

Swiss TPH 

Spatiotemporal modelling of ambient concentration of airborne ultrafine particles in Switzerland

Sensing and Environmental Epidemiology

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Introduction

- Since early 2000s, studies identified UFP in different human tissues, e.g. lung, heart and brain. In animal studies, UFP was linked to several health outcomes
- To investigate the independent effect of UFP on short-term (strokes, myocardial infarctions) and long-term (cancer, dementia) health outcomes on a population level, UFP exposure models need to be
 - large-scale (regions, countries)
 - long-period (years, decades)
 - high-resolution (in time and space)
 - paired with fitting cohort health data (with similar scale and resolution)
- Historically, the lack of high-density UFP monitoring, compact, high-performance UFP measurement devices and computational power impeded population-level epidemiological studies.

Noise and/or ultrafine particulate matter induced cerebral and cardiovascular damage: novel insights from experimental and epidemiological brain-heart axis biomarkers and computational models



START DATE 01st January 2025
DURATION: 4 years
MEMBERS: 15 institutions from 10 countries
EU GRANT AMOUNT: 7.99 million Euro
SWISS GRANT AMOUNT: 1.28 million Euro

COORDINATOR: **Prof. Andreas Daiber (UMC-Mainz)**



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MORE INFO: www.markersofpollution-markopolo.eu



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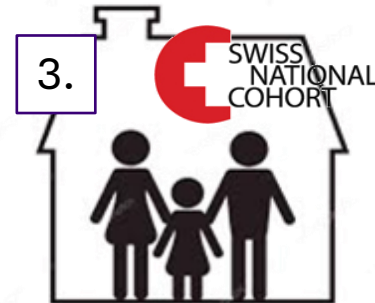
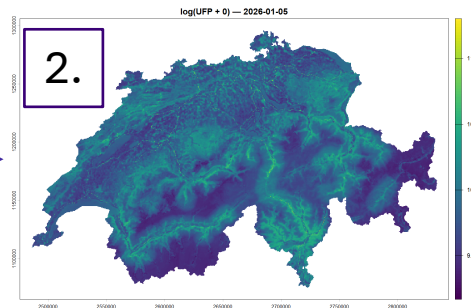
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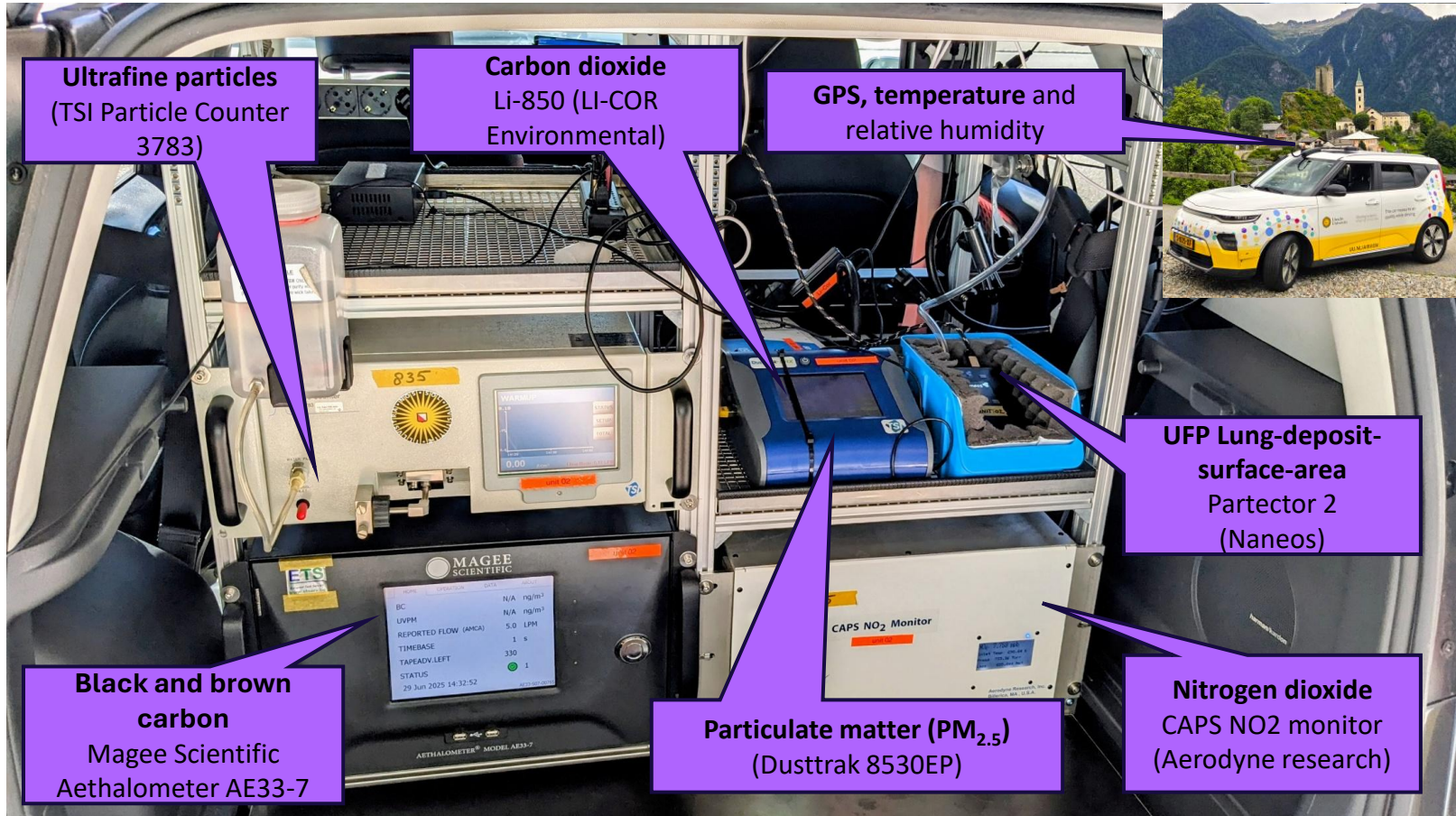
Aim



1. To perform a large-scale, multi-season UFP(PNC) mobile measurement campaign across Switzerland.
2. To develop a nation-wide, long-period, highly resolved (25x25m, daily) UFP(PNC) exposure model for Switzerland between 2010 and 2026.
3. To investigate the independent effect of UFP(PNC) on short-term (strokes, myocardial infarctions) and long-term (cancer) health outcomes among the Swiss population using the *Swiss National Cohort* and *Swiss Stroke Registry*.



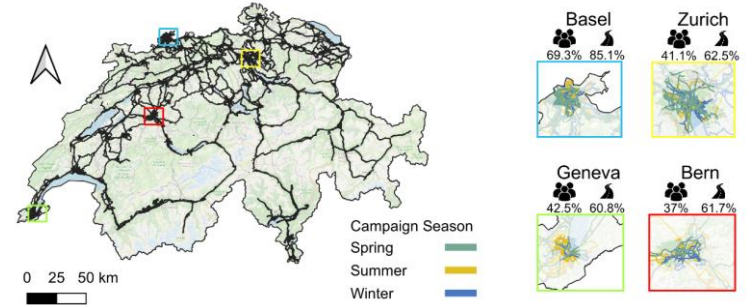
Methods: equipment



Methods: Mobile Measurement Campaign

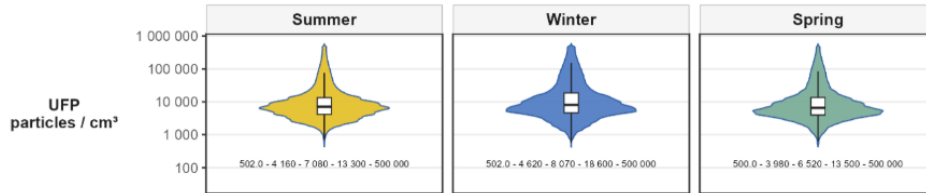
- ~900 hours (June 2025 – April 2026)
- ~17,000 unique road km
- ~2.5 million (~29%) of the Swiss population
- ~900,000 averaged daily UFP values
- 7,130 particles/cm³ (IQR: 4,190 –14,600)

Swiss national mobile measurement campaign of airborne ultrafine particles

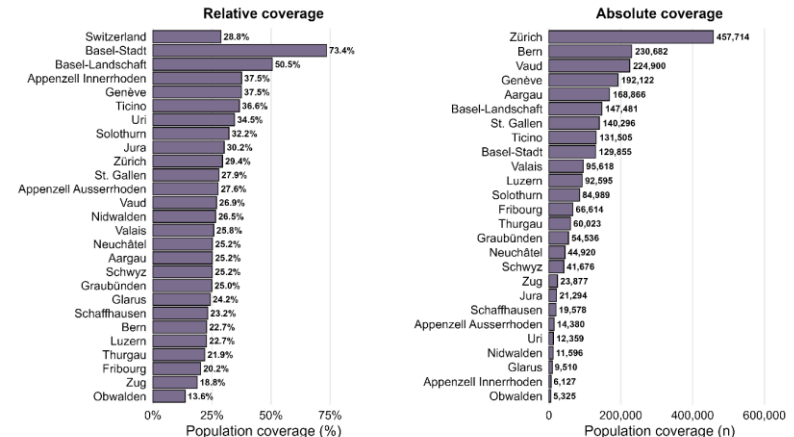


Pollutant distributions by season

Values below violins: min - Q1 - median - Q3 - max



Covered population by canton



Methods: Exposure Modelling

Random Forest Classifier Model

UFP (PNC)



Land use



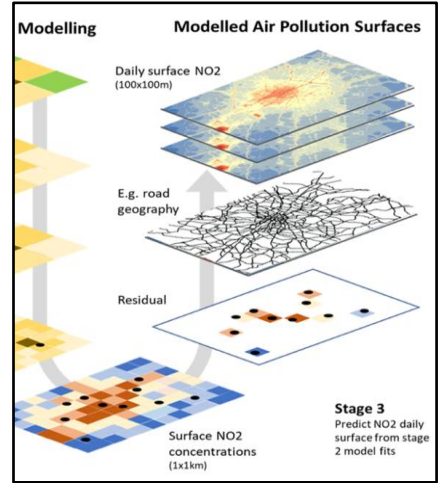
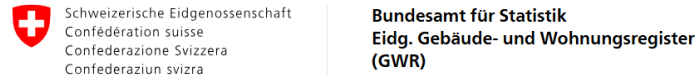
Meteorology



Streets & Traffic



Heating Emissions



De Hoogh et al., 2019

$$\log(\text{PNC}_{25\text{m},\text{day}}) = f_{\text{RF}}(\text{street+traffic+ERA5 meteo+land use+cyclic time+other predictors})$$

$$\widehat{\text{PNC}}_{25\text{m},\text{day}} = \exp(\log(\widehat{\text{PNC}}))$$

Twomey, Rösli, Eeftens et al., *in preparation*



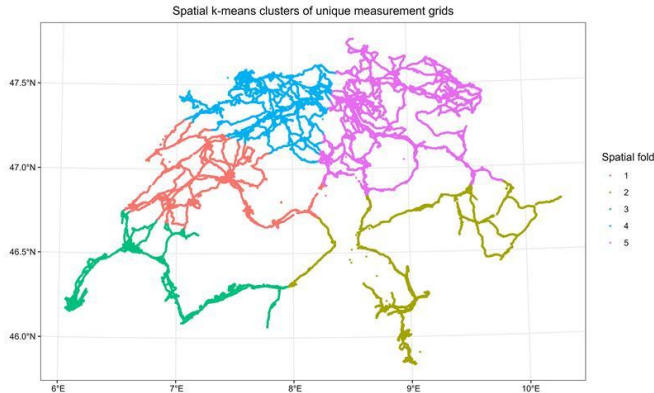
Predictors

Preliminary Results: Exposure Modelling

Random Forest Classifier Model

- **Performance UFP log(PNC):**

- R^2 0.91; MAE_{\log} 0.26; $RMSE_{\log}$ 0.42
- 80/20 cross-validation (CV): 0.90
- Temporal CV: 0.67



- Spatial CV (5 k-means cluster): 0.39

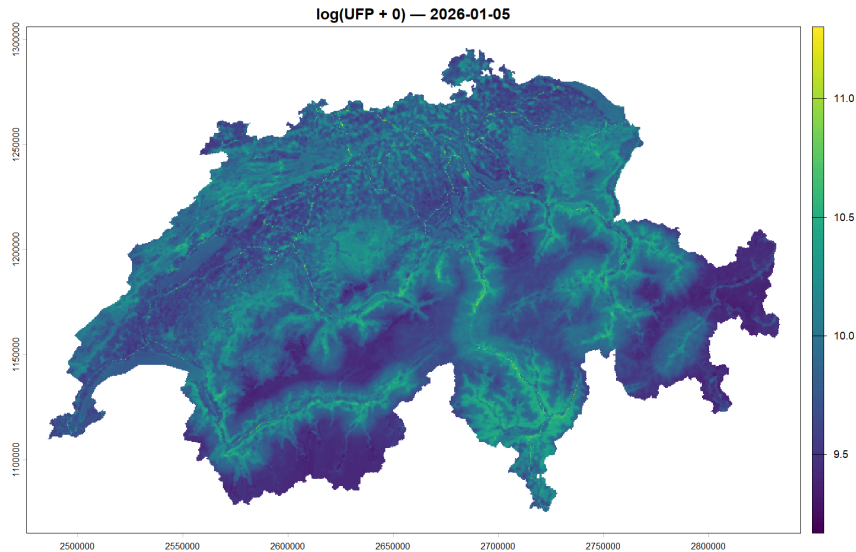
Variable Importance

- Temporal
- Spatial
- Temporo-spatial

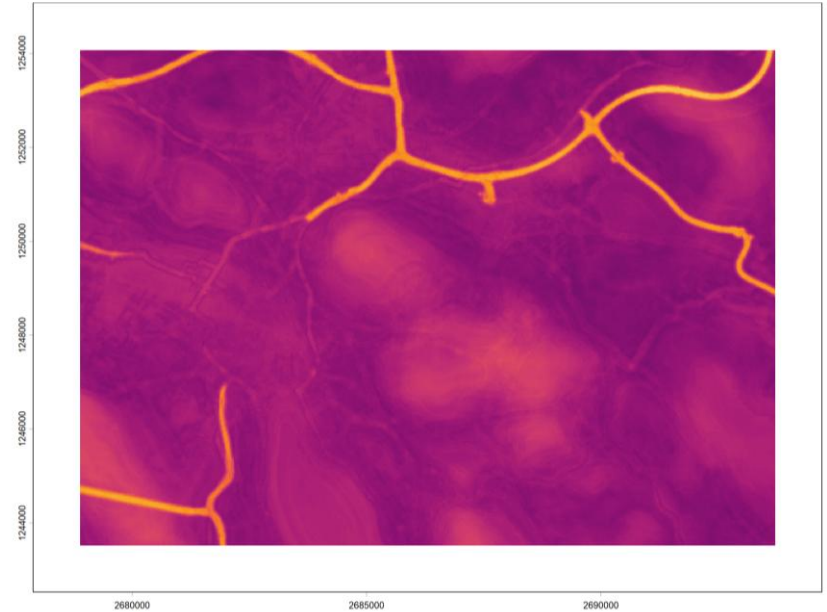
rank	variable	importance
1	Traffic volume by distance to road	0.57
2	Boundary layer height	0.56
3	Motorway 100m buffer	0.50
4	Day of the week	0.48
5	Motorway 50m buffer	0.40
6	Boundary layer height yesterday	0.39
7	Motorway 25m buffer	0.30
8	Relative humidity	0.30
9	Distance to major road	0.27
10	Total precipitation yesterday	0.26
11	Total precipitation	0.26
12	Wind v10-component	0.25
13	Temperature	0.25
14	Altitude	0.25
15	Surface pressure yesterday	0.24
16	UV-radiation yesterday	0.24
17	Distance to Chiasso	0.24
18	Surface pressure	0.23
19	UV-radiation	0.23
20	Total cloud coverage yesterday	0.23
21

Preliminary Results: Exposure Modelling

Spatial prediction



log(PNC) on January 5th, 2026, Switzerland, 25x25m



log(PNC) on 23rd – 30th January 2026, Zurich, 25x25m

Preliminary Results: Exposure Modelling

Temporal prediction

Daily predicted UFP vs. NABEL PNC

Grey ribbons: prediction min-max and Q1-Q3. Orange thin lines: individual included NABEL sites. Black and orange thick lines: prediction and NABEL trends.



Mean log(PNC) between, 2010 and 2026, Switzerland, with **NABEL** and **mobile measurement** data

Twomey, Rösli, Eeftens et al., *in preparation*

Strengths & Limitations

Strengths

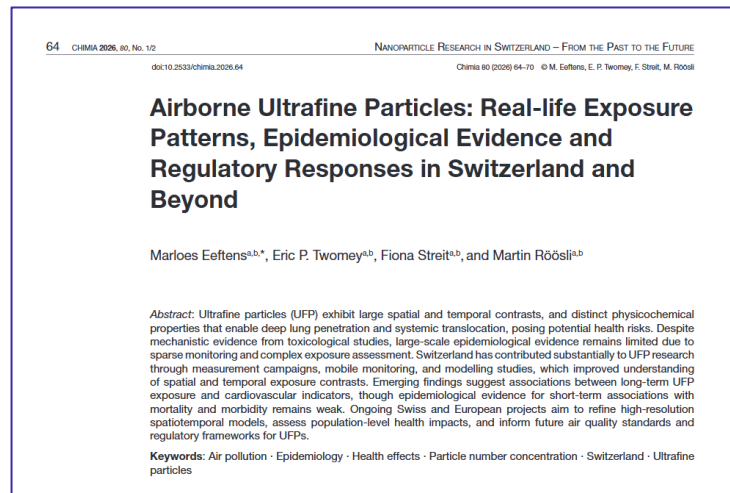
- Sampled real-world UFP with high temporal, spatial and populational coverage
- Among first nation-wide UFP models
- Among first UFP models including multiple temporo-spatial predictors
- Long period (NABEL anchored 16 years)
- High resolution (daily, 25m)
- Co-pollutant independent UFP model

Limitations

- UFP Measurements limited to streets and street-level height
- Models x, y, t only, no z -dimension
- PNC only, no UFP composition or size-distribution (possibly in future models)

Next steps

1. Compare performance and contrast retention from Random Forest Model to XGBoost, Lasso, stepwise-linear regression, artificial neural networks, ensemble learners
2. Finalize model and prediction
3. Use UFP exposure model to assess independent health effects of UFP on stroke, brain cancer and overall mortality in Switzerland



Eeftens, Twomey, Streit, Rössli et al., *CHIMIA*, 2026
<https://doi.org/10.2533/chimia.2026.64>

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