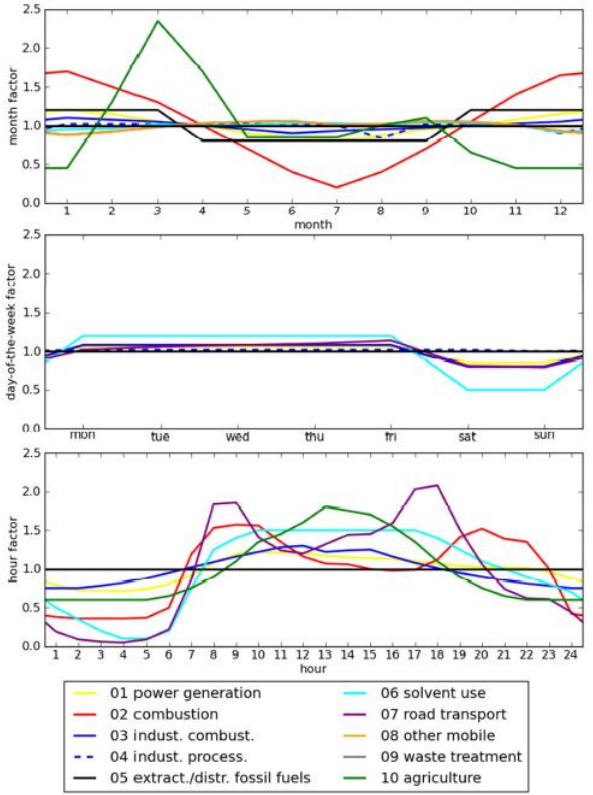
sum of line + point sources gas heating

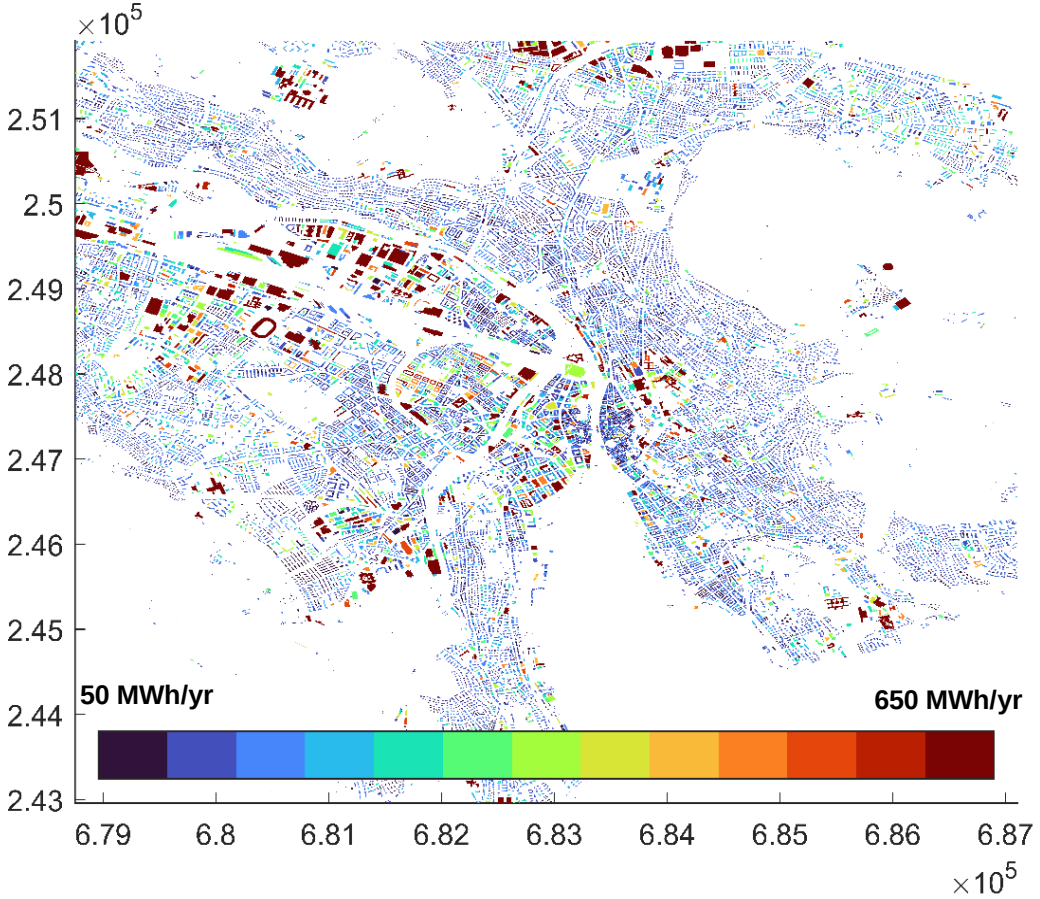


Berchet et al. 2017

- Temporal disaggreation needed because observations are sensitive to emissions at a given hour
- Examples of temporal variability
  - Traffic morning and evening peaks Reduced on weekends
  - Heating demand affected by weather
  - Industrial emissions affected by holidays

Standard temporal profiles (TNO Report 2011)

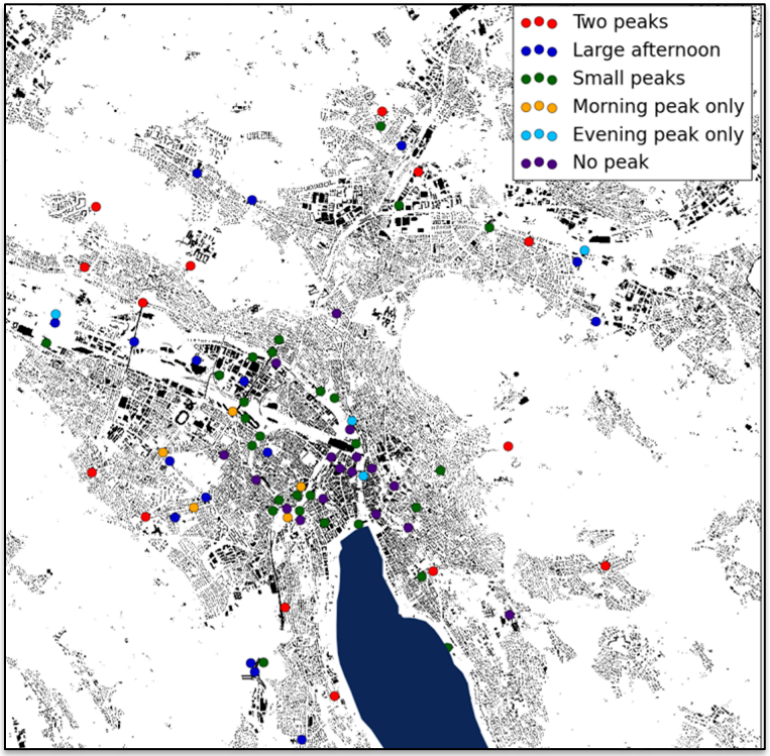




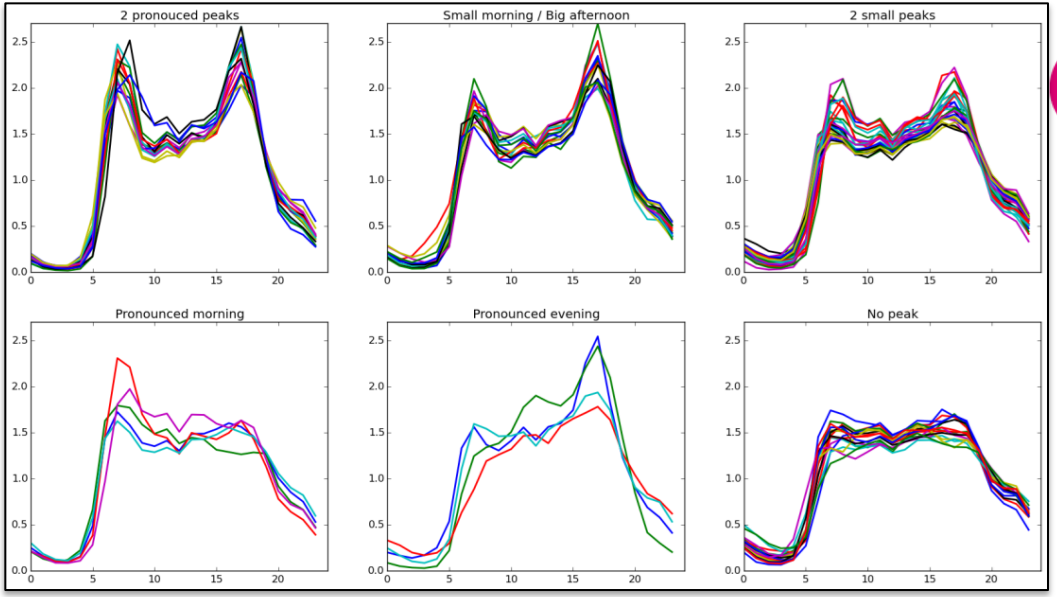
- EnergyPlus model of US DoE
- Detailed data for each building (age, material)
- Hourly simulation per building considering actual temperature, radiation and wind conditions
- Will consider CO_2 emissions from heating systems and from human respiration

Fazel Khayatian & Kristina Orehounig
Urban Energy Systems, Empa

~90 traffic counters in Zurich

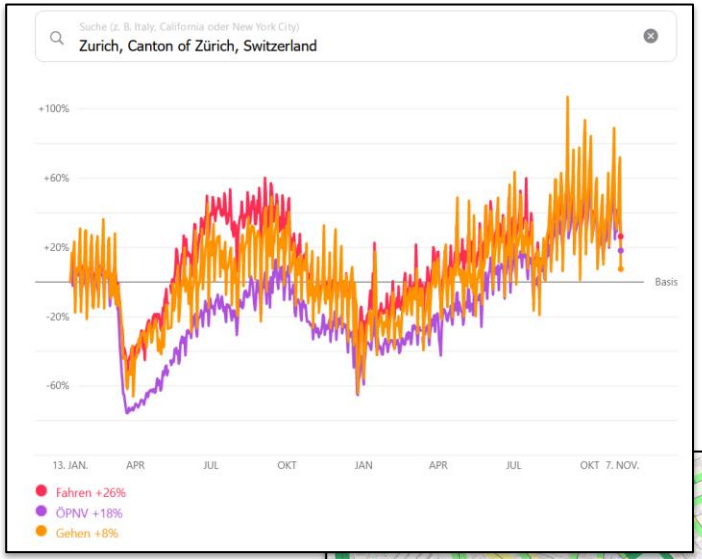


Cluster analysis of diurnal behavior



Analysis by Antoine Berchet (unpublished)

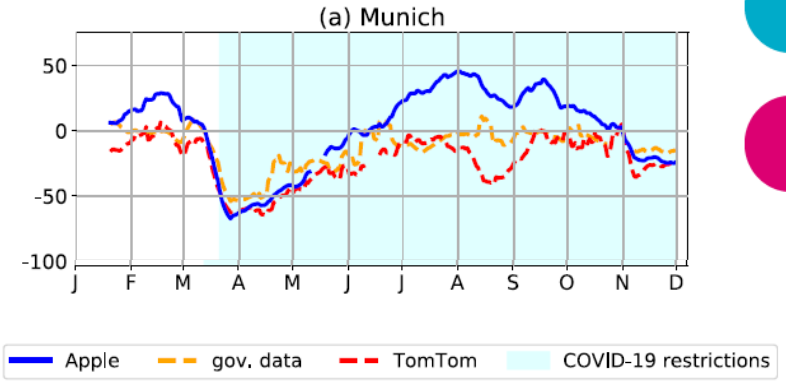
ICOS INTEGRATED CARBON OBSERVATION SYSTEM

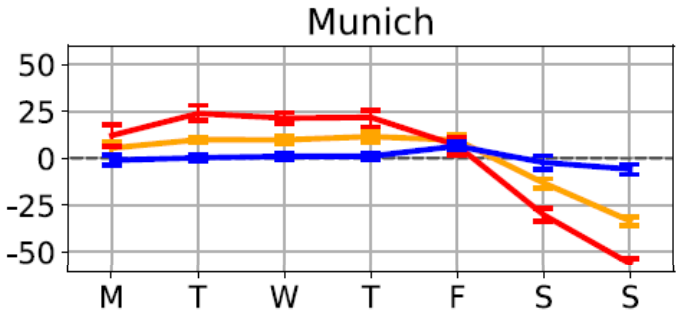


Apple Covid-19 Mobility

TomTom Road Analytics

Quality of mobility data not yet well understood





Gensheimer et al. (2021)

- Extremely detailed inventory for Zurich with line, point and area sources for 9 air pollutants & 3 greenhouse gases for 65 categories
- Inventory is produced by city itself, which has access to detailed statistical data (traffic, heating systems, industrial activities, etc.)
- Spatially explicit inventory is an important planning tool
- Inventory has been used as input for dispersion models
- Uncertainties of inventory not well known
- Spatial and temporal disaggregation is key for atmospheric modelling
- Temporal disaggregation is not available but has to be generated separately, ideally from measured activitiy data

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