Monitoring the air quality inside a classroom using multiple low-cost sensors

Presenter:
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Postdoctoral Researcher

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The Synair-G project

Disrupting Noxious Synergies of Indoor Air Pollutants and their Impact in Childhood Health and Wellbeing, using Advanced Intelligent Multisensing and Green Interventions

- We spend more than 90% of our time indoors
- The classroom is where children spend 1/3 of the day
- There is evidence suggesting that the impact of air pollutants on health goes beyond the cumulative effect of the different pollutants. Although still not completely characterised, the interactions between chemical and biological pollutants, including allergens, may be in some cases synergistic

The Synair-G project

25 schools in five countries are monitored

...

SynairG box

→ Pollensense

ENSENSIA

CO, NO, NO_2, O_3, CO_2, Total VOCs, $PM_{2.5}$

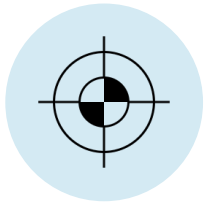
Objective

What is the general performance of each sensor (factory-calibrated)

What is the sensor performance in detecting significant events (van engine, drawing, etc.)

What is the variability between the sensors inside the classroom? In what extent in this variability a problem

Is installing a second device outside useful? Can two devices be used to identify outdoor sources that influence indoor concentrations?



What calibration methods do we suggest for each sensor to achieve the above goals?

Measurement setup

26th Jan – 15th Feb 2024 || Athens (Zografou)

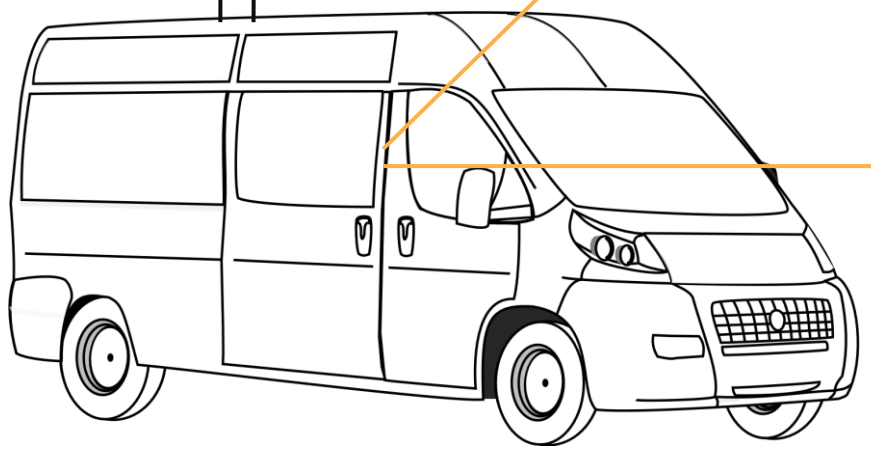
Classroom

Sampling lines

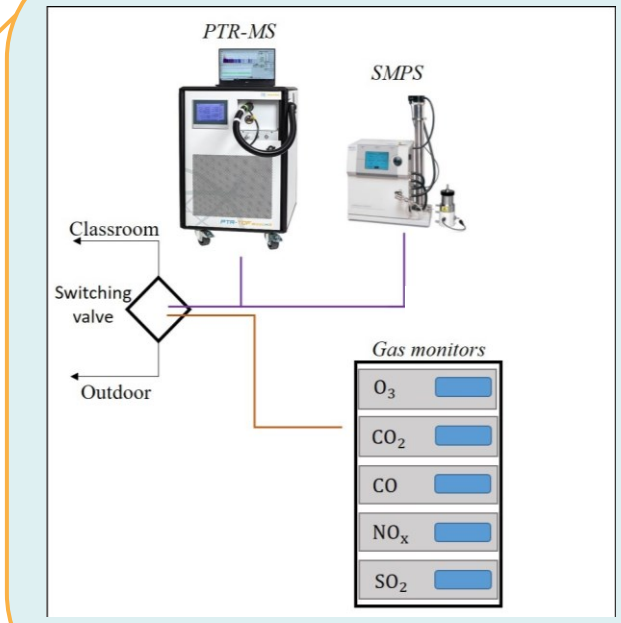
~5m

~10m

Ambient sensors



Mobile Laboratory



Implementation pictures

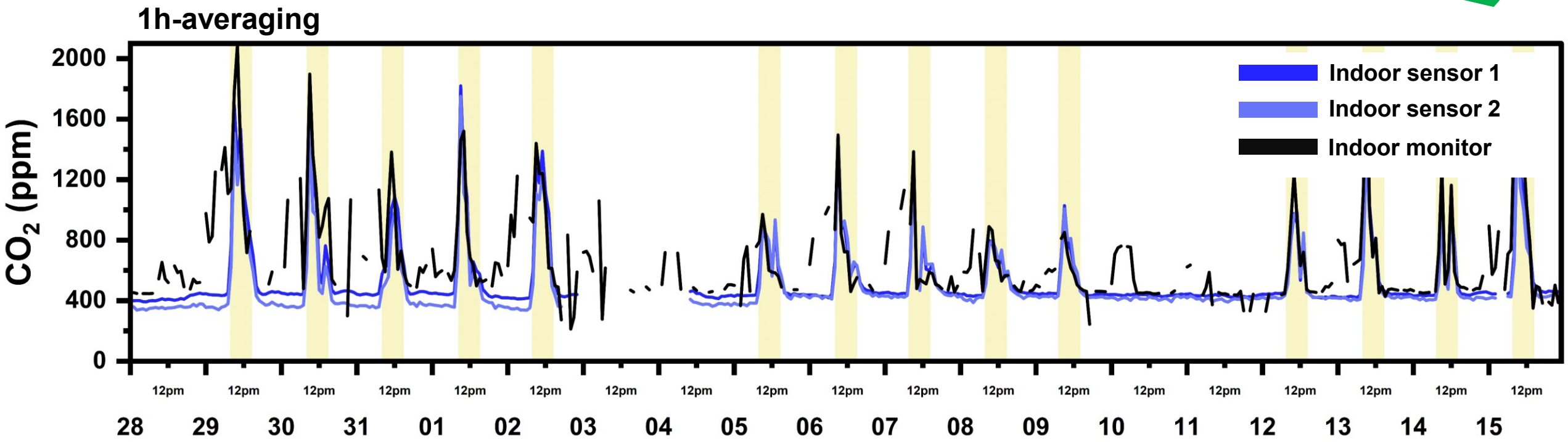
The Good case

CozIR®-AH 10,000 ppm CO_2 Sensor

150 – 170 eur.

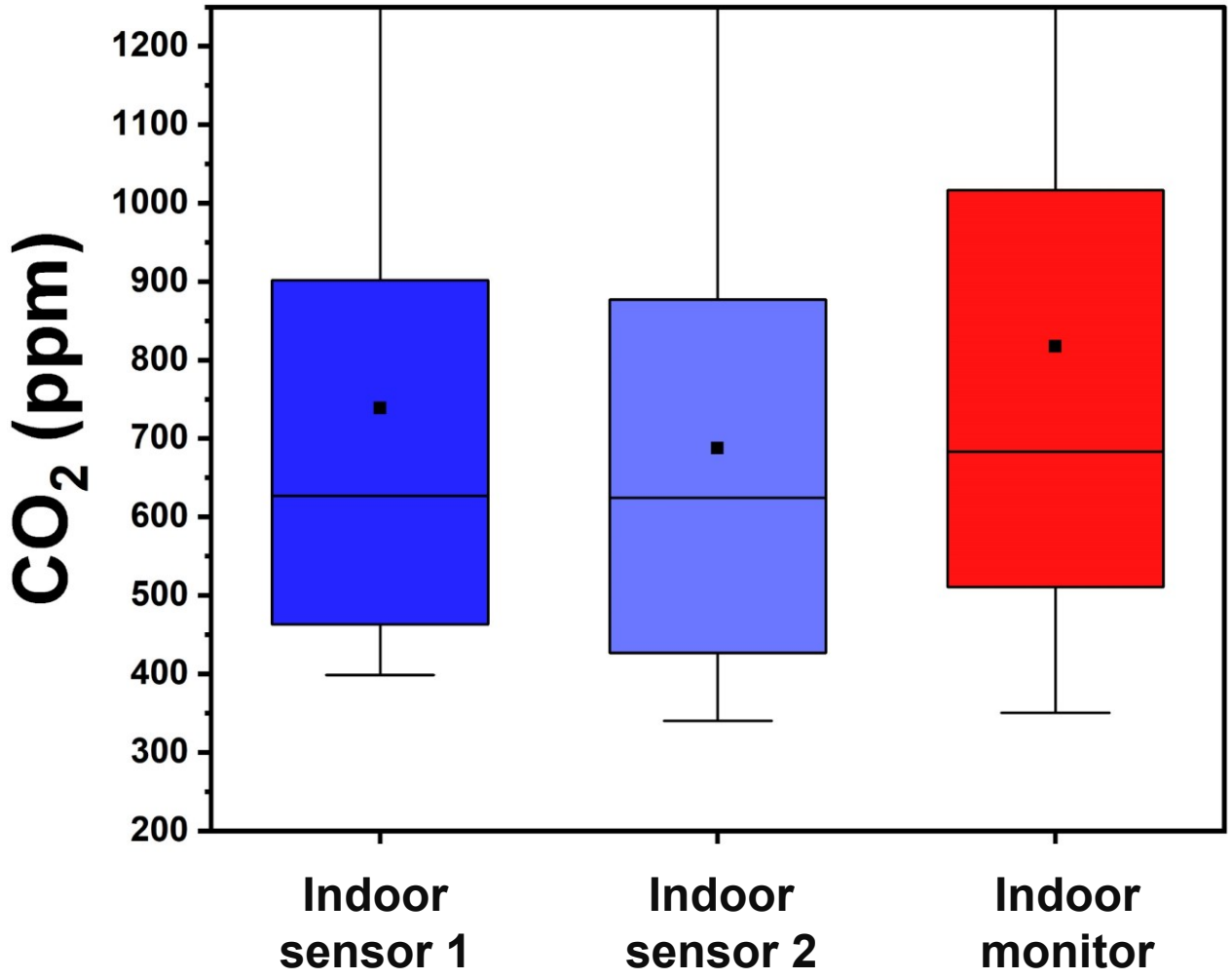
CO_2 timeseries of the indoor sensors and monitor

The Good case



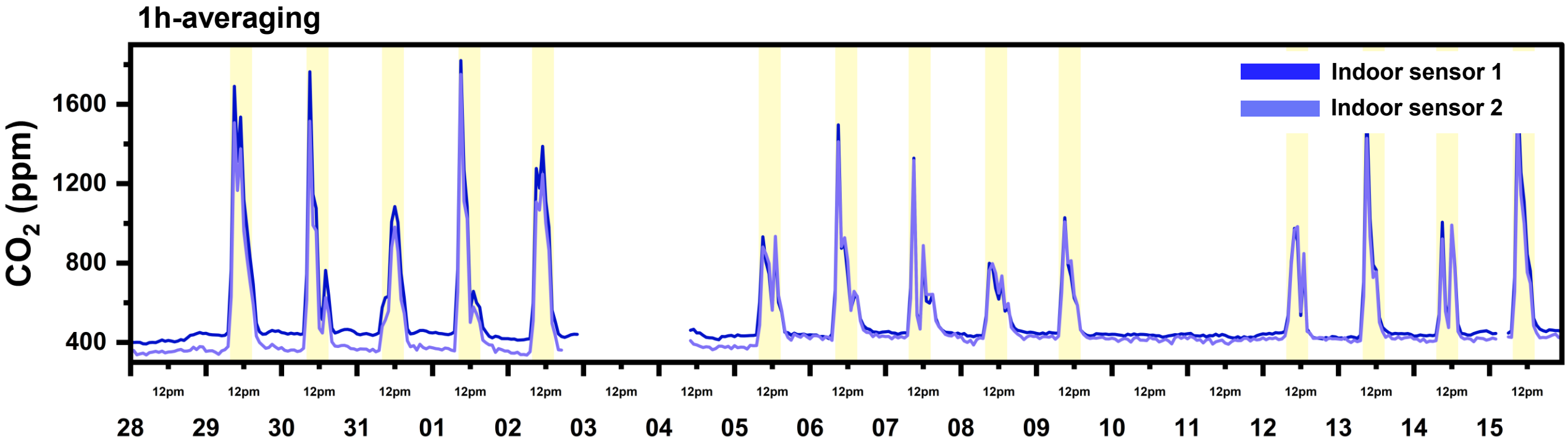
- The sensors agree
- The sensors follow the trend (R^2 = 0.72)

CO_2 boxplot of the indoor sensors and monitor

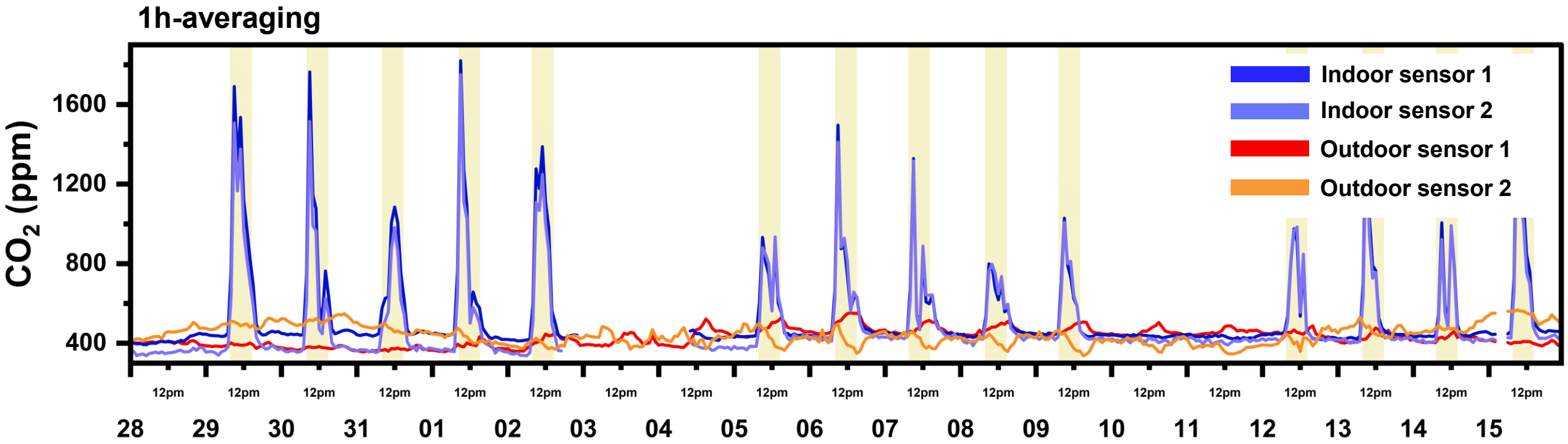


R^2 = 0.72
nME = 47%
ME = 137 ppm

CO_2 timeseries of the indoor sensors

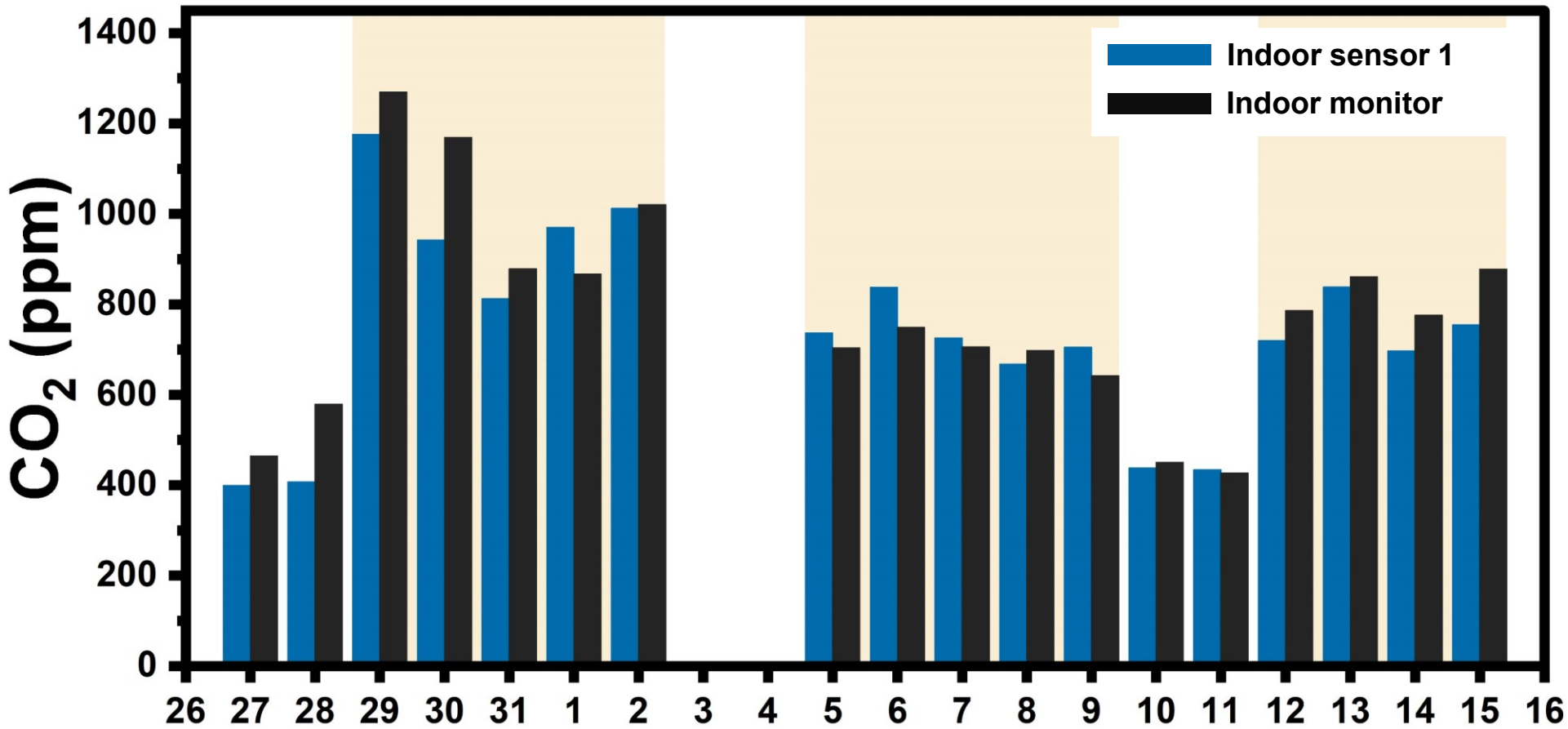


CO_2 timeseries of the all sensors



- The sensors confirm the obvious (CO_2 is greater indoor, no outdoor sources)

Average daily student exposure to CO_2 (08:00 – 14:00)



nME = 11%
ME = 90 ppm
8-h averaging

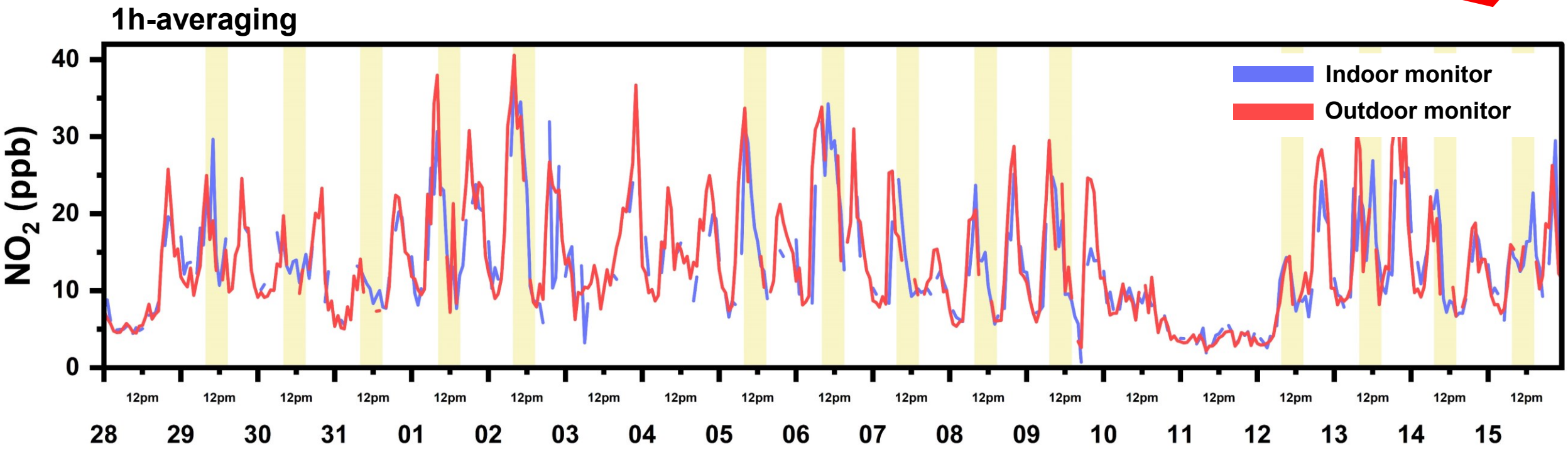
The “Bad” case

Nitrogen Dioxide sensor NO2-B43F - Alphasense

150 eur.

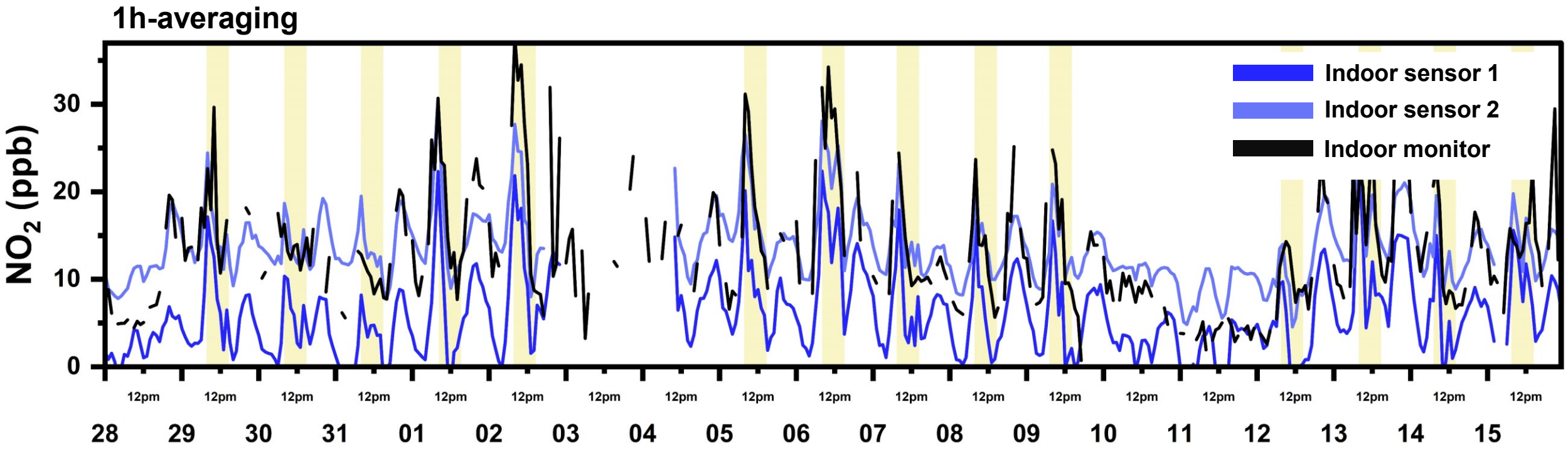
NO_2 indoor and ambient profile

The Bad case



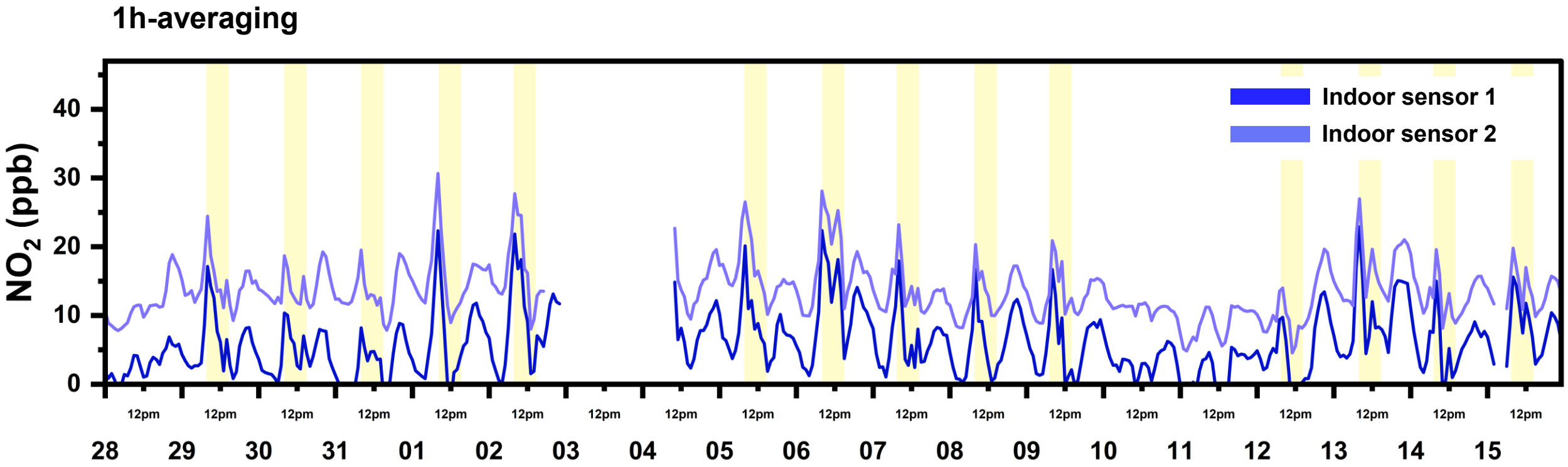
- Indoor NO_2 is similar to ambient
- No indoor source of NO_2

NO_2 timeseries of the indoor sensors and monitor

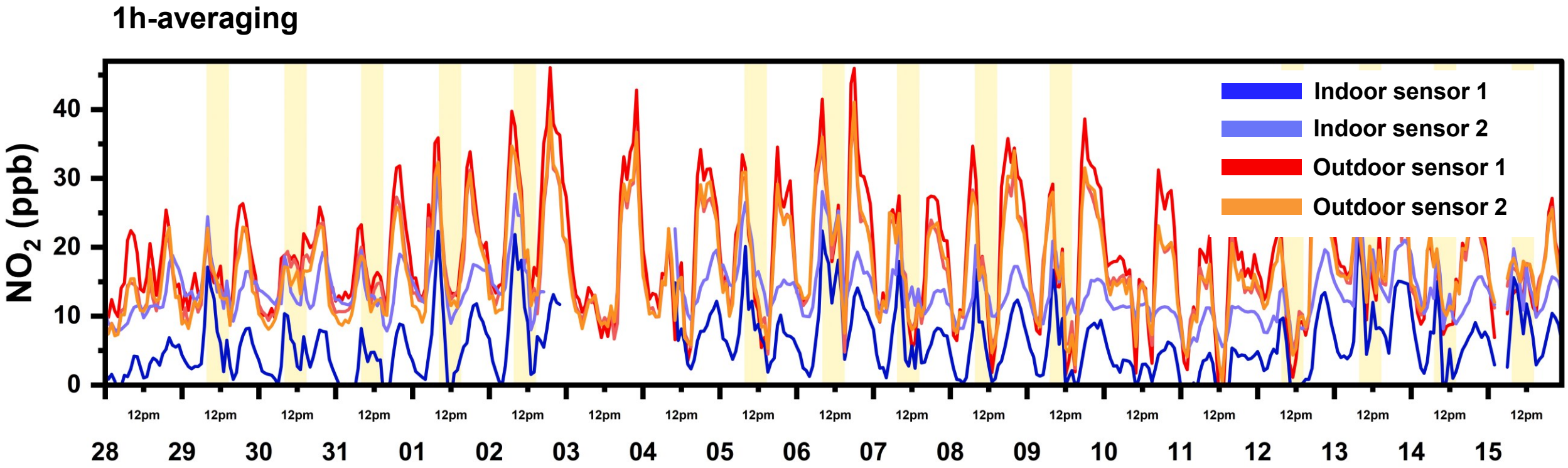


- Sensors disagree (2-fold at least)
- Sensors are capturing the pattern (R^2 = 0.7), nevertheless

NO_2 timeseries of the indoor sensors

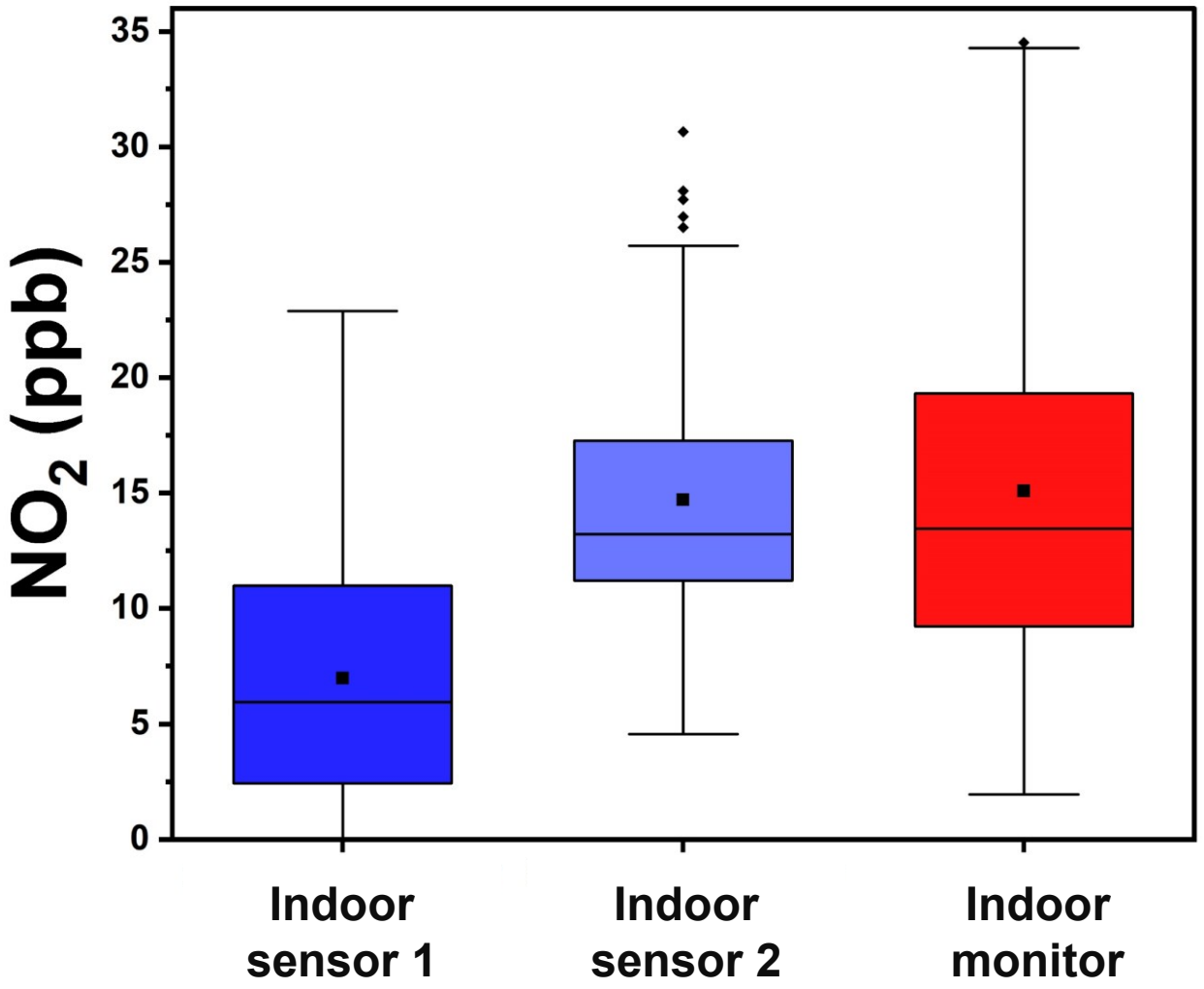


NO_2 timeseries of the all sensors



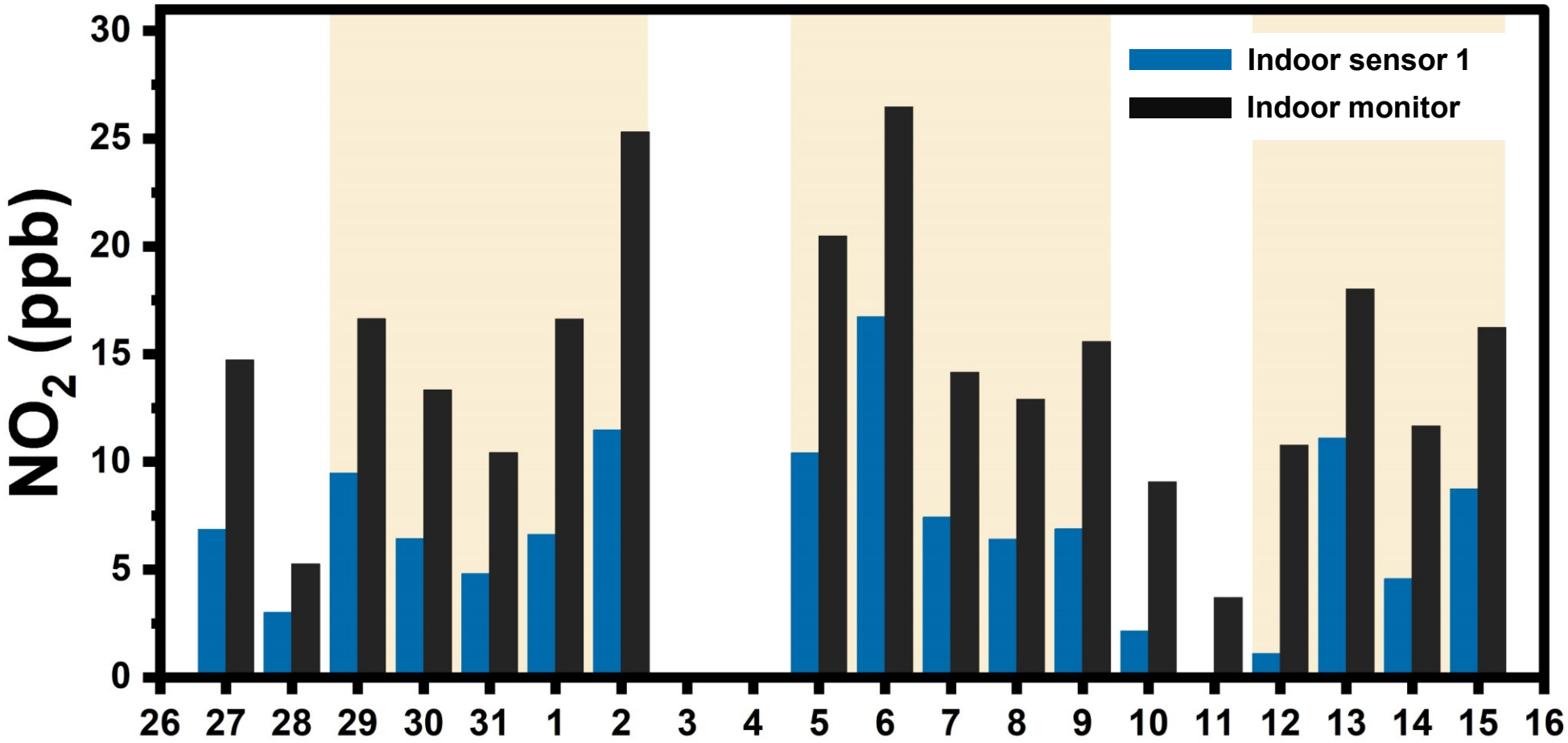
- Indoor NO_2 is less than ambient (Sensor 1)
- Indoor NO_2 is far less than ambient (Sensor 2)

NO_2 boxplot of the indoor sensors and monitor



R^2 = 0.7
nME = 61%
ME = 8 ppb

Average daily student exposure to NO_2 (08:00 – 14:00)



nME = 58%
ME = 8 ppb

Performance in estimating the average daily exposure

Error percentage (absolute) 08:00 – 14:00	
CO_2	11% (92 ppm)
NO_2	58% (7 ppb)
O_3	72% (17 ppb)
CO	28% (152 ppb)
NO	300% (5 ppb)

R-squared (1h averaging) 08:00 – 14:00	
CO_2	0.72
NO_2	0.7
O_3	0.75
CO	0.1
NO	0.75

*8-h averaging

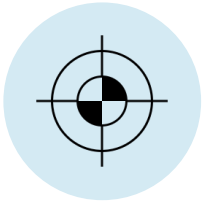
Overview of sensor performance

	Sensors agree	$R^2 > 0.7$	nME < 75%	
CO_2	✓	✓	✓	
$PM_{2.5}$	✓	✓	✓	
TVOC	✓	?	?	
CO	✓	✗	✓	Needs calibration
NO	✗	✓	✗	Needs calibration
NO_2	✗	✓	✓	Needs calibration
O_3	✗	✓	✓	Needs calibration

Remaining questions

What is the sensor performance in detecting significant events (van engine, drawing, etc.)

How to deal with the variability between the sensors



What calibration methods do we suggest?

Contributors

- **Prof. Spyros Pandis** (Supervision)
- Dr. George Fouskas (Supervision)

- **Androulakis Silas, Argyropoulou Georgia, Dovrou Eleni, Florou Kalli, Georgopoulou Maria, Kaltsonoudis Christos, Matrali Angeliki, Pandis Spyros, Seitanidi Katerina** (Campaign Team)

- **Xrysanthi Ikkou** (Elementary School's Director)

FORTH

FORTH INSTITUTE OF CHEMICAL ENGINEERING SCIENCES

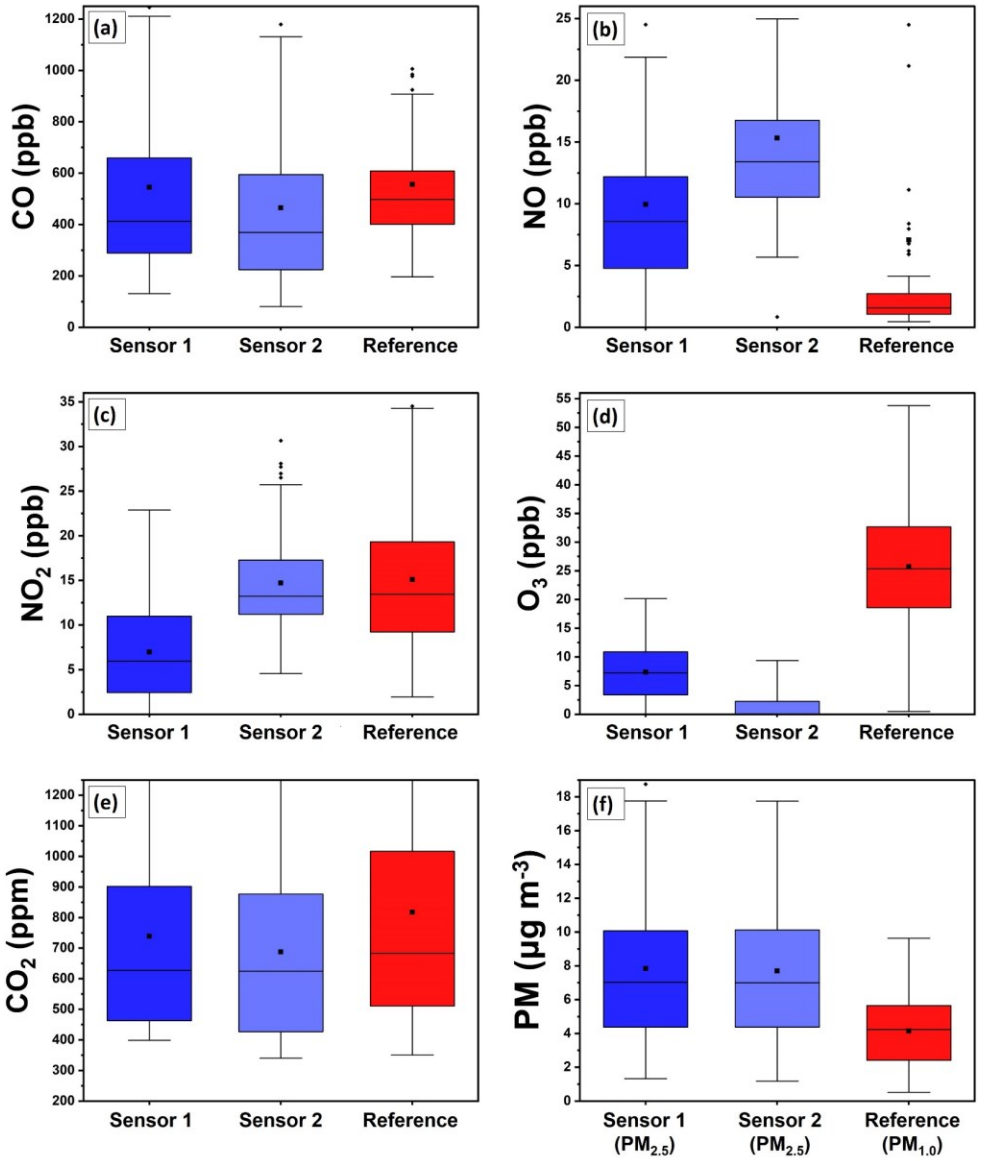
C·STACC

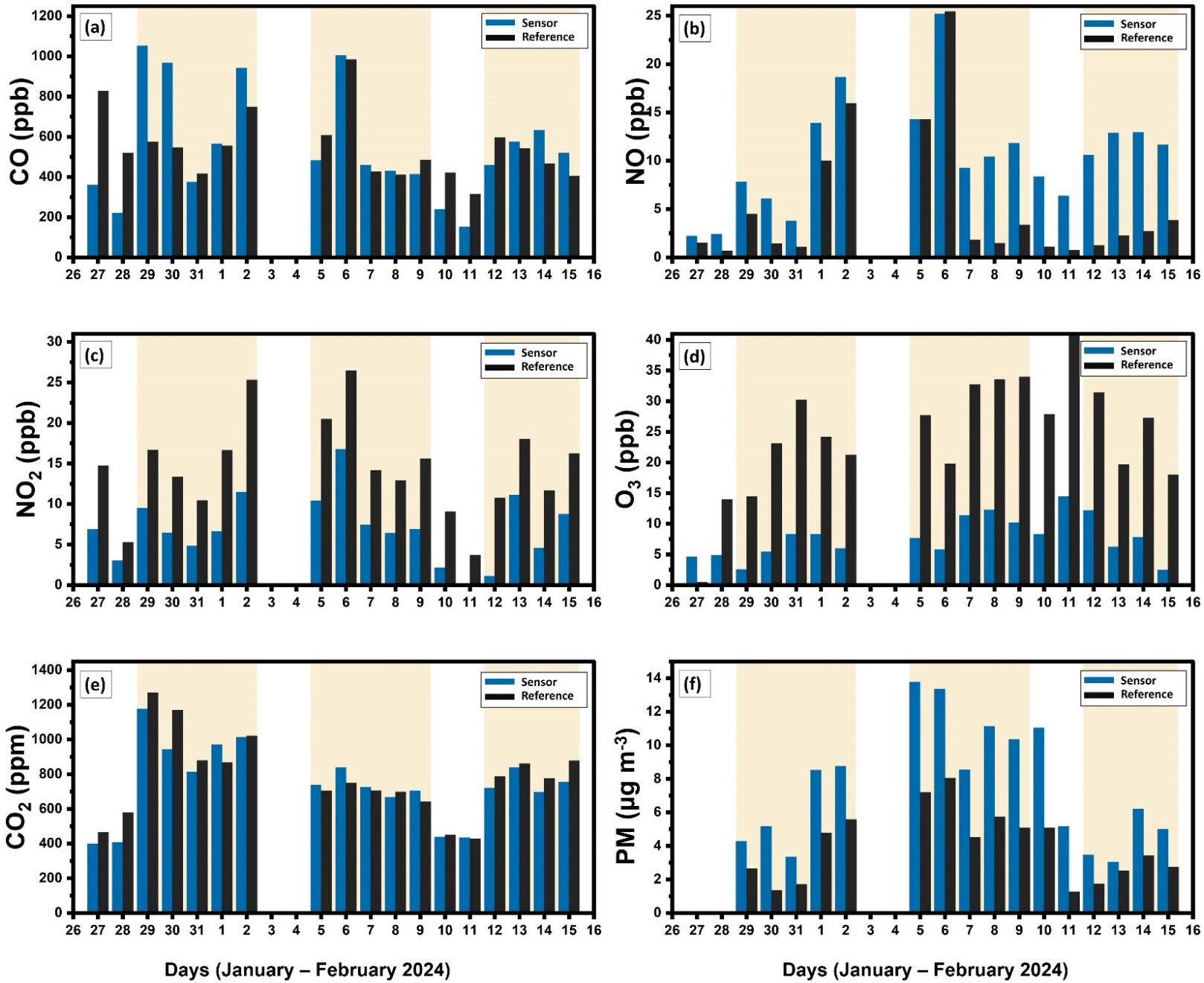
Center for the Study of Air Quality & Climate Change

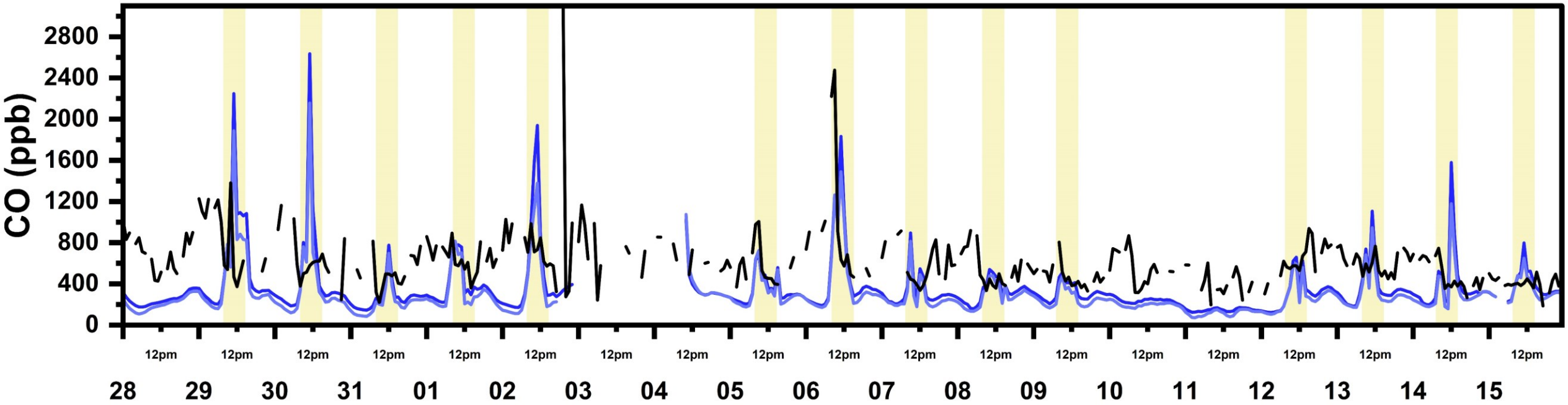
SynAir-G

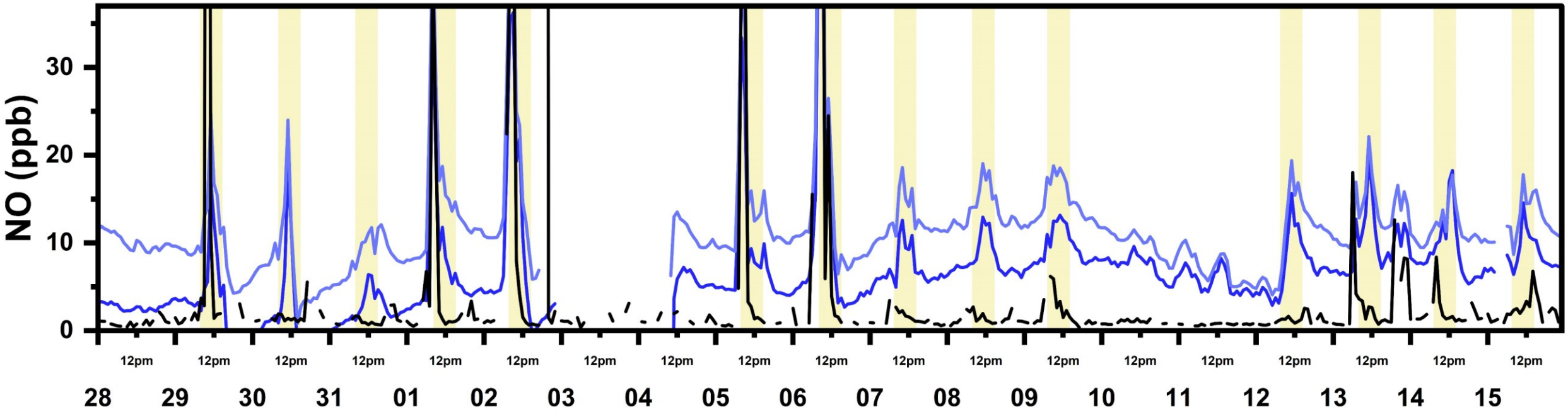
Table S1. Performance metrics of the indoor sensors during school hours (08:00-14:00) at multiple averaging times for the complete campaign. CO, NO, NO_2, and O_3 sensor's and reference's measurements are in ppb. CO_2 measurements are in ppm. $PM_{2.5}$ measurements are in µg m^{-3}.

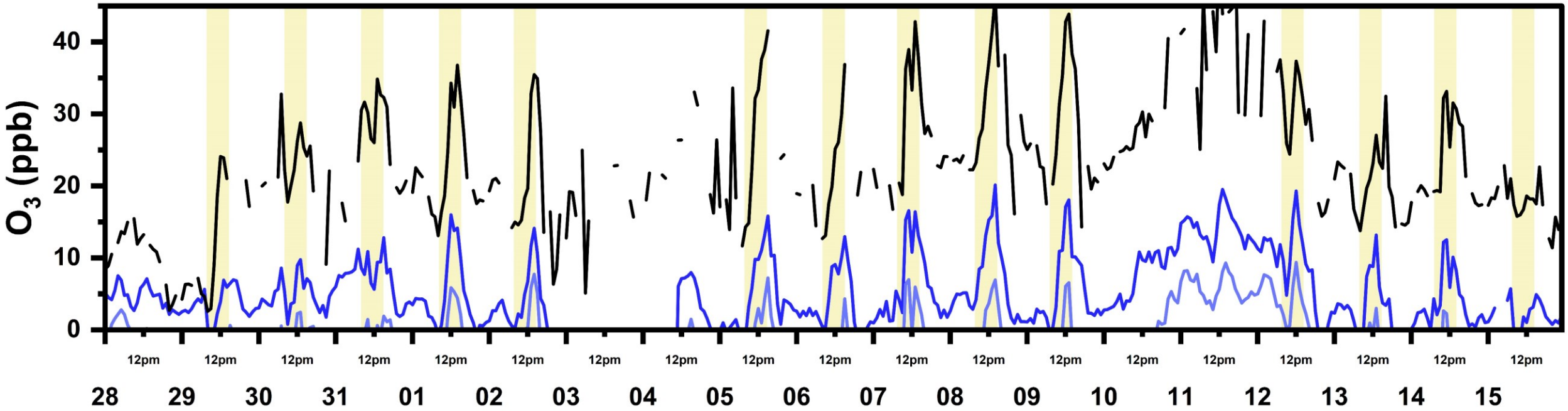
Sensor	5-min			15-min			60-min			Average daily (8h)		
	ME	nME	R^2	ME	nME	R^2	ME	nME	R^2	ME	nME	R^2
CO	288	51%	0.1	290	52%	0.1	258	48%	0.1	152	28%	-
NO	8.5	500%	0.79	8.3	480%	0.78	7.7	450%	0.75	5.3	300%	-
NO_2	8.9	61%	0.65	8.6	61%	0.67	8	61%	0.7	7.6	58%	-
O_3	18	77%	0.75	18	75%	0.73	18	80%	0.75	17	72%	-
CO_2	150	17%	0.72	160	20%	0.64	136	17%	0.72	92	11%	-
$PM_{2.5}$	-	-	0.77	-	-	0.72	-	-	0.70	-	-	-

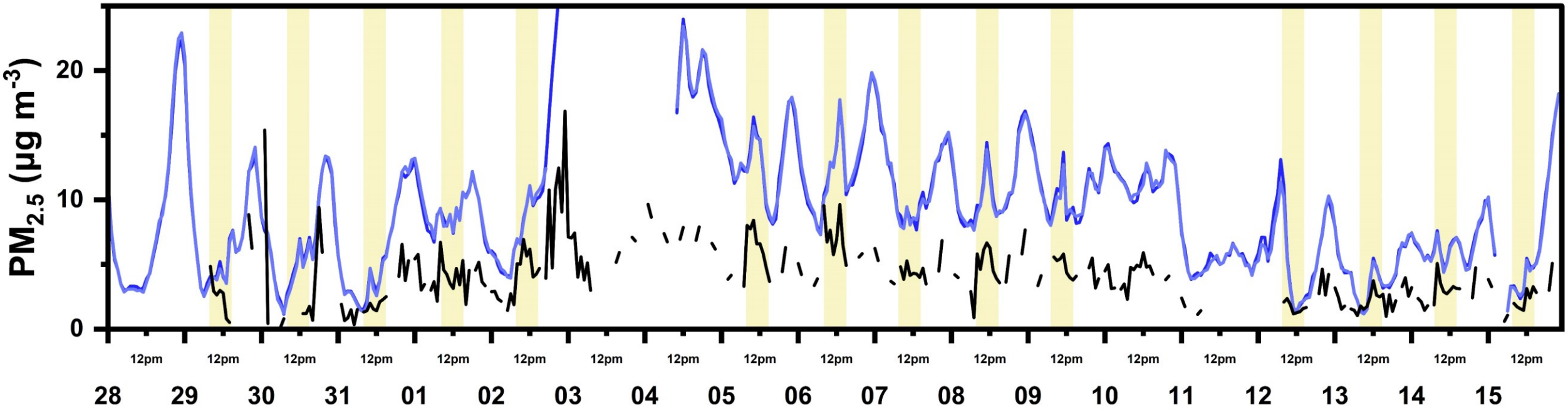

(a)
CO (ppb)
Sensor 1
Sensor 2
Reference
(b)
NO (ppb)
Sensor 1
Sensor 2
Reference
(c)
NO2 (ppb)
Sensor 1
Sensor 2
Reference
(d)
O3 (ppb)
Sensor 1
Sensor 2
Reference
(e)
CO2 (ppm)
Sensor 1
Sensor 2
Reference
(f)
PM (µg m-3)
Sensor 1 (PM2.5)
Sensor 2 (PM2.5)
Reference (PM1.0)


(a)
Sensor
Reference
CO (ppb)
(b)
NO (ppb)
(c)
NO_2 (ppb)
(d)
O_3 (ppb)
(e)
CO_2 (ppm)
(f)
PM (µg m^{-3})
Days (January – February 2024)
Days (January – February 2024)


CO (ppb)
2800
2400
2000
1600
1200
800
400
0
12pm
28
29
30
31
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15


NO (ppb)
30
20
10
0
12pm
28
29
30
31
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15


O_3 (ppb)
0
10
20
30
40
12pm
28
29
30
31
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15


PM2.5 (µg m-3)
0
10
20
12pm
28
29
30
31
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15

Data pre-processing