17th ETH-Conference on Combustion Generated Nanoparticles

23rd – 26th June, 2013

Modeling of short-term Ultrafine Particle Number Concentrations in a Swiss City

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EXTENDED SUMMARY

Traffic noise and air pollution exposure models are usually built on similar traffic-related and land use predictors, which may lead to misinterpretation of air pollution and noise effects on cardiovascular health. As spatial distribution of road traffic noise and air pollution differs significantly across different urban areas, city-specific analyses are required to disentangle these effects. This is the aim of the project TRITABS (Projet Tri-national Trafic, Air, Bruit et Santé), which looks at traffic air pollution, noise and cardiovascular health in three European cities: Basel (CH), Girona (ES) and Grenoble (FR).

The focus of this paper is on the spatial distribution and modeling of ultrafine particles in the urban area of Basel.

20-minutes measurements of particle number concentration (PN) and traffic volume were collected at 60 locations across the city of Basel during non-rush hour (9:30-16:00h) and repeated in three seasons (spring, summer and winter) in 2011. PN was collected using a portable particle counter, miniDiSC (miniature diffusion size classifier, Matter Aerosol, CH), which measures ultrafine particles in a 10-300 nm range. For each monitoring location detailed spatial characteristics were recorded and potential predictor variables were derived using geographic information systems (GIS). During the whole study period PN was measured continuously at a fixed federal monitoring station (NABEL, Basel/Binningen) with a condensation particle counter (CPC 3775). Multivariate linear regression models were built for predicting PN concentrations in Basel using the NABEL measurements and different combinations of spatial characteristic, GIS, meteorological and time variables.

Average PN levels by season and site type are listed in Table 1. In general, 20-min median levels were lower than mean levels, with the highest concentrations in winter and the lowest in summer. Average PN levels at street sites were higher compared to urban, regional and NABEL sites.

Table 1: Summary statistics for median and mean of 20-min measurements by season and by site type

	20-min Median PN (#/cm^3)					20-min Mean PN (#/cm^3)				
	N	Mean (NABEL)	StdDev	Min	Max	N	Mean (NABEL)	StdDev	Min	Max
Season										
Spring	57	13'600 (13'100)	6'100	4'900	32'200	57	15'800 (13'300)	7'500	5'200	36'800
Summer	59	8'800 (8'200)	4'400	3'600	24'100	59	11'500 (8'400)	7'300	3'900	41'500
Winter	59	17'000 (13'200)	12'600	1'100	53'100	59	20'000 (13'500)	13'900	1'600	57'500
Site type										
Street	122	14'700 (12'000)	9'100	1'600	53'100	122	17'800 (12'300)	10'500	1'700	57'500
Urban	45	9'900 (10'100)	8'600	1'100	50'500	45	11'300 (10'200)	10'000	1'600	50'500
Regional	8	9'000 (11'400)	5'300	2'200	17'800	8	9'800 (11'600)	5'700	2'400	18'000

Table 2: Performance of the different models for median and mean PN concentrations

	Median PN				Mean PN			
Model	**Model R^2**	**Adj. Model R^2**	**RMSE**	**Mean Bias**	**Model R^2**	**Adj. Model R^2**	**RMSE**	**Mean Bias**
GIS, season	0.58	0.56	6400	-1100	0.48	0.47	8200	-1700
GIS, meteo, season	0.60	0.58	6200	-1100	0.49	0.48	8100	-1700
GIS, meteo, time, season	0.63	**0.61**	5900	-1000	0.57	**0.55**	7600	-1300
Characteristics, season	0.63	0.61	6200	-1000	0.59	0.57	7700	-1200
Characteristics, meteo, season	0.64	0.62	5900	-1000	0.60	0.58	7700	-1200
Characteristics, meteo, time, season	0.65	**0.63**	5300	-900	0.65	**0.62**	7000	-1000
All variables	0.68	**0.66**	5300	-900	0.67	**0.65**	6600	-900

RMSE: root mean squared error
Model R^2s for log transformed PN; RMSE and bias back transformed to PN

Model performance for predicting median and mean PN concentrations are listed in Table 2. Models for median PN generally performed better than models for mean PN concentrations. For median PN, model performance using only GIS or only characteristic variables was almost the same. In contrary, for mean PN predictions using only site characteristic variables improved the model performance compared to models using only GIS variables. The most important predictor for all models was the background (NABEL) PN concentration explaining 50% in the median and

38% in the mean models. For the GIS models “Distance to main road” explained an additional 5% and 8% in the median and mean models, respectively. For the characteristics models additional common contributions differed between median and mean models with “site / neighborhood type” (6%) and “Total traffic flow” (9%), respectively.

We could show that short-term PN levels in Basel could be moderately predicted with models using GIS-derived traffic and land-use variables and/or spatial characteristic variables. The representativeness of these short-term predictions for longer-term (hourly, daily) PN exposures will be additionally examined.

Swiss TPH

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Epidemiology and Public Health
Environmental Exposures and Health

ETH Conference on Combustion Generated Nanoparticles, June 23-26, 2013

Modeling of Short-Term Ultrafine Particle Number Concentrations in a Swiss City

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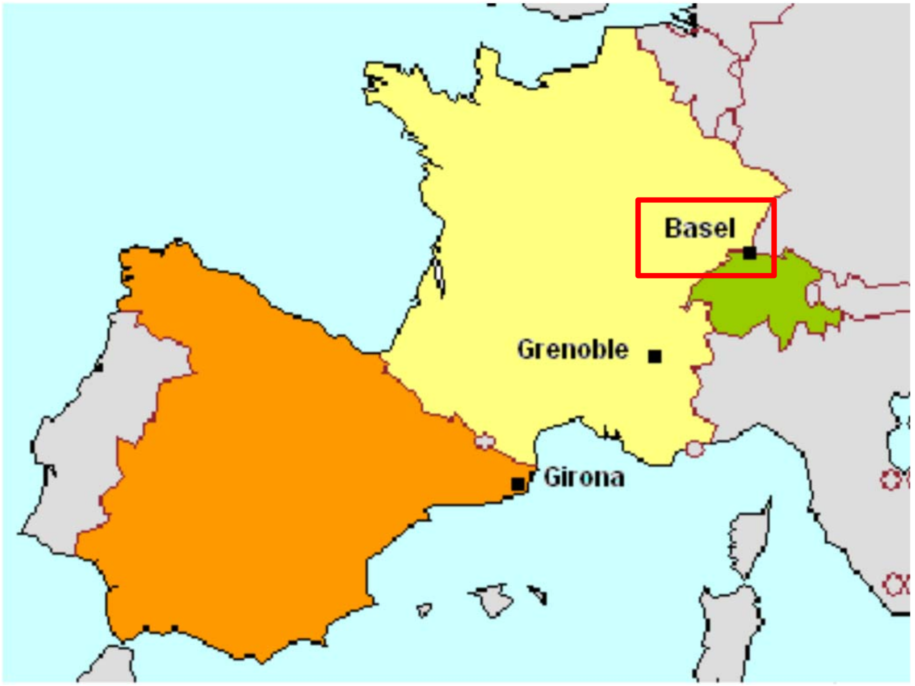
TRITABS - Projet Tri-national de Trafique, Air, Bruit et Santé

1. Description, comparison, and spatial characteristics of traffic related air pollution and noise in Basel, Grenoble and Girona

- **Measurements:** ultrafine particles (UFP), traffic flow and noise
- **Models:** UFP, noise

2. Investigate the association between ambient noise levels and blood pressure in Basel and Girona (controlling for traffic related air pollution)



Measuring Sites in Basel

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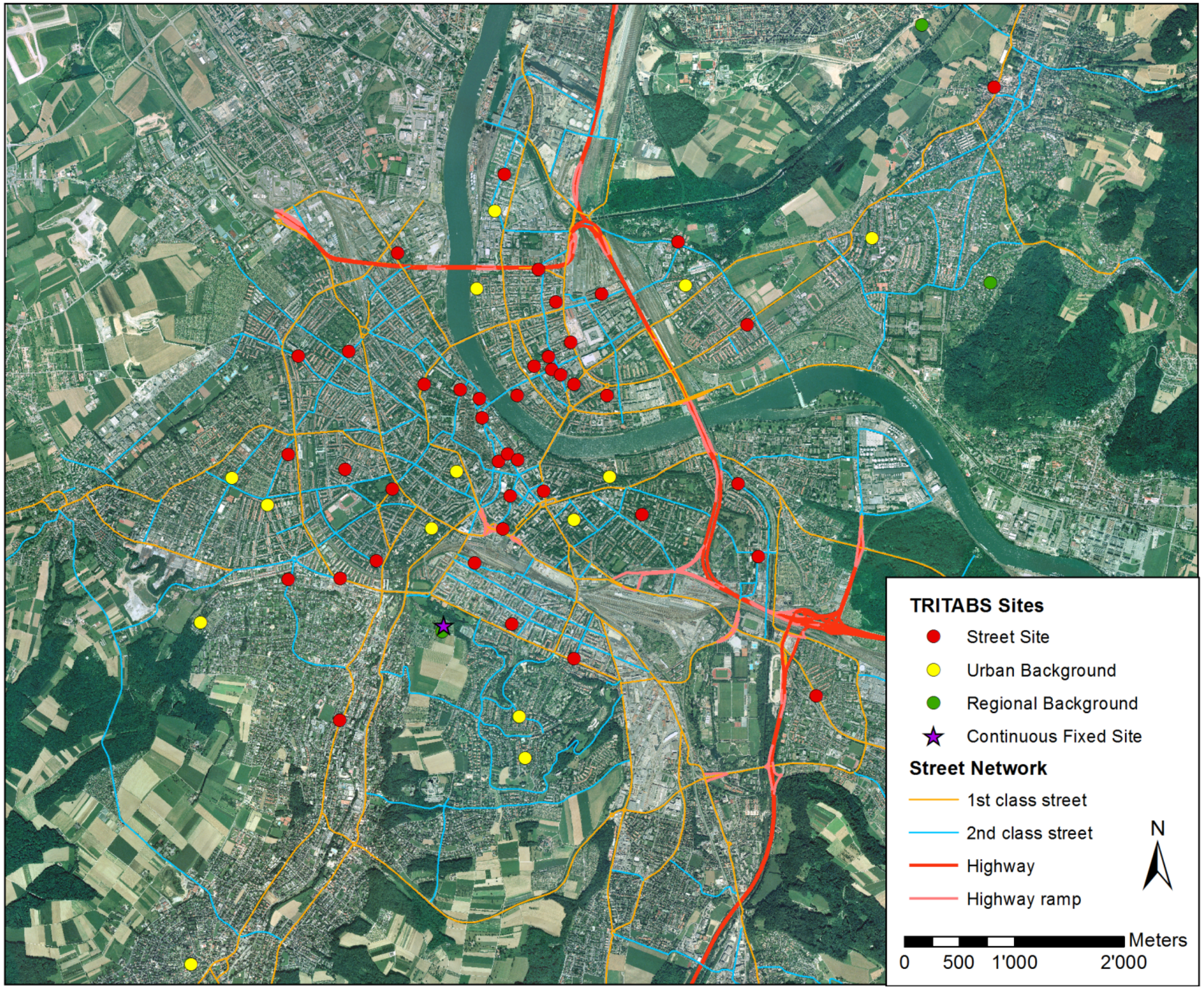
60 measuring sites

(Including 20 SAPALDIA sites with concurrent UFP measurements)

1 continuous background site (NABEL)



UFP Measurements in Basel

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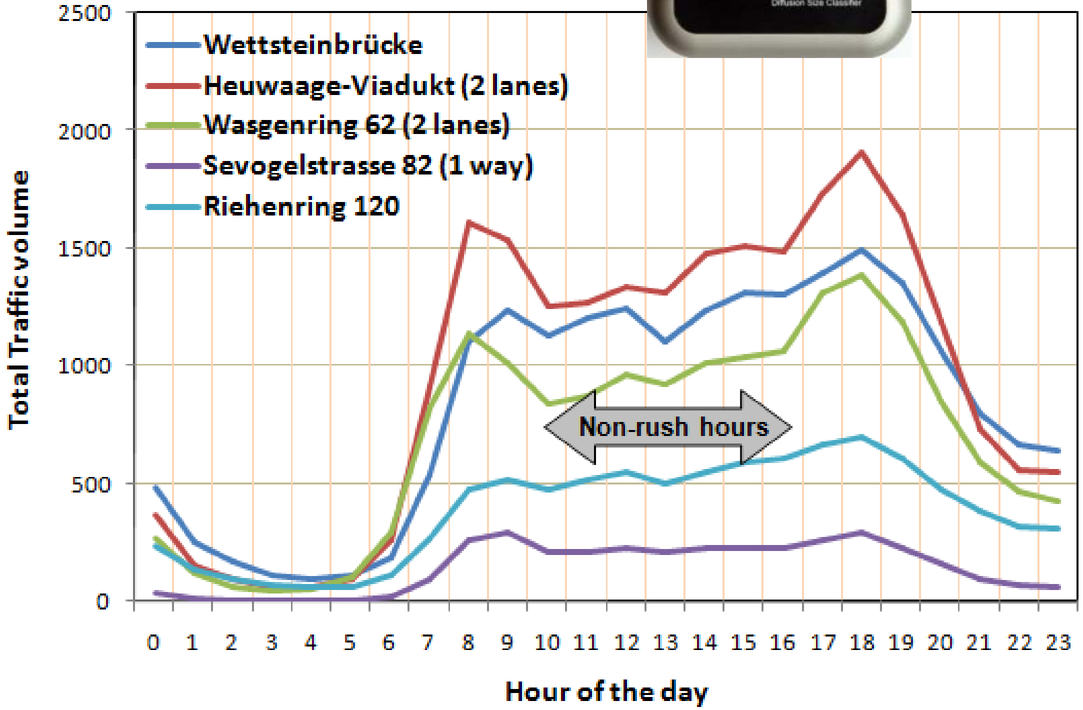
- **Measurement device:** miniDisc (Matter Aerosol, CH)
  1-sec data on particle number, size & surface area
  (size range 10-300nm)

- One **20-min measurement** per season in 2011
  (spring: Mar/Apr, summer: June, winter: Nov/Dec)
  total: 175 valid measurements

- Measurements taken during **working day non-rush hours** (between 9:30 and 16:30)



Measuring Sites in Basel

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Samples of site characteristics

Site characteristics	
Both sides of the street have buildings	88%
Neighborhood type: multi family houses & densely built area with homes, stores and offices	82%
Median street width	8m (range 4-27m)
Traffic in both directions	73%
Parking lane in the street	42%
Sites with bus lines	33%
Sites with tram lines	42%
…	…

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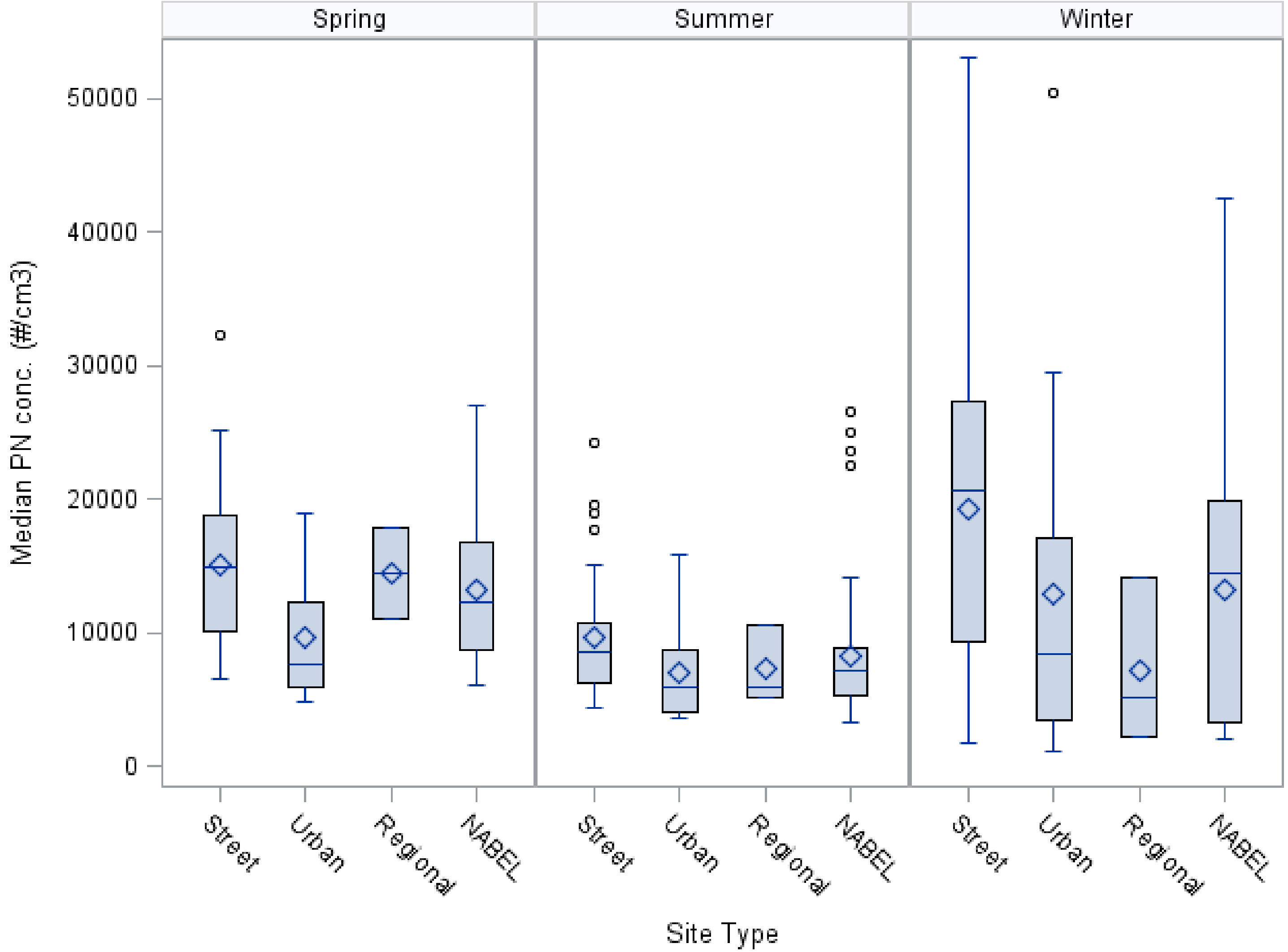
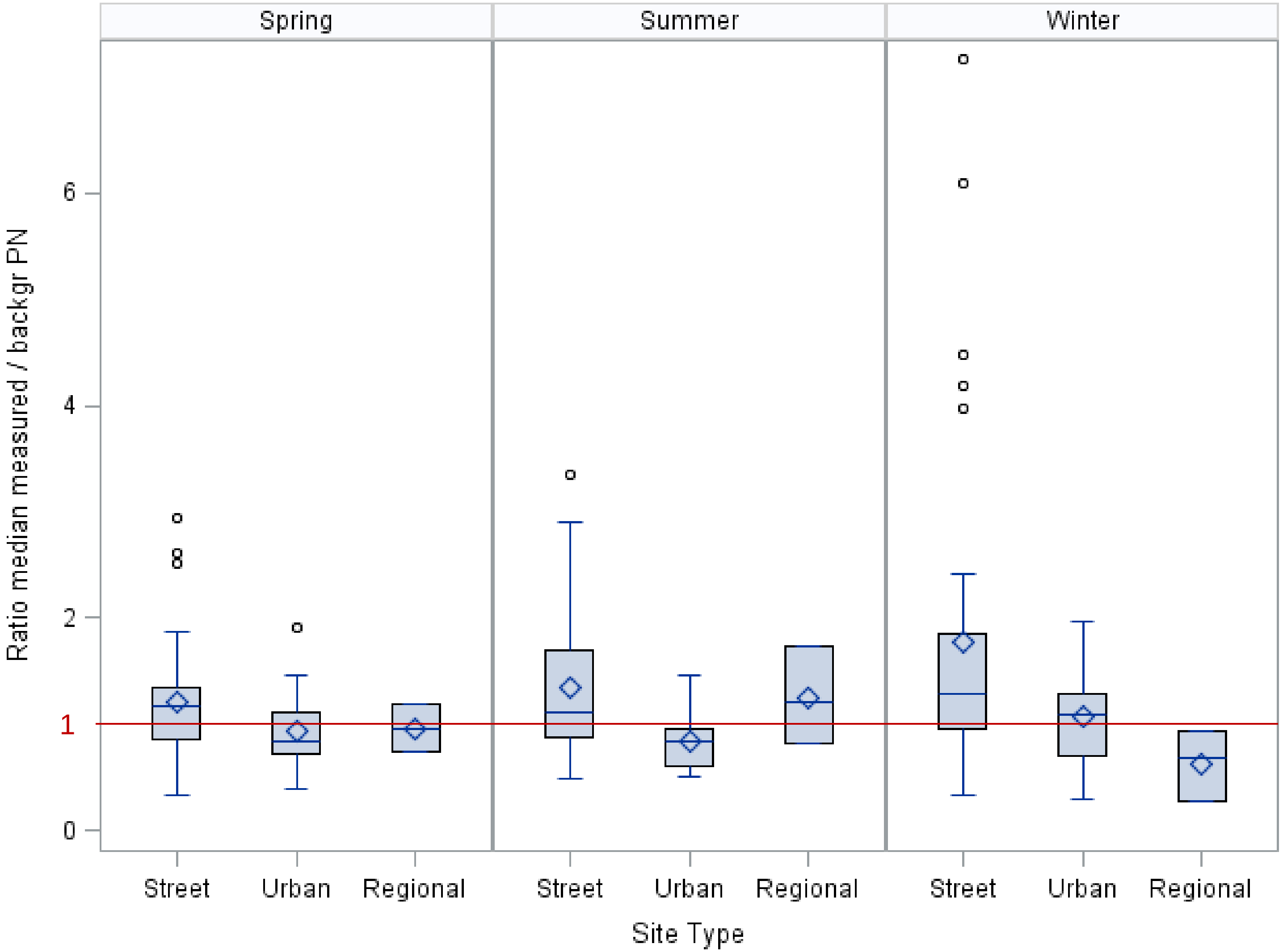
Measured 20-min median particle number (PN) concentration



Ratio of measured / background (NABEL) median PN



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Modeling approach:

- Multivariate linear regression
- Supervised stepwise forward selection (0.01 increase in R^2, direction of effect physically predefined, $p<0.05$)
- Used **log transformed** measured PN (measuring sites and NABEL)
- Models for median PN and mean PN
- Leave one site out cross validation

Different models (incl. NABEL measurements & season in all models)**:**

- **Only GIS variables:**
  (1) GIS, (2) GIS & meteo, (3) GIS, meteo & time
- **Only Characteristic variables:**
  (1) Char, (2) Char & meteo, (3) Char, meteo & time
- **GIS & Characteristic variables**

Models for median PN

Model	Variables	Model R^2	Adj. Model R^2	RMSE	Mean Bias
GIS, season	**log_median_NABEL_PN, Distance to main road**, GIS_FIELDS4000m, Season	0.58	0.56	6400	-1100
GIS, meteo, season	**log_median_NABEL_PN, Distance to main road**, Temperature, Wind speed, Population density_200m	0.60	0.58	6200	-1100
GIS, meteo, time, season	**log_median_NABEL_PN, Distance to main road**, sin_hour, cos_hour, GIS_FIELDS4000m, Temperature	0.63	**0.61**	5900	-1000
Characteristics, season	**log_median_NABEL_PN**, Stop signs, Car flow, Lowest hight of buildings, Inclination, Traffic direction, Season	0.63	0.61	6200	-1000
Characteristics, meteo, season	**log_median_NABEL_PN, Site type**, Temperature, Motorcycle flow, Stop signs, Wind speed, Traffic direction	0.64	0.62	5900	-1000
Characteristics, meteo, time, season	**log_median_NABEL_PN, Neighbourhood type**, sin_hour, cos_hour,Temperature, Motorcycle flow, Gaps	0.65	**0.63**	5300	-900
All variables	**log_median_NABEL_PN, Neighbourhood type**, sin_hour, cos_hour, Temperature, GIS_FIELDS4000m, Motorcycle flow, Gaps, GIS_RESIDENT1000	0.68	**0.66**	5300	-900

Model R^2s for log_median_PN; Root mean squared error (RMSE) and bias back transformed to PN

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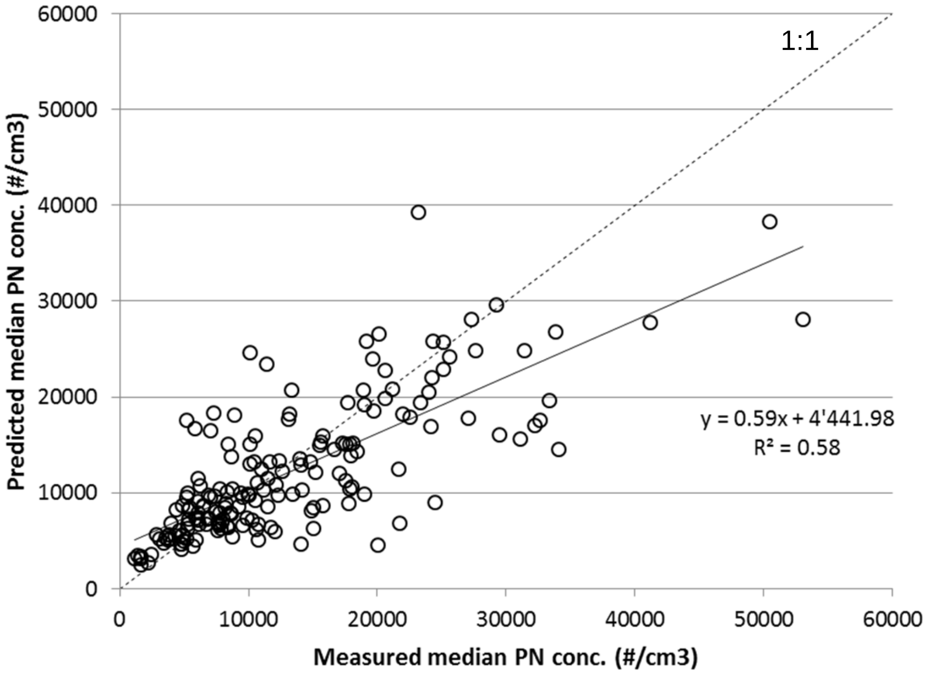
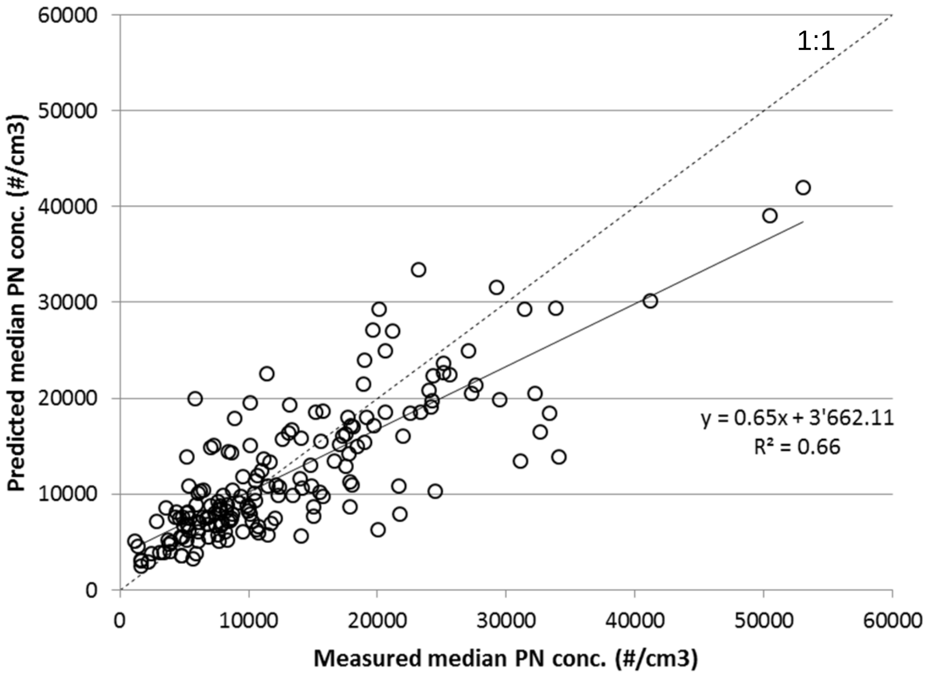
Predicted vs. measured concentration for median PN

Model: GIS, meteo & time



Model: Characteristics, meteo & time



Comparison median vs. mean PN models

Model	Median PN				Mean PN			
	Model R^2	Adj. Model R^2	RMSE	Mean Bias	Model R^2	Adj. Model R^2	RMSE	Mean Bias
GIS, season	0.58	0.56	6400	-1100	0.48	0.47	8200	-1700
GIS, meteo, season	0.60	0.58	6200	-1100	0.49	0.48	8100	-1700
GIS, meteo, time, season	0.63	**0.61**	5900	-1000	0.57	**0.55**	7600	-1300
Characteristics, season	0.63	0.61	6200	-1000	0.59	0.57	7700	-1200
Characteristics, meteo, season	0.64	0.62	5900	-1000	0.60	0.58	7700	-1200
Characteristics, meteo, time, season	0.65	**0.63**	5300	-900	0.65	**0.62**	7000	-1000
All variables	0.68	**0.66**	5300	-900	0.67	**0.65**	6600	-900

Main predictors:

Median PN:
- Log NABEL PN (50%)
- GIS: Distance to main road (5%)
- Char: Site/neighborhood type (6%)

Mean PN:
- Log NABEL PN (38%)
- GIS: Distance to main road (8%)
- Char: Total vehicle flow (9%)

Summary & Outlook

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- PN concentrations were **higher in winter** and at **street sites**
- Models using GIS and / or site characteristic variables could **reasonably well predict short-term PN concentrations**
- For **median PN models** performance was the **same** for GIS or site characteristics
- For **mean PN models** performance was **better** for **site characteristics**
- **Background PN** concentration was the **main predictor** for all models
- Second important predictors were "**Distance to main road**" for **GIS** models, "**site/neighborhood type**" for **characteristics median** models, and "**Total vehicle flow**" for **characteristics mean** models

Outlook

Validating these short-term measurements / models for "longer" terms (hourly, daily) with concurrent SAPALDIA measurements

THANK YOU

Regina Ducret-Stich, Elisabetta Corradi, Harish Phuleria, Nino Künzli

Maria Foraster, Inmaculada Aguilera, Xavier Basagaña

Xavier Morelli, Rémy Slama

Marcela Rivera

Additional slides

MiniDisc (Miniature Diffusion Size Classifier)

Number concentration & average diameter (size range 10-300nm)

Principle of operation: Unipolar diffusion, current detection

Time resolution: 1 second

Size: 45×80×500mm

Weight: ~1kg

Battery life: 36h

Company: Matter Aerosol Wohlen, Switzerland

Models for mean PN

Model	Variables	Model R^2	Adj. Model R^2	RMSE	Mean Bias
GIS, season	**log_mean_NABEL_PN, Distance to main road**, Season, GIS_FIELDS4000m	0.48	0.47	8200	-1700
GIS, meteo, season	**log_mean_NABEL_PN, Distance to main road**, Wind speed Temperature,	0.49	0.48	8100	-1700
GIS, meteo, time, season	**log_mean_NABEL_PN, Distance to main road, sin_hour**, cos_hour, Wind speed, GIS_FIELDS4000m, Season	0.57	**0.55**	7600	-1300
Characteristics, season	**log_mean_NABEL_PN, Total vehicle flow**, Lowest hight of buildings, Gaps, Inclination, Season, Motorcycle flow, Distance miniDisc to street	0.59	0.57	7700	-1200
Characteristics, meteo, season	**log_mean_NABEL_PN, Total vehicle flow**, Lowest hight of buildings, Gaps, Inclination, Distance miniDisc to street, Motorcycle flow, Temperature	0.60	0.58	7700	-1200
Characteristics, meteo, time, season	**log_mean_NABEL_PN, Total vehicle flow, sin_hour**, cos_hour, Gaps, Neighbourhood type, Motorcycle flow, Season, Mean lowest hight of buildings, Distance miniDisc to street	0.65	**0.62**	7000	-1000
All variables	**log_mean_NABEL_PN, Total vehicle flow, sin_hour**, cos_hour, Lowest hight of buildings, Gaps, GIS_WATER4000m, Motorcycle flow, GIS_OTHER500m, Season	0.67	**0.65**	6600	-900

Model R^2s for log_mean_PN; Root mean squared error (RMSE) and bias back transformed to PN