Laboratoire Chimie Environnement

Instrumentation et Réactivité Atmosphérique

LCE-IRA

In Field Study of NextPM Sensor

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Abstract :

Since more than ten years, we are studying the rise of micro sensors technology to monitor Air Quality. Each generation of sensor come with its improvements and gain a better accuracy, lifetime, reliability, …
We thus decided to focus a study on the new born sensor of Tera Sensor, a Groupe Tera company, the NextPM to check if its performances will be enough high to be used for ambient air monitoring. The study will be complete thanks to the help of our partner AtmoSud and the "supersite" of Marseille.

The first results obtained are promising, the NextPM sensors deployed responses were equivalent, the correlation is > 0.99 and the sensitivity is more or less 15 %. We also found high correlation between the reference instrument and the NextPM for PM1, PM2.5 and PM10, the daily correlations were comprised between 0,91 for PM2.5 to 0,71 for PM10 and the hourly correlations from 0,82 for PM2.5 to 0,60 for PM10. We found the best correlation result for PM2.5 and the weakest for PM10 except for some period where the correlation of PM10 were as high as the others.

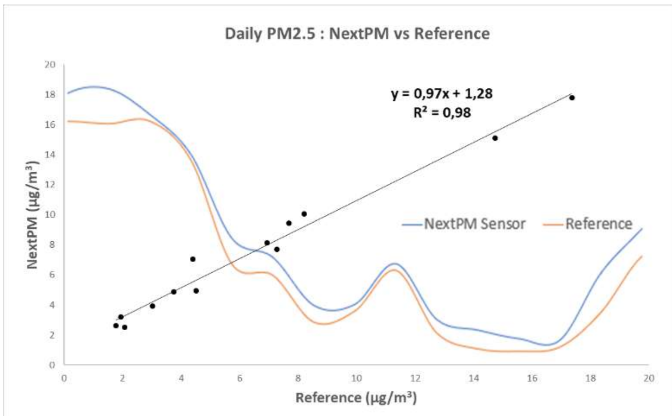


Figure 1: Daily correlation between the NextPM and the FIDAS from the 09/18/20 to the 09/30/20

Nonetheless, we found that the slopes of the correlation curve could change from one week to another, during the week 08, the slope of PM2.5 was 0.9 whereas it was 1.4 the week 01 and came back to 1.4 at week 09. These results showed that some external effect change the response of sensors and we will try to found what in a next study.

SUMMARY

Tables and Figures list:

1. Introduction

1.1. Context

In recent years, air pollution has received considerable attention while remaining a major threat to human health (Kampa & Castanas 2007). Air quality currently represents a global health and environmental issue, thus becoming a significant place in scientific debates. In France, account given the thousands of premature deaths per year from which they are the source, fine particles are at the heart of these public health debates (Air quality in Europe - 2015 report). Therefore, the fight against pollution atmospheric, focusing on improving air quality, goes through two axes namely raising citizens' awareness of environmental and health issues as well as through various strategies in place to reduce this air pollution.

To this end, several associations and approved scientific laboratories are responsible for monitor changes in the rate of certain pollutants (https://atmo-france.org), particularly fine particles regulated like PM10 and PM2.5, which penetrates the respiratory tract, damages the walls of pulmonary alveoli thus causing, in the subjects concerned, respiratory problems and various cardiovascular diseases (Li et al, 2018).

The monitoring of these PM focuses on their characterization in size and number (Coquelin L. et al, 2013) thanks to the use of various measures which are constantly improve and automate to offer continuous monitoring, in real time, of the evolution of measurements of the particles in question in the air. However, there are different types of sensors including efficiency, cost, or even deployment offer heterogeneous solutions. The goal of our study is therefore to compare a new range of sensors (micro-sensors) which present two advantages namely their lower cost compared to the reference analyzers used mostly so far as they also offer the possibility of being deployed on many sites thanks to their small size.

1.2. Aim and Domain

NextPM sensor has been commercialized since January 2019 by Tera Sensor company (from Groupe Tera). This sensor has been developed for outdoor PM monitoring applications. The targeted markets are outdoor monitoring to reach the requirements for indicative measurement, the automotive market in order to protect passengers from outside bad air quality and the industry with a lot of specific applications.
NextPM could make this possible thanks to its innovative and patented technology. The sensor is the only one on the market that can manage relative humidity inside the detection cell to avoid interferences on the measures. Also, it can size the particles from 0.3 µm to 10 µm instead of using a linear algorithm as its competitors do, and most of all, thanks to its inlet aeraulic filter its measures stand still over time and seems not affected by any drift.

Figure 2 : NextPM detailed technology

The former results obtained by the technology in Tera Sensor laboratory and field, in the international large study led by AirParif and its Airlab "Microsensors challenge 2019" and by its first integrators, show high performances.
Regarding these performances, we, the Air Quality regional expert AtmoSud and its scientific partner LCE from AMU (University of Aix-Marseille), wanted to launch a complete test on the technology, into our most equipped field station near the "Longchamp Palace" in Marseille, in order to check what possibilities the technology could offer to our needs.

Figure 3 : Super Site localization

The aims were numerous and listed below:

1- Do the sensors are as performant as the previous results showed?
2- What will happen when the relative humidity will be near saturation?
3- What will be the response of the sensor to different kinds of aerosols?

Thanks to the specific equipment owned by AtmoSud and the LCE into this complete station, the study will soon reveal the answers to these questions.

Figure 4 : Picture of NextPM installation

The study has been launched in August 2020 and will last one year. The first data (2 months of August and September) will be presented in this short report as an introduction for the future complete study.

1.3. Detailed set up of the "Super-site"

Since 1995, nearly 25 years, AtmoSud in partnership with the University of Aix-Marseille have been extending air quality monitoring to numerous pollutants beyond regulatory requirements, this location is of great use to us since it represents the average level of air breathed by the inhabitants of Marseille. On this site, we have in addition to the instrumentation necessary to measure all the regulated parameters (PM10, PM2.5, NOx, O3, SO2) and the main greenhouse gases (CO2, CH4), the "super site" is specifically equipped, on a continuous basis, with:

- ToF-ACSM (Time of flight-Aerosol Chemical Speciation Monitor) for on-line analysis of the non-refractory fraction of submicron particles with a temporal resolution of 15 min (ie. Organic fraction-OA-, Sulfate, Nitrate, Ammonium ...) and this since February 2017.
- Aetholometer (AE33) for the measurement of Black Carbon (BC) with a temporal resolution of 15 min.

- ➢ Online analyzer of metallic elements (Xact 625i, time resolution 60 min) since July 2018.
- ➢ SMPS (Scanning Mobilty Particle Sizer) for the measurement of the total number of submicron particles (15-700 nm) and their particle size distribution with a temporal resolution of 5 minutes and this since September 2018.
- ➢ Meteorological station (Temperature, Relative Humidity, 3D sonic anemometer).

The "super site" therefore makes it possible to know the temporal evolution of the mass and numerical concentration and of the composition of fine and ultrafine particles as well as to determine their source as we have studied between 2017 and 2018 (https://acp.copernicus.org/preprints/acp-2020-1015/).

1.4. The reasons why

Why do we study fine and ultrafine particles?

- Particulate pollution which has become a subject of major concern
- 3rd cause of death in France (Santé Publique France, 2016)
- If the WHO guideline value were respected: 7,700 anticipated deaths would be avoided each year, ie a decrease of 4% mortality. A potential gain in life expectancy of 12 to 18 months in Marseille (INVS - EQUIS study)
- Today the health impact is generally only based on the mass concentration (PM2.5, PM10). It is based on the implicit assumption that particles have the same health impact regardless of their numbers, their compositions, their origins, their physical properties…

Why in Marseille?

The peculiarities of Marseille are numerous: strong sunshine, multitude of sources (presence of a maritime opening and an airport, as well as the surrounding mountains and forests). This allows us to have a broad horizon of the various causes of certain particles (topography and circulation of particulate air masses). In our study, we will focus on Next-PMs which allow us to see PM1, 2.5, 10 as well as other X-sensors to try to interpret or see a consequence with weather factors.

2. Results and discussion

The first part of the exploitation is public and standard. It consists in the comparison between NextPM in order to check their in between sensors reproducibility and in the comparison of the NextPM with one reference instrument periodically verified by the expert team of AtmoSud.

We decided to realize a campaign using the same format as the AQ-SPEC in the United States to easily compare the results of NextPM sensors to the ones of its competitors.

We used a batch of 2 weeks continuous data in ambient air to calculate the following results:

- Data recovery
- In between reproducibility
- Hourly mean comparison
- Daily mean comparison

The two following weeks show one of the best results obtained in the whole two months period. The results over the complete time period will be presented after.

The second part of the exploitation will cover the core test period and the differences of correlation we noticed between two weeks or two months.

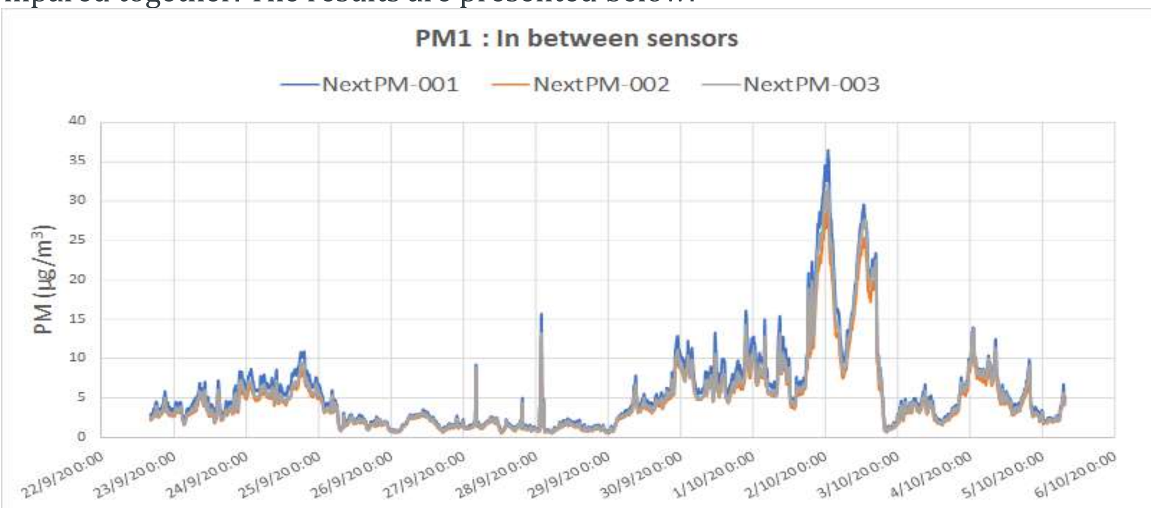
2.1. Two weeks set performances

2.1.1. Data recovery

The data recovery of the NextPM and the software used was 100% for the three sensors. The reference method had few hours missing, its data recovery score is 94%.

2.1.2. In between reproducibility

3 NextPM (NextPM-001, NextPM-002 & NextPM-003) were exposed in ambient air and compared together. The results are presented below:



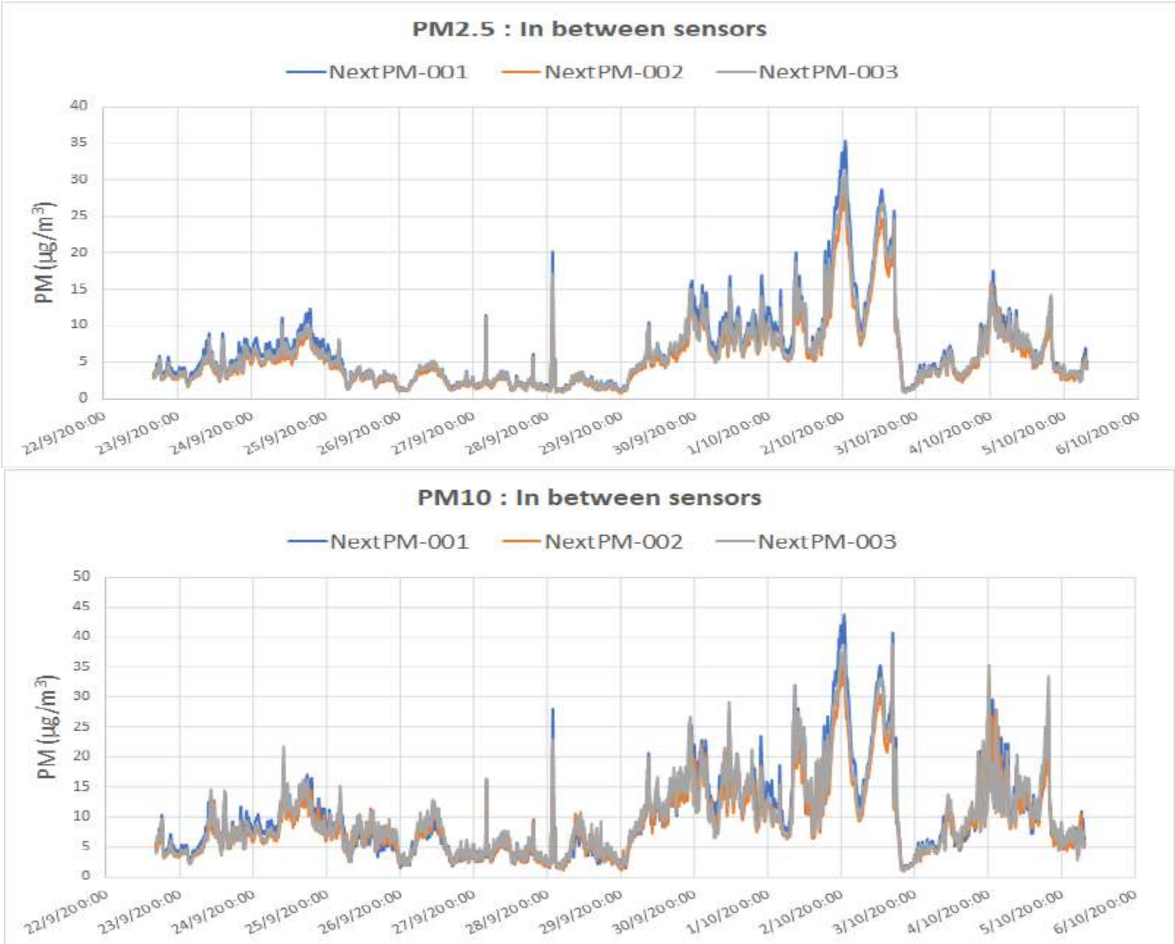


Figure 5 : chart of NextPM in between data (PM1, PM2.5 and PM10, respectively A, B and C)

Following, some examples of correlation curves obtained between NextPM sensors:

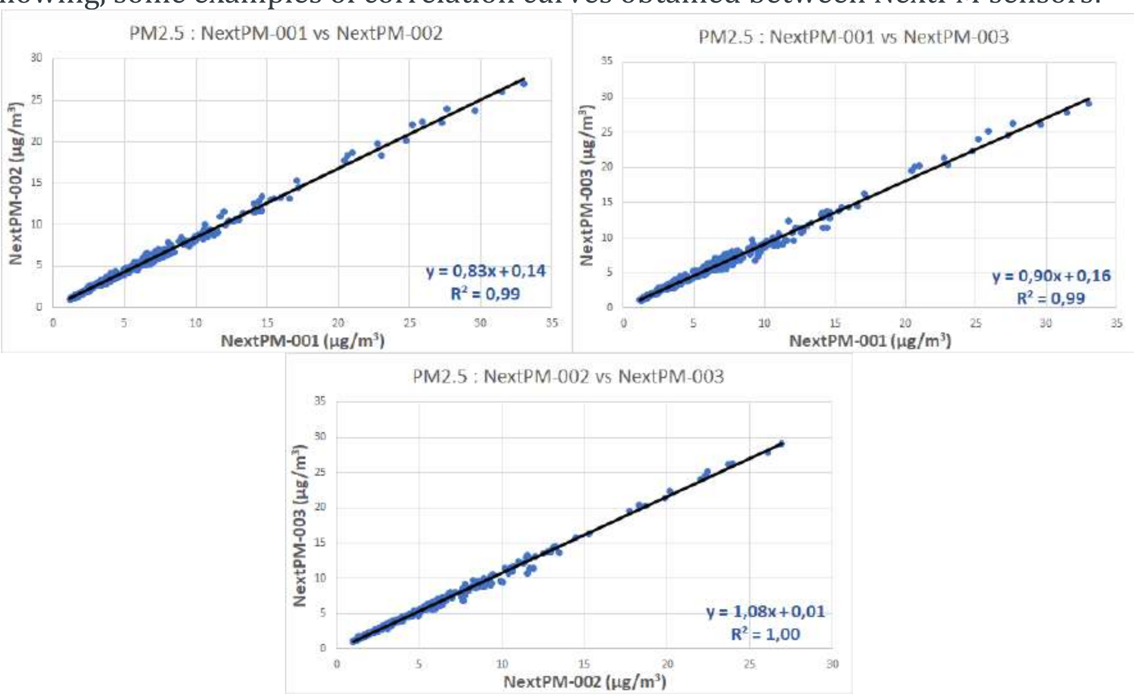


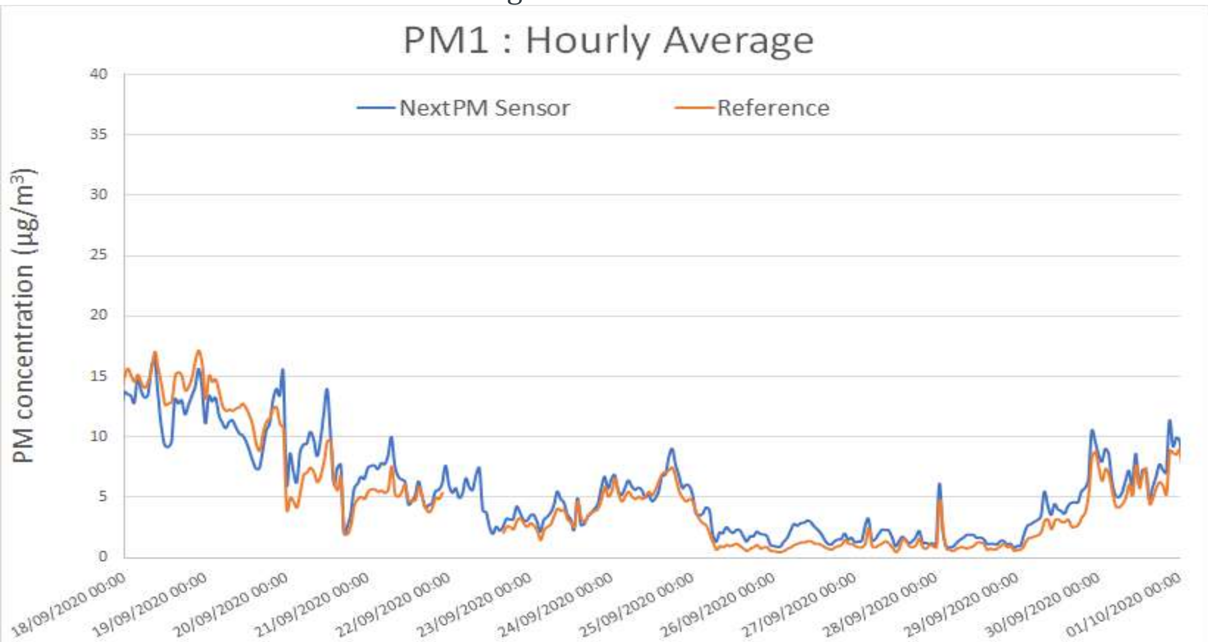
Figure 6 : NextPM hourly average in-between correlation (PM1, PM2.5 and PM10, respectively A, B and C)

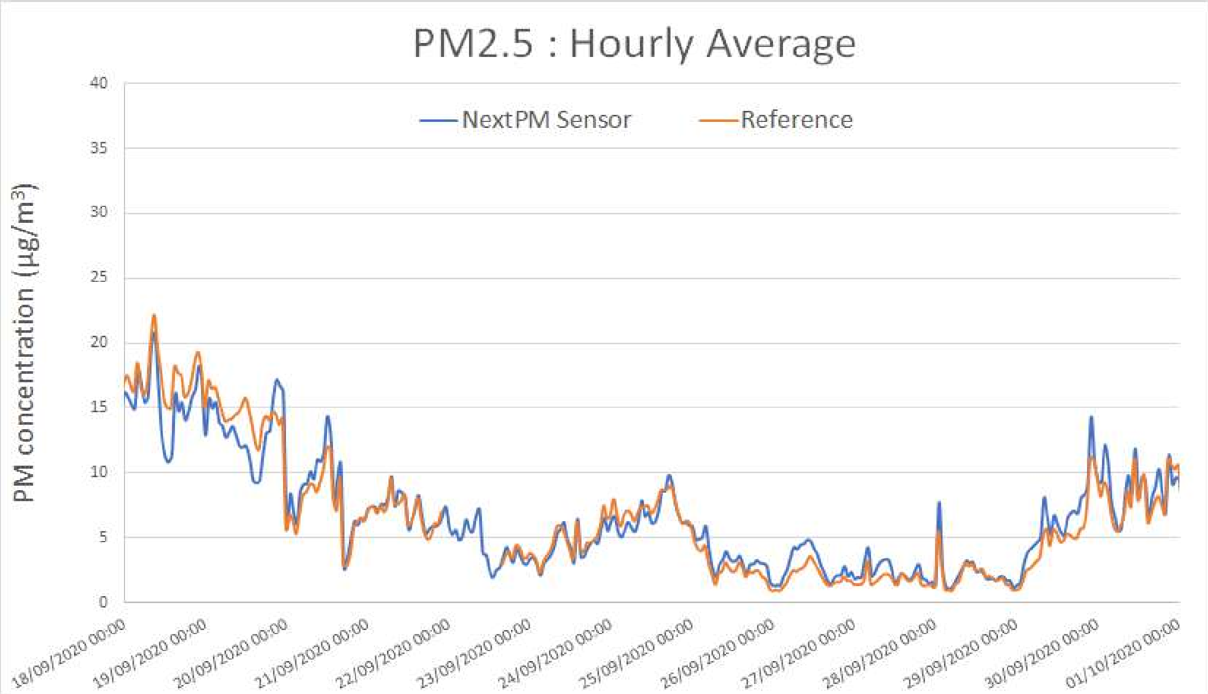
The correlation factor, the slope and the intercept show that the NextPM sensors have a **high in between reproducibility**.

2.1.3. Field comparison with certified instrument

The NextPM-003 has been compared to the certified instrument on site for two weeks. We compared the three PM fractions (i.e. PM1, PM2.5, PM10) using hourly means and daily means.

The results are shown in the following charts:





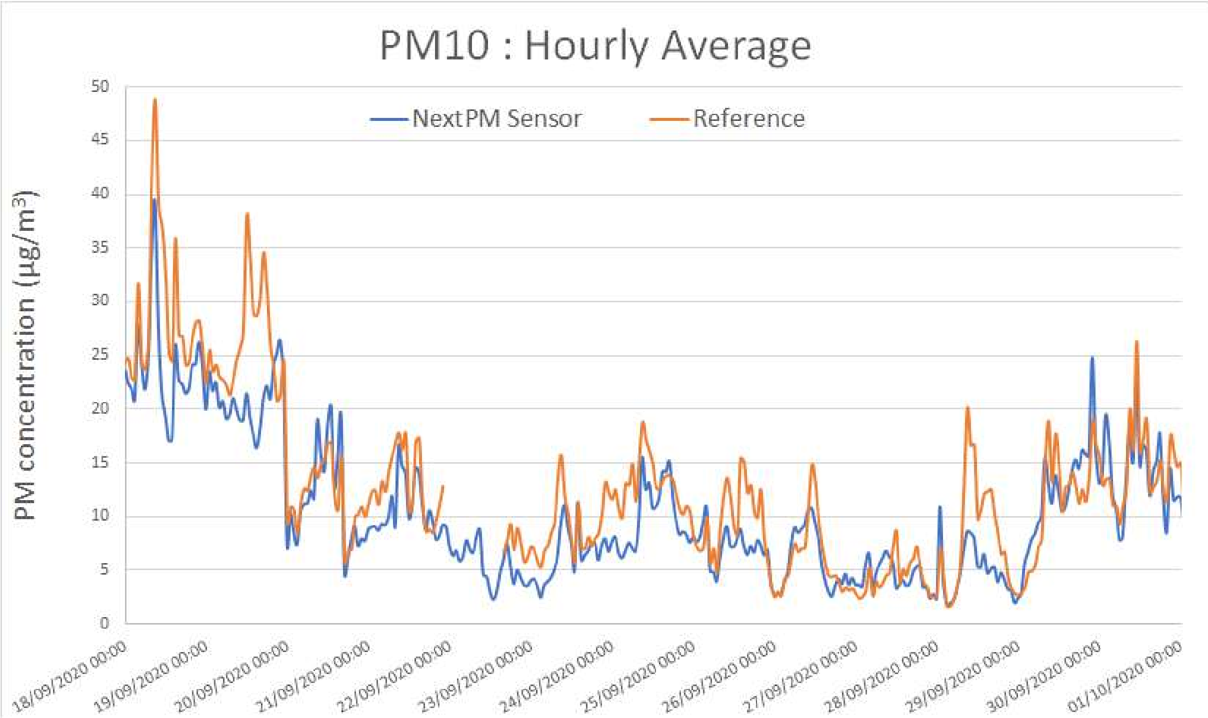


Figure 7 : Two weeks hourly average charts (PM1, PM2.5 and PM10, respectively A, B and C)

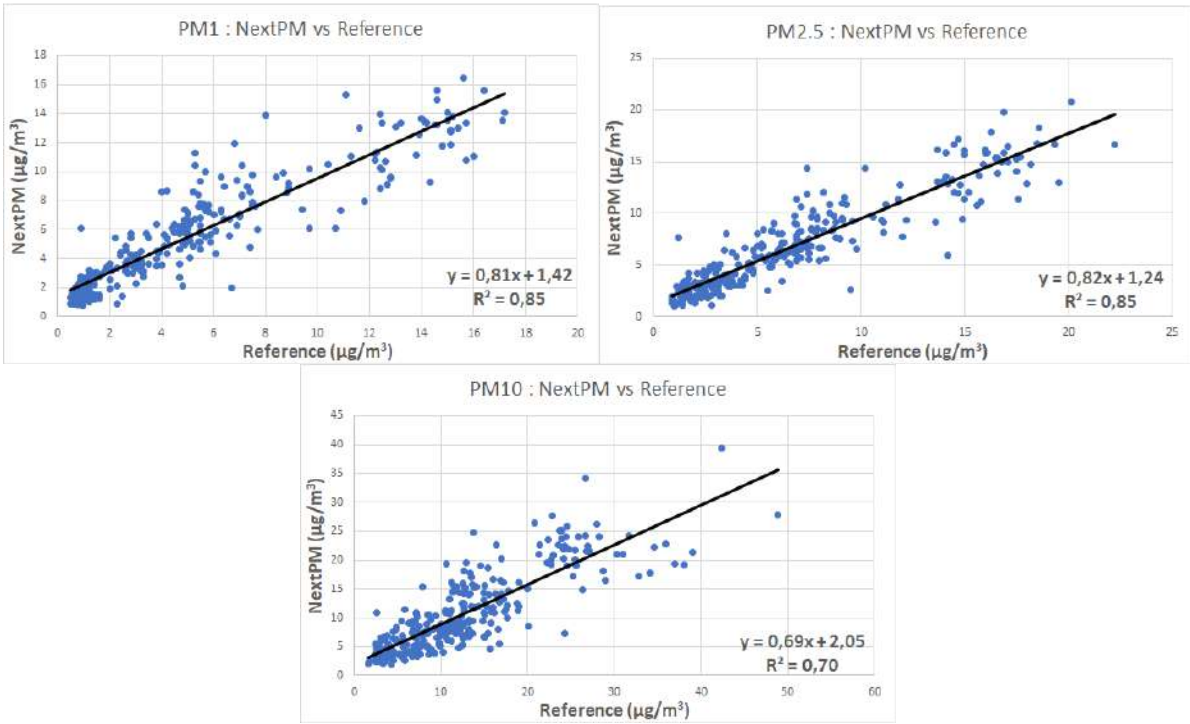
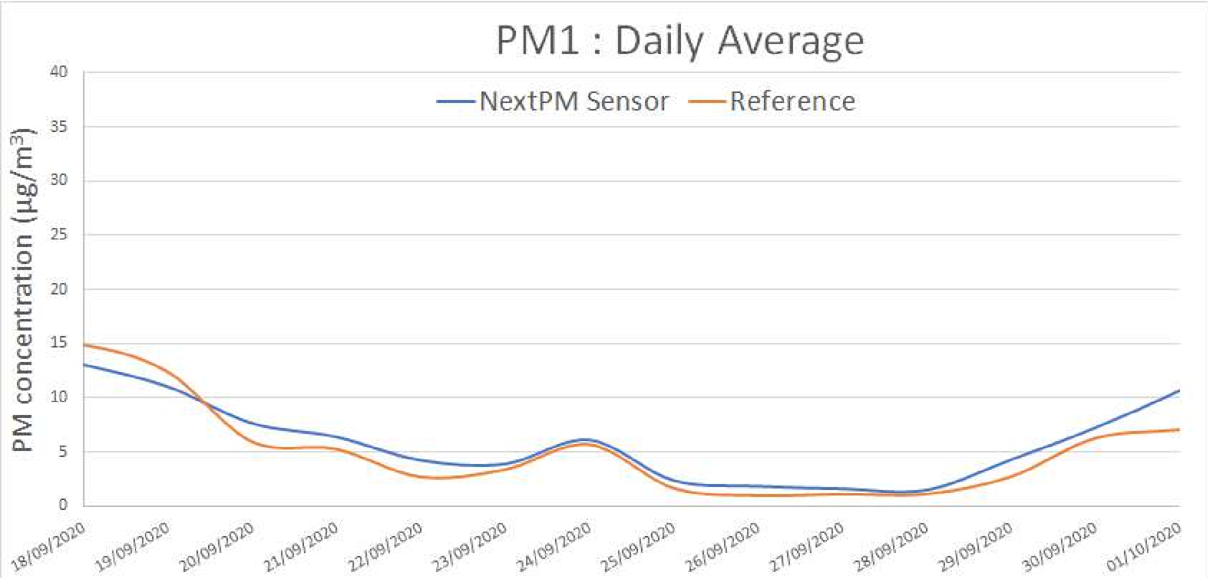


Figure 8 : hourly average correlations with reference instrument (PM1, PM2.5 and PM10, respectively A, B and C)


PM1 : Daily Average
NextPM Sensor
Reference
PM concentration (µg/m3)
0
5
10
15
20
25
30
35
40
18/09/2020
19/09/2020
20/09/2020
21/09/2020
22/09/2020
23/09/2020
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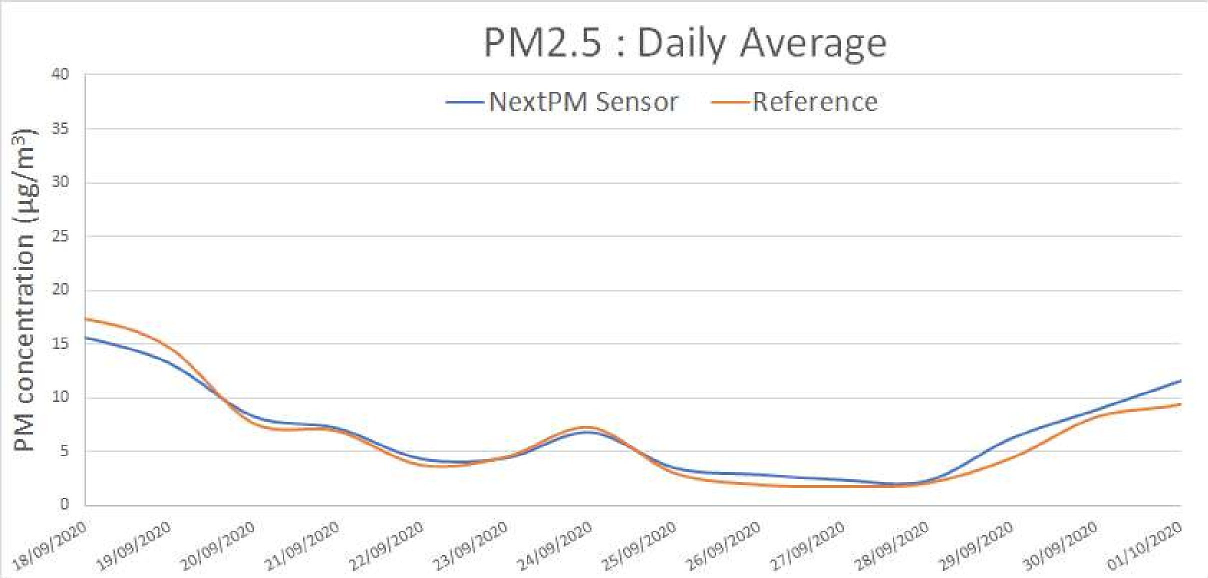
27/09/2020
28/09/2020
29/09/2020
30/09/2020
01/10/2020


PM2.5 : Daily Average
NextPM Sensor
Reference
PM concentration (µg/m3)
0
5
10
15
20
25
30
35
40
18/09/2020
19/09/2020
20/09/2020
21/09/2020
22/09/2020
23/09/2020
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29/09/2020
30/09/2020
01/10/2020

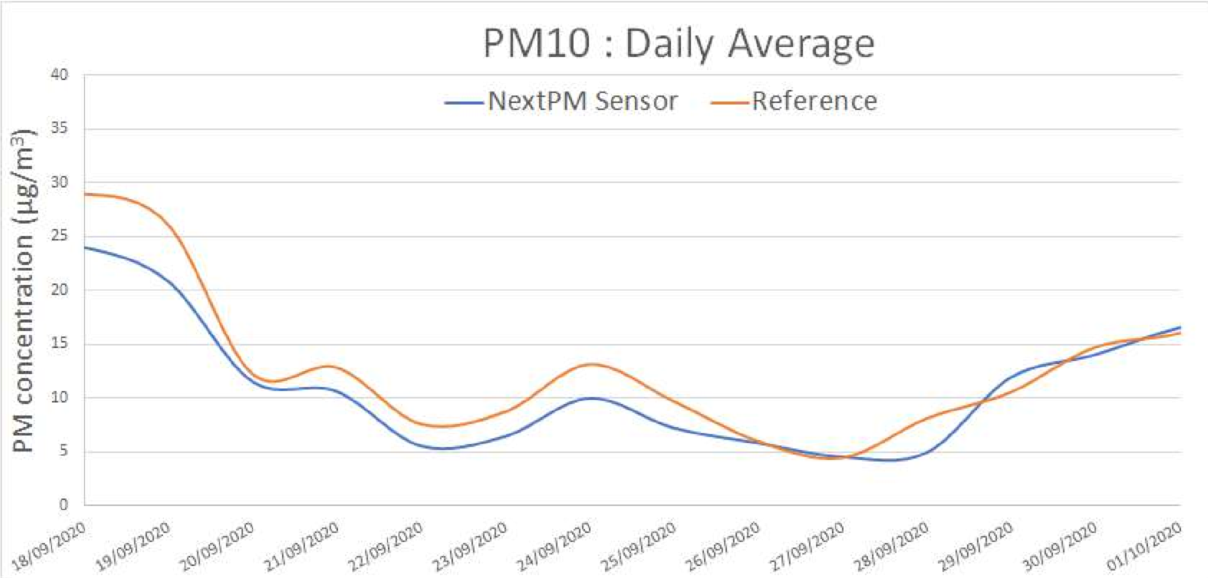


Figure 9 : two weeks daily average charts (PM1, PM2.5 and PM10, respectively A, B and C)

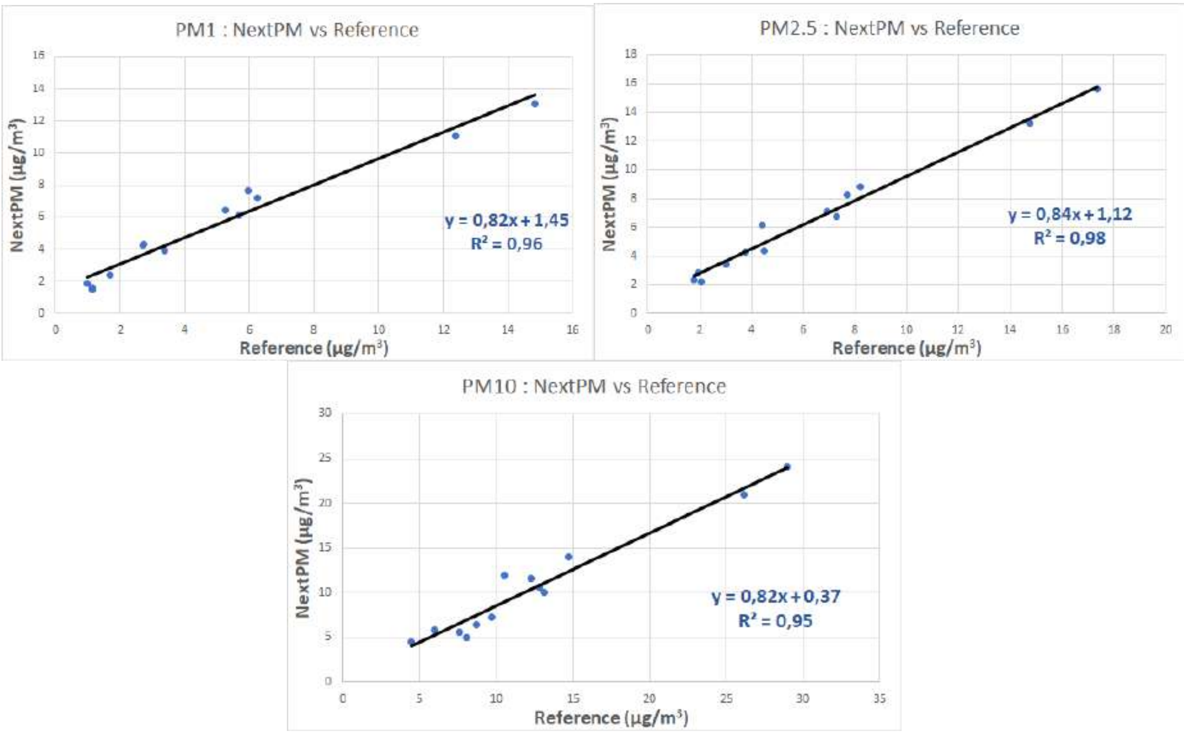


Figure 10 : daily average correlations with reference instrument (PM1, PM2.5 and PM10, respectively A, B and C)

The results are summarized below:

		Fractions		
Conditions	**Parameters**	**PM1**	**PM2.5**	**PM10**
NA	Data recovery	100%	100%	100%
In between reproducibility	r^2	0,997 +/- 0,002	0,99 +/- 0,01	0,97 +/- 0,02
	Slope	0,9 +/- 0,1	0,9 +/- 0,1	0,9 +/- 0,1
	Intercept	0,08 +/- 0,06	0,10 +/- 0,08	0,6 +/- 0,4
1-Hour average compare to Reference	r^2	0,85	0,85	0,70
	Slope	0,81	0,82	0,69
	Intercept	1,42	1,24	2,05
1-Day average compare to Reference	r^2	0,96	0,98	0,95
	Slope	0,82	0,84	0,82
	Intercept	1,45	1,12	0,37

Table 1 : summary data from two weeks correlation

2.1.4. Discussion

Using this kind of exploitation method, the NextPM **correlation coefficient** with the certified analyzer for PM1, PM2.5 and as well PM10 is very high, **> 0.95**. This means that the NextPM could be able to measure particles as well as a reference instrument, almost 1000 times more expensive, for daily use.

Even with hourly mean the correlation coefficient is still high, around 0,85 for PM1 and PM2.5 and 0,7 for PM10. Thus, NextPM is also able to give a real time value near a certified gravimetric method. The slope average around 0.8 shows that NextPM slightly underestimated the PM concentration.

This first step in the study of NextPM field performances shows that the technology is **very reliable** and has a **high measurement accuracy**, near the performances of the certified method in an uncontrolled environment. Also, the technology has almost the same performances for the real time measurement of the three PM fractions, PM1, PM2.5 and PM10. The accuracy on PM10 is slightly lower because the sampling is very important for this fraction while NextPM has a limited airflow and air sampling direction.

2.2. Two months performances

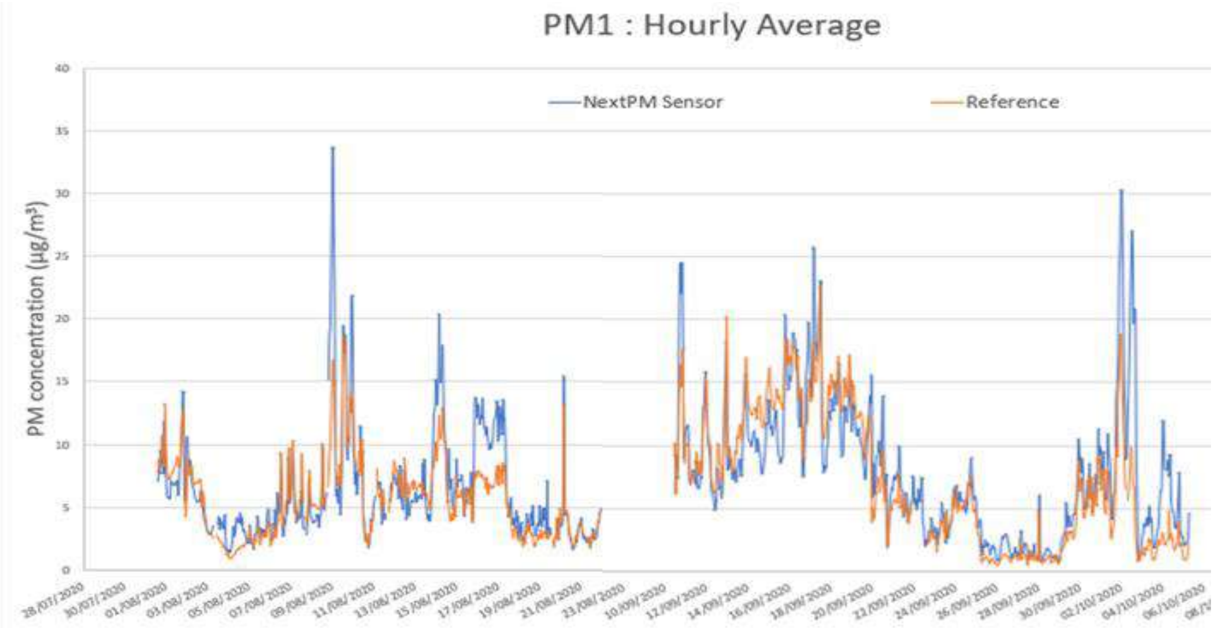
The following results are the whole set of data obtained during this first campaign. Some data are missing between the end of August and mi-september because the power supply wires of the sensors had been cut.

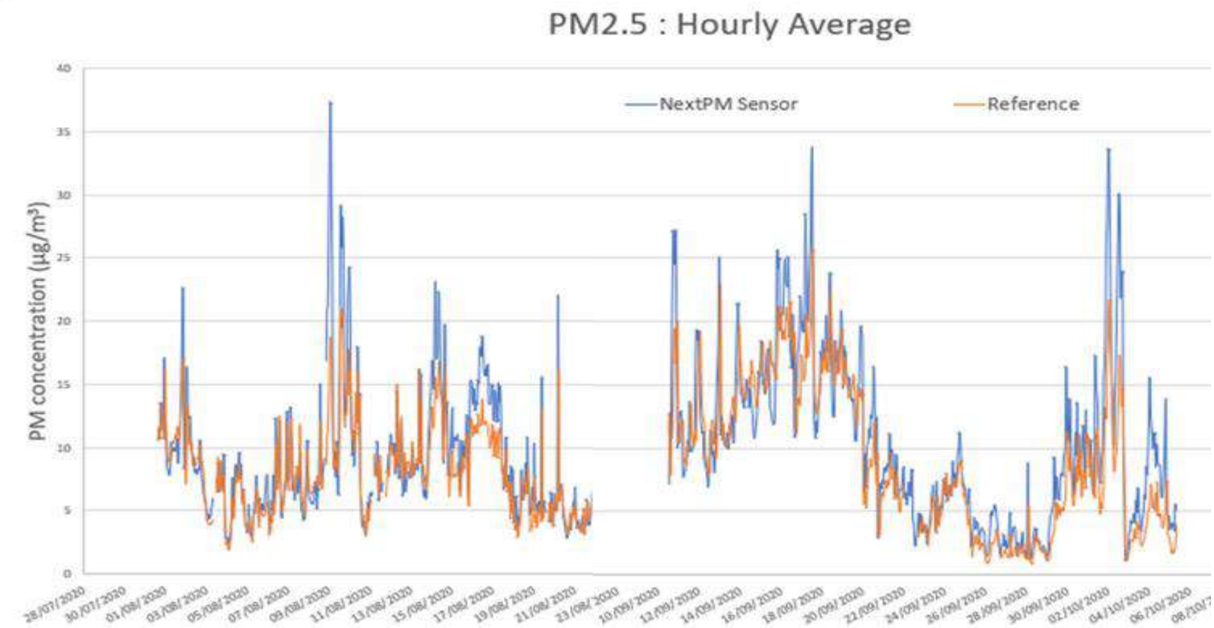
We will first show the charts of hourly average for PM1, PM2.5 and PM10, then the correlation between the NextPM and the reference method. The hourly average data had also been processed by week in order to check if the correlation were still or if it changed because of an unknown factor.

Finally, we will show the daily mean that is still the reference in Europe. As for the hourly mean, we will compare the correlation obtained during different periods. The period will be a one-month period in order to have enough data for a reliable correlation.

2.2.1. Results

We will first have a look on the hourly average:





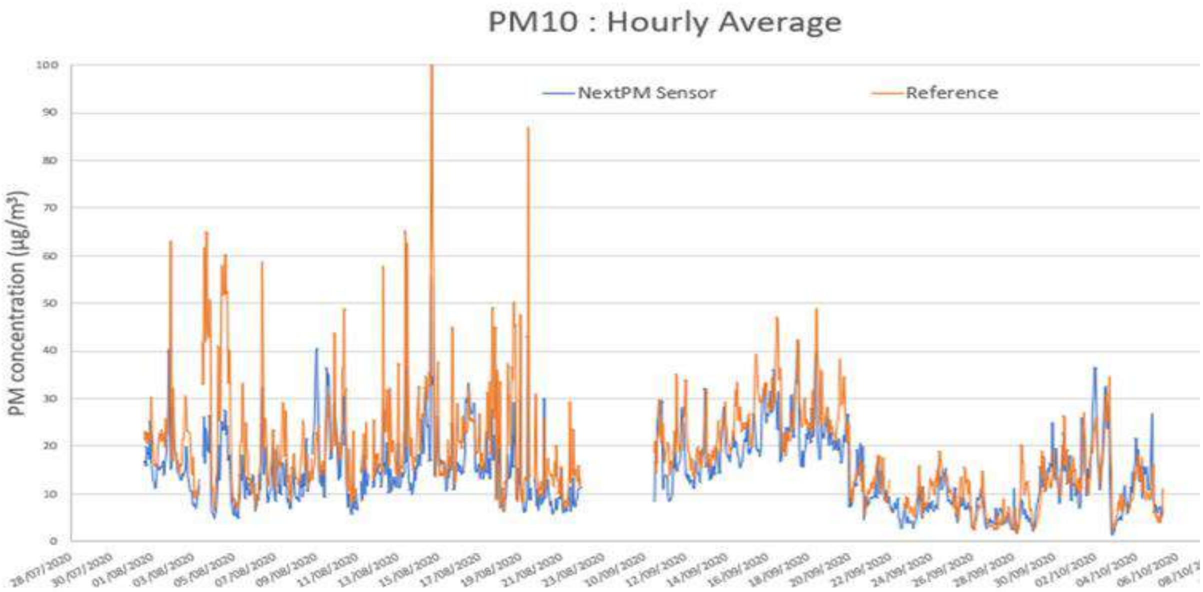


Figure 11 : complete set hourly average charts (PM1, PM2.5 and PM10, respectively A, B and C)

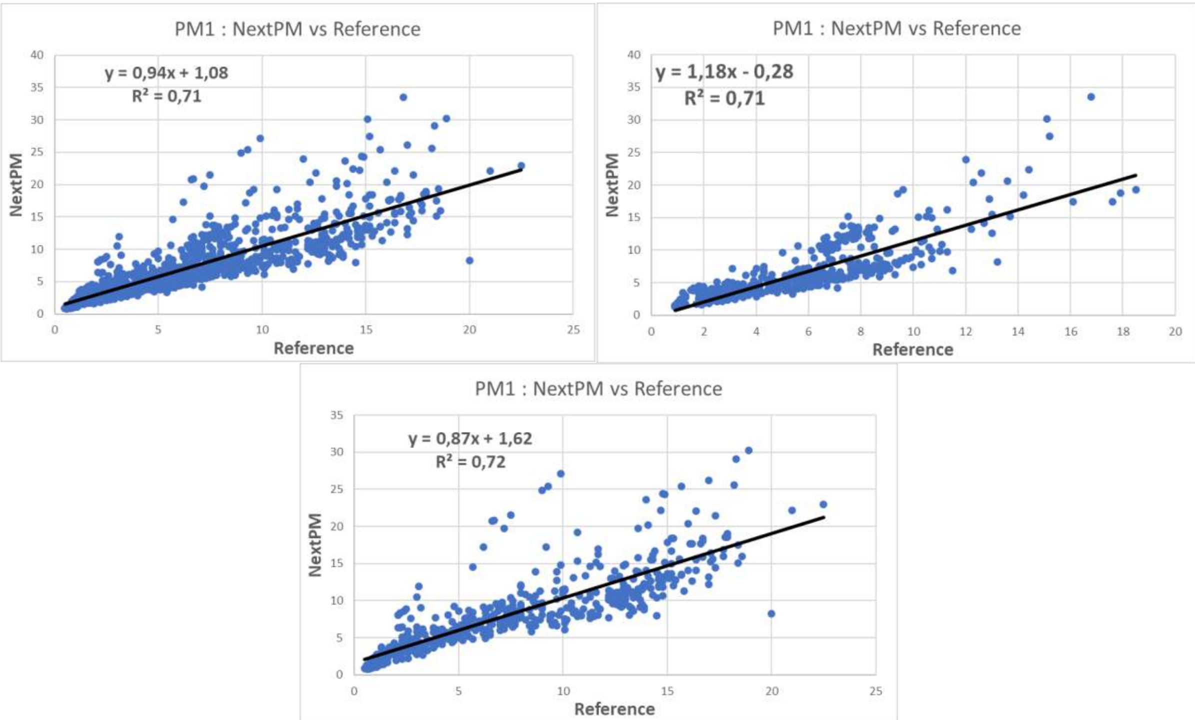


Figure 12 : PM1 correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

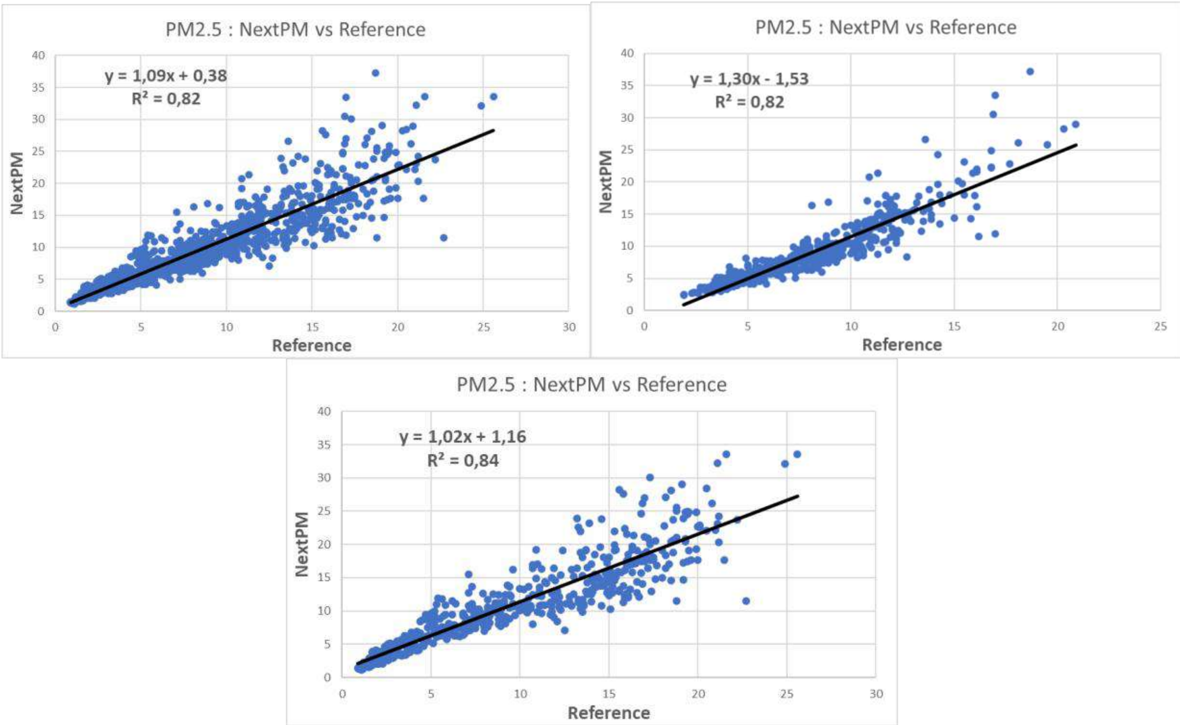


Figure 13 : PM2.5 correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

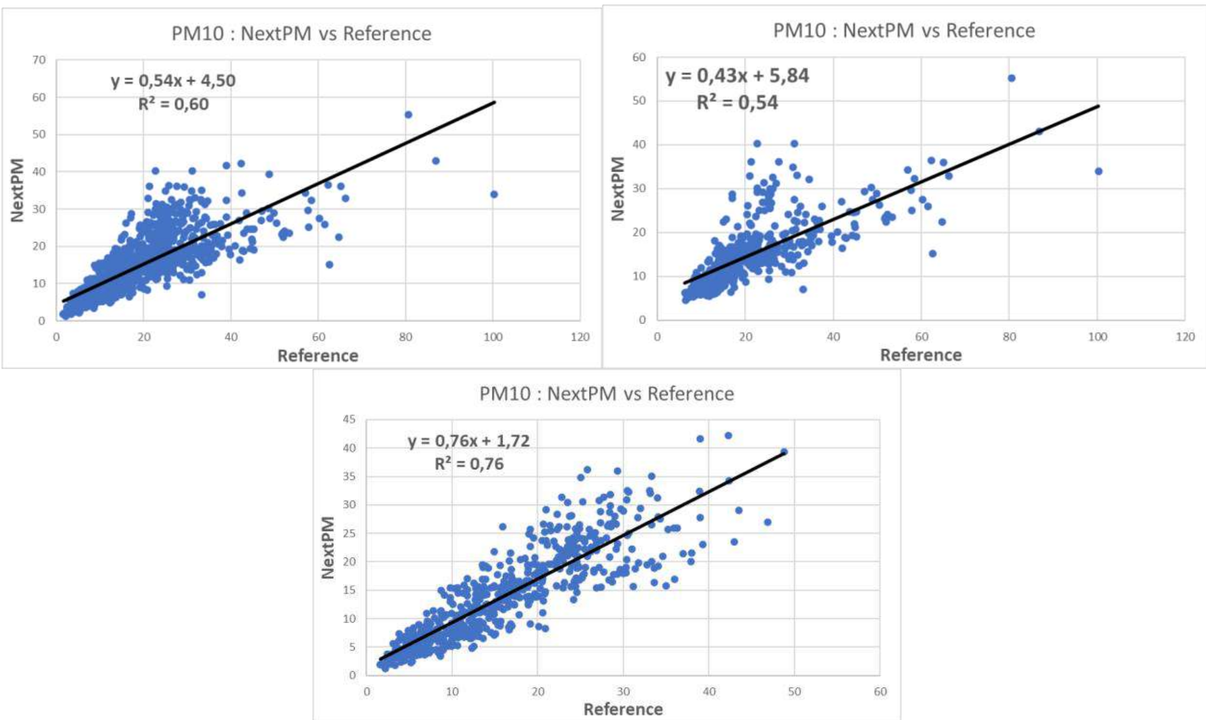


Figure 14 : PM10 correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

The following correlations were carried out over a period of one week:

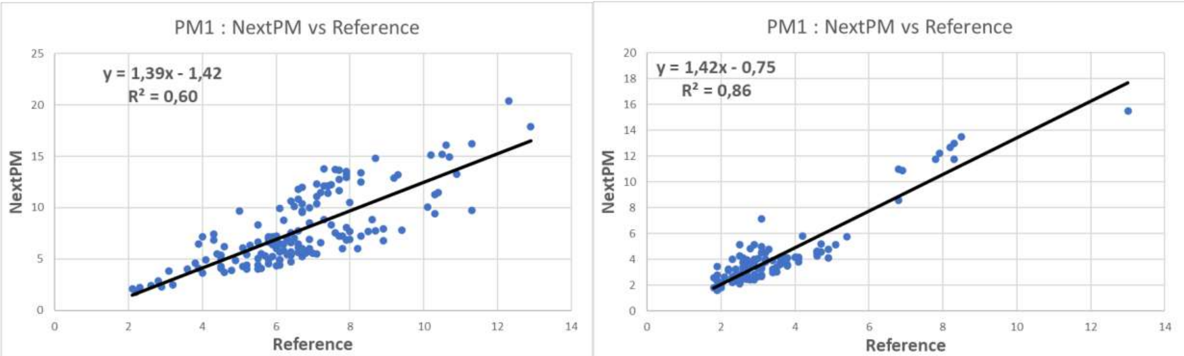


Figure 15 : PM1 correlation, worst (left) and best week (right)

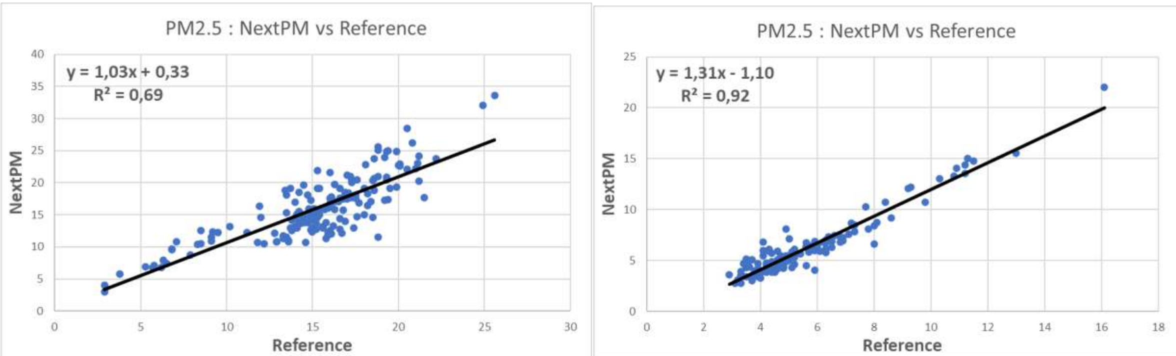


Figure 16 : PM2.5 correlation, worst (left) and best week (right)

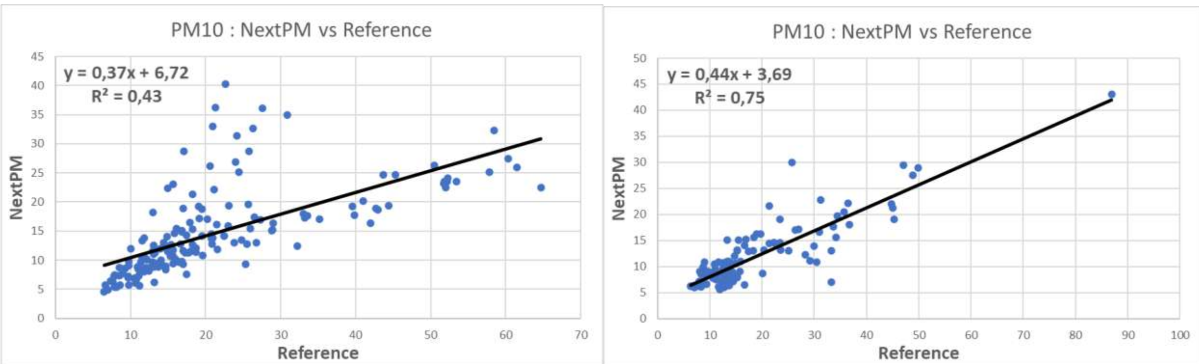
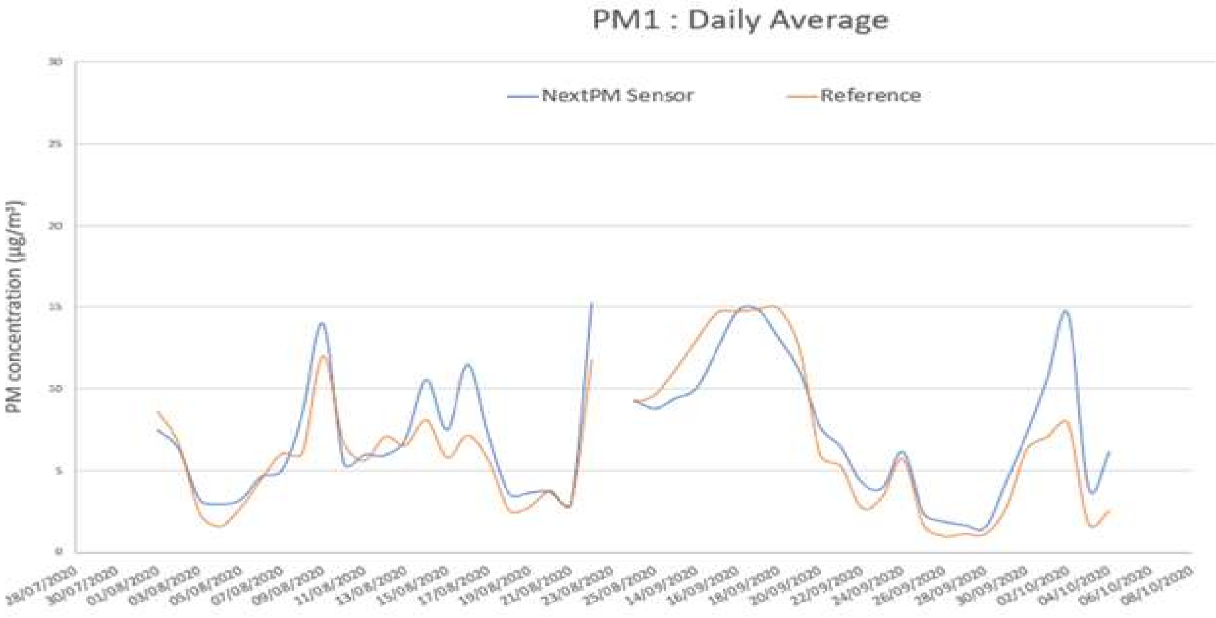
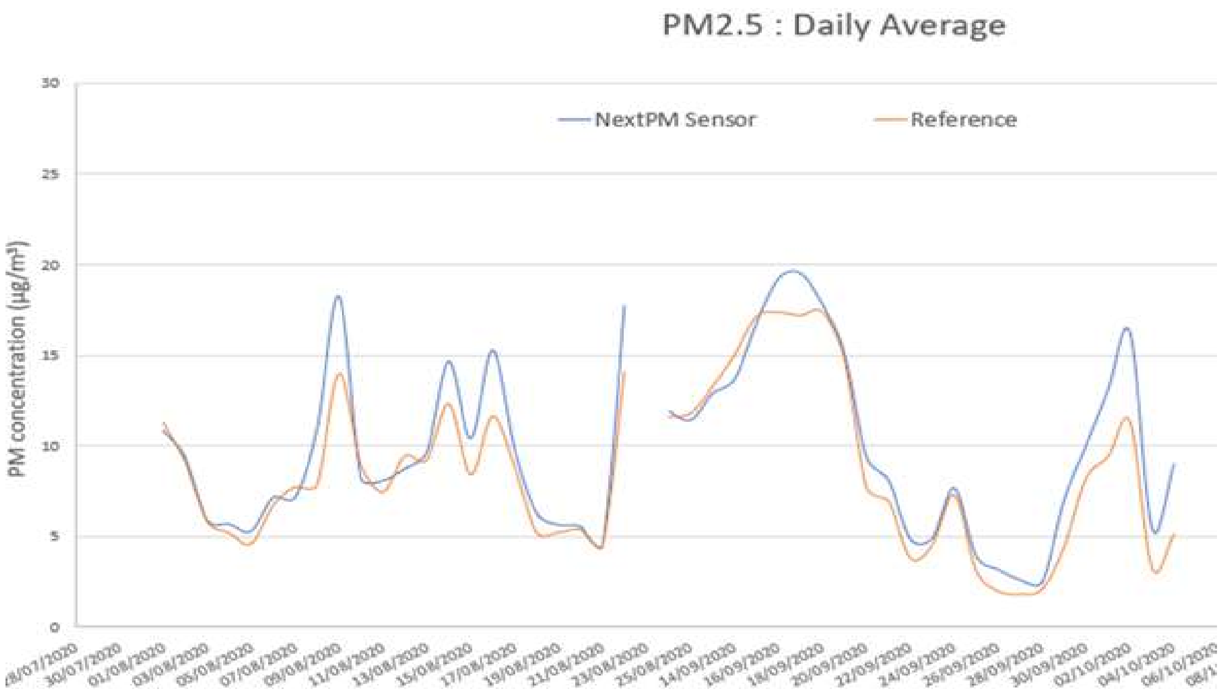


Figure 17 : PM10 correlation, worst (left) and best week (right)

The following results are the daily average:





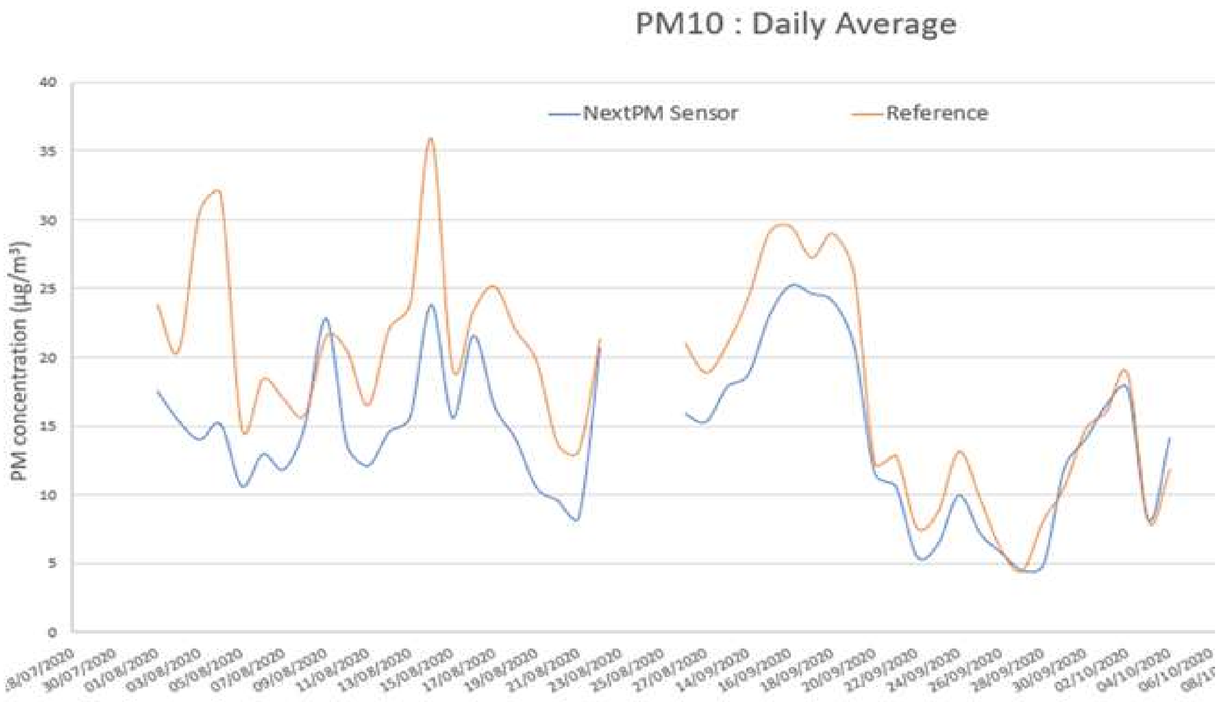


Figure 18 : complete set Daily average (PM1, PM2.5 and PM10, respectively A, B and C)

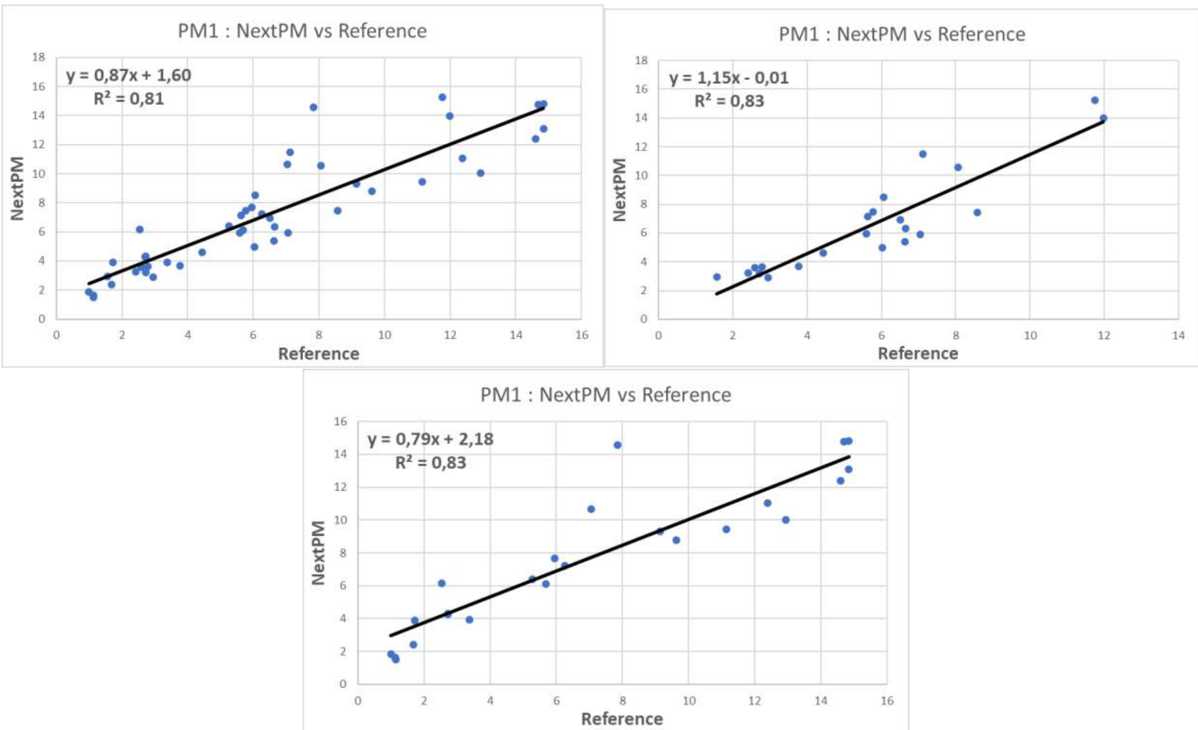


Figure 19 : PM1 Daily correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

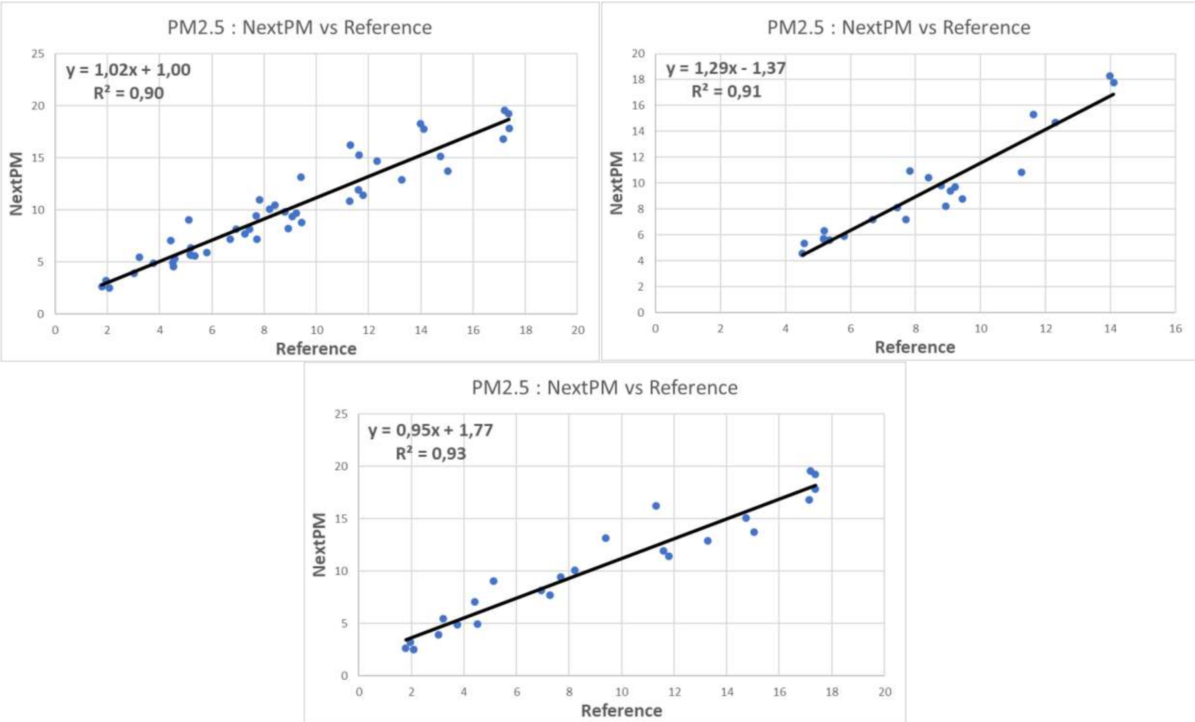


Figure 20 : PM2.5 Daily correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

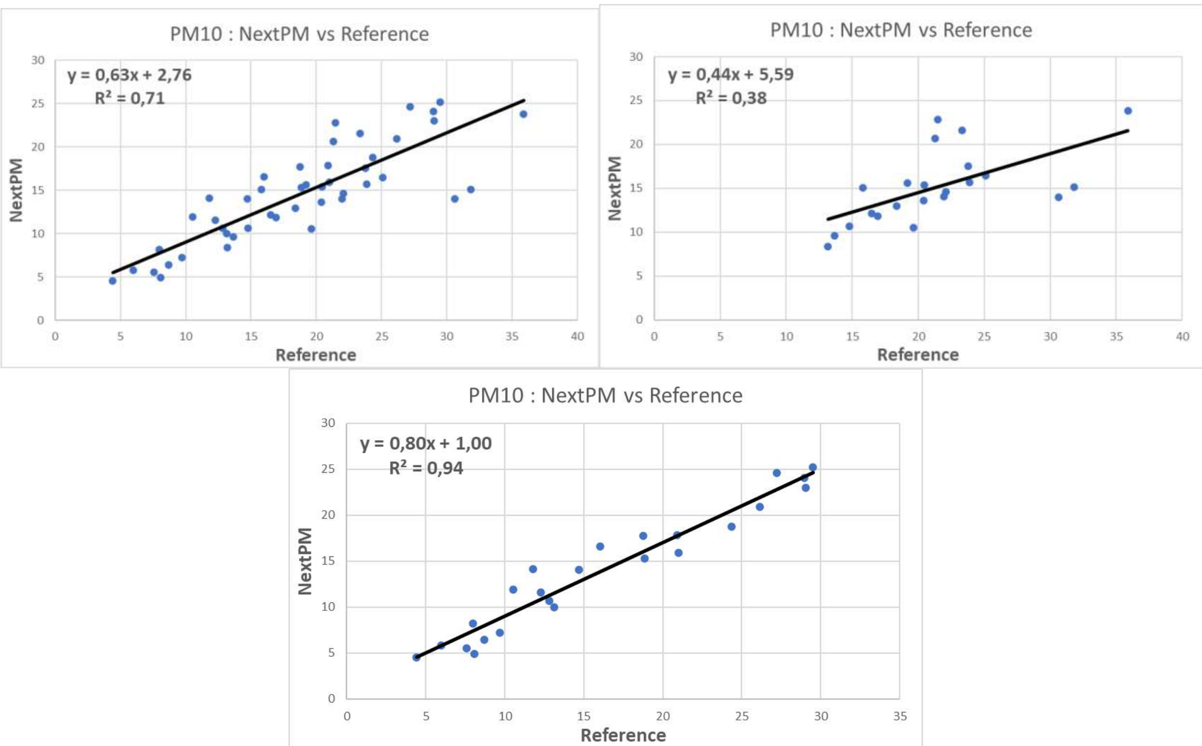


Figure 21 : PM10 Daily correlation (top left, whole period, top right, 1st period (August), bottom, 2nd period (Sept-Oct))

The results are summarized in the following tables:

		Fractions		
Conditions	**Parameters**	**PM1**	**PM2.5**	**PM10**
NA	Data recovery	100%	100%	100%
1-Hour average on complete set	r^2	0,71	0,82	0,60
	Slope	0,94	1,09	0,54
	Intercept	1,1	0,4	4,5
1-Hour average on part 1 (August)	r^2	0,71	0,82	0,54
	Slope	1,2	1,3	0,43
	Intercept	-0,3	-1,5	5,8
1-Hour average on part 2 (mid-Spet to mid-Oct)	r^2	0,72	0,83	0,76
	Slope	0,87	1,02	0,76
	Intercept	1,6	1,2	1,7
1-Hour average worst week	r^2	0,60	0,69	0,43
	Slope	1,4	1,03	0,37
	Intercept	-1,4	0,3	6,7
1-Hour average best week	r^2	0,86	0,92	0,75
	Slope	1,4	1,3	0,44
	Intercept	-0,8	-1,1	3,7

		Fractions		
Conditions	**Parameters**	**PM1**	**PM2.5**	**PM10**
NA	Data recovery	100%	100%	100%
1-Day average on complete set	r^2	0,81	0,90	0,71
	Slope	0,87	1,02	0,63
	Intercept	1,6	1	2,8
1-Day average on part 1 (August)	r^2	0,83	0,91	0,38
	Slope	1,15	1,3	0,44
	Intercept	0	-1,4	5,6
1-Day average on part 2 (mid-Spet to mid-Oct)	r^2	0,83	0,93	0,94
	Slope	0,79	0,95	0,8
	Intercept	2,2	1,8	1

Table 2 : summary table of the core set correlations

2.2.2. Discussion

The results show a strong correlation between the NextPM and the reference method for PM1 and PM2.5 (r^2 between 0,7 and 0,8 for hourly average and between 0,8 to 0,9 for daily average, considering the whole period). Moreover, the correlations are very stable over time for these fractions, same values for the part 1 and the part 2. Only the slope shows significant changes between these two periods, 1,2 to 0,9 for PM1 and 1,3 to 1,0 for PM2.5. This change could be the effect of the chemical composition of the aerosols.
If we go deeper to the study of these fractions, we can see that weekly correlations could also show significant differences. For PM1, the worst week shows a correlation to the reference method of 0,60 whereas the best one shows a correlation of 0,86. For PM2.5, the worst is 0,69 and the best is 0,92. These change in the correlation can be the consequences of several factors like:

- changes in the chemical nature of the particles during the week
- meteorological phenomena like strong wind
- effect of temperature or humidity on the response
- ...

These root causes will be studied during the second part of the project thanks to all the data available on site.
For PM10, we can see that the NextPM sensor always underestimates the concentration and that the correlation with the reference method is less stable than for PM1 and PM2.5. The mean value of the correlation over the whole set of data is 0,71, nonetheless, on daily average, this correlation could change from 0,38 during the first part of the campaign, which is a poor correlation, to 0,94 during the second part of the campaign, which is a very high correlation.
Once more, the analysis of the core data available on site will help us to understand this behavior.

A. Annex 1: Certificate of equivalent method for PALAS FIDAS

Umwelt Bundesamt

TÜVRheinland® Precisely Right.

CERTIFICATE

of Product Conformity (QAL1)

Certificate No.: 0000040212_02

Certified AMS:	Fidas® 200 S respectively Fidas® 200 for particulate matter PM_{10} and $PM_{2.5}$
Manufacturer:	PALAS GmbH Greschbachstraße 3b 76229 Karlsruhe Germany
Test Institute:	TÜV Rheinland Energy GmbH

This is to certify that the AMS has been tested and certified according to the standards VDI 4202-1 (2010), VDI 4203-3 (2010), EN 12341 (1998), EN 14907 (2005), Guide to Demonstration of Equivalence of Ambient Air Monitoring Methods (2005), EN 15267-1 (2009) and EN 15267-2 (2009)

Certification is awarded in respect of the conditions stated in this certificate (this certificate contains 10 pages).
The present certificate replaces certificate 0000040212_01 of 30 September 2015

TÜVRheinland CERTIFIED
Suitability Tested
Complying with 2008/50/EC
EN 15267
Regular Surveillance
www.tuv.com
ID 0000040212

Publication in the German Federal Gazette (BAnz.) of 26 August 2015

This certificate will expire on: 31 March 2019

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TÜV Rheinland Energy GmbH
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