A Q M O

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AQMO

Air Quality and MObility

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D2.2

Report on the full platform and results of the measurement campaign

Final

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References and Applicable Documents

[0] AQMO – Air Quality and Mobility, http://aqmo.irisa.fr/

[1] AQMO deliverable D2.1 Report on the preliminary sensor platform

[2] AQMO deliverable D6.1, AQMO platform integration

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List of Acronyms and Abbreviations

Below is an extensive List of Acronyms used in previous deliverables.

AQMO	Air Quality and Mobility
API	Application Program Interface
GSM	Global System for Mobile communications
IoT	Internet of Things
IP	Internet Protocol
LoRa/LoRaWAN	Long-Range Wide Area Network
TRL	Technology readiness level, a method for estimating the maturity of technologies.

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Executive Summary

Air quality in urban areas and the impact of pollution on the citizen health has risen in the past decades as a major concern, and the public administrations made huge investments in the evaluation of this risk. Nowadays, air quality monitoring is done at the city scale using very accurate but costly fixed measurement stations placed in a few strategic locations. The AQMO air pollution measurement campaign aims at extending the current measurement approach thanks to the deployment of a mobile micro-sensor platform in the Rennes metropolitan area, at a scale more representative of the scale variability of air pollution, allowing to catch transitory situations that could have been missed neither by surveillance stations, nor by simulations, which results depend on the representativeness of source of emissions they are using.

Between March and December 2020, ten sensors measuring the fine particle matter $PM_{2.5}$ have been gradually installed in two fixed locations and eight metropolitan buses. At the time of this report, these sensors have produced a large amount of data with more than 1.2 million measurements for nearly 2000 aggregated days. The total area covered is around 672 km^2. Most of the measurement data happened on a smaller zone of 60 km^2. Due to a late installation of the mobile platform, linked to the Covid-19 lockdown and the induced limitations on the access of working facilities, the current time and geographical coverage need to be improved. The platform is still running and producing data.

Figure 1, focus on two points of interest, one close to the railway technical center, the other one in a specific street. A high-level resolution of this picture (64Mo) is available at the following address: https://data.aqmo.org/db/2020-12-28-AqmoAllperiod20m-avgPM25-center-HR.png.

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The measurement campaign provided us promising technical and scientific results that led us to continue the experiment. The chosen micro-sensor – the AlphaSense OPC-N3 – is precise when we compare its measurements in different conditions. Illustrated in Figure 1, they have already shown that they could detect interesting transient $PM_{2.5}$ pollution variations all over the city. Among them, we identified at least two unexpected points of interest that would require more investigations: a specific street in the city, and an industrial area close to the railway technical center. We plan to improve and extend our measurements capacity for the next months, and perform more advanced data analysis – especially on data accuracy. Combined with simulation capabilities, we expect to enrich our knowledge on the fine particle pollution dynamic in the Rennes metropolitan region. These pilot experiments and methodology could be reused over many metropolitan areas, over France, Europe or elsewhere across the world, providing both interesting scientific data for researcher, understandable data (provided in an efficient way) for citizen (allowing citizen science and/or actions of mitigation of pollution sources and pollution exposure) and policy makers to take informed decisions.

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1 Introduction

The purpose of the AQMO project is to provide an end-to-end urban platform able to operate air quality measurements, process them at the edge or on supercomputers, and analyze them for citizen and local authorities/decision-makers. The project deployed a set of micro-sensors (OPC-N3 [8] from Alphasense) that collected data during several months. At this stage, the air quality analysis data is limited to the fine particle matter below 2.5µm ($PM_{2.5}$). The measurement campaign was operated on two fixed locations and 8 metropolitan buses. A study of the sensor's characteristics and a comparison with regulatory instruments is available in the deliverable D6.2 [3] .

This report provides a quick overview of the deployment of the sensor platform, and a synthesis of the first data collected in 2020. The main data fields are:

- The PM2.5 value
- The measurement timestamps
- The GPS point or path of the measurement if mobile.

The data set description is available on the "Irisa data" web portal [6] .

The results presented in this report aims at helping the specification of future deployment and measurement campaigns. It does not aim at performing any assessment on the Rennes Metropolis air quality.

The remainder of this report is organized as follow: Section 2 proposes an overview on the measurement campaign conditions and limitations; then, the section 3 provides a description of the first data set collected. Section 4 gives a first analysis of the data collected and illustrate how the use of mobile micro-sensors complement the existing air quality monitoring system. We conclude with a set of perspectives for the AQMO platform beyond the CEF project.

2 An overview of the practical conditions of the measurement campaign

The experiment is based on a mobile sensor platform operating as a measurement node situated at the edge of the global AQMO platform. The platform takes in charge the deployment, the acquisition, the treatment, and the multi-modal communication of the measurement data with the project's servers. Its technical description may be found in details in the deliverable D2.1 [1] .

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2.1 Sensor locations: fixed and mobile

We have operated our measurement campaign with the deployment of 10 sensors. They are described below:

- Eight mobile sensors installed on the roof of buses. The Method department of Keolis selected those buses to get the largest spatial coverage possible. The sensor position is shown in Figure 2. A more detailed description of the installation of the mobile sensor platform is available in the deliverable D6.1 [2] .

Figure 2, Sensor positioned on the roof of one of the bus (black oval)

- Two fixed sensors. Figure 3 shows the positions of the fixed sensors on a map. These sensors are the same as the one used by AirBreizh in the Laennec measurement station [7] , and described in the D6.2 [3] . These sensors have been active during most of the measurement period (March to November 2020).

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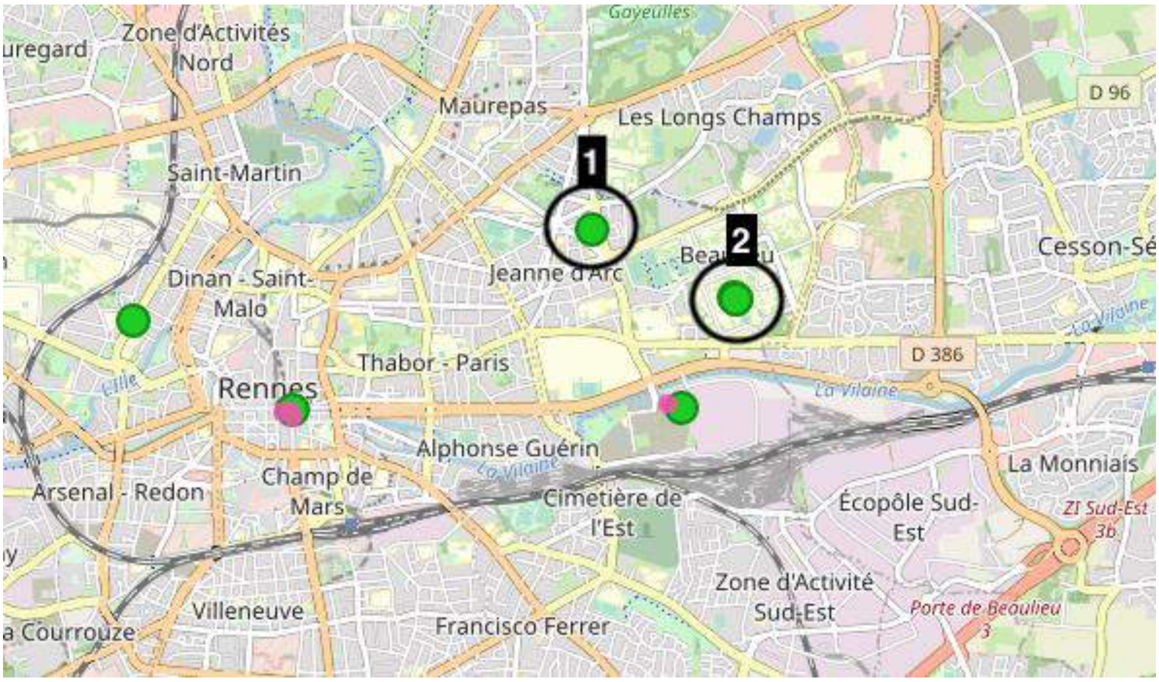

Figure 3, Two fix sensors: number one is Boulevard Charles Peguy – a road with traffic. The second one is on the University Campus – a place with very few vehicles.

2.2 Properties and limits of the measurement campaign

The measurement campaign relies on edge nodes of the AQMO mobile sensor platform currently deployed on eight buses that are selected for their coverage capabilities of the Rennes metropolitan area. Keolis appointed its specialists to select the bus that will maximize the geographical coverage of our campaign. Our experiments shown that this approach provided a strong advantage and was key in our capacity to optimize the collect of a maximum of data with a minimal deployment effort.

The main properties and advantages of the measurement platform are described below:

- The measurement campaign enabled to sample data over a large area including heavy urbanized locations, small villages beside the city, high speed roads with a dense traffic, narrow residential streets, and more. This level of coverage was made possible with only a few sets of sensors
- With a minimal installation setup, the project's measurement tests could start as soon as November 2018 (26^{th}). The measurement campaign is still ongoing with eight buses actively running nearly every day, all carrying the final version of our sensor platform. Among them two are facing problems due to the LoRa data recording procedure. During this period, measurement equipment was installed gradually, with a last step achieved in October 2020 with the addition of three new buses
- With the multi-modal communication infrastructure, the mobile sensor platform could be adjusted and partially developed on live buses. Faulty sensor management or hardware failure could be detected, and in some cases the maintenance scheduled

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- The AQMO project's objective was also to develop a platform with a high TRL level. Working with a company in charge of ensuring the operational transportation of the metropolitan population every day has proven to be a crucial asset to achieve a more mature and a more future-proof infrastructure. We consider that the platform is now ready for more advanced studies. This work could not have been achieved without the integration of work methodologies, on one side from the research laboratory, on the other side with the constraints of a maintenance team from a major industrial partner
- One important feature of the chosen micro-sensors is their high frequency measurement capability. Indeed, they are able to produce data every 10 seconds which make them adequate for mobility. On the other side, air quality surveillance instruments such as BAM provide one value every hour, or a quarter of an hour for the Fidas 200 sensor. Beside their size and cost, their measurement method (which is the basis for their accuracy) makes them impractical for mobile usage

However, the measurement campaign stressed our infrastructure and shown the limits of our approach in some cases. We faced three kinds of problems: technological limitations, organizational limitations, and theoretical limitations. If the two first limitations can be solved by the proper investments, the last one is inherent of our approach.

- Technological limitations were mostly related to the coverage of our communication infrastructure

The consequence is a set of minor geographical and temporal discontinuities in the measurements of pollution values.

Main pollution data are recovered by the LoRa network [10] . We have used a network with a partial and varying coverage of the city. This limitation shall be removed when we will have totally migrated to the more extended metropolitan-own LoraWan network deployed all over the metropolitan area.

In addition to the LoRa limitations, a set of dysfunctional installation on LoRa communication devices led to the misrecording of some measurements. This can be seen in the total number of values recorded for some sensors. This problem is under correction.

As a consequence, we limited from the beginning the sensor value type to the $PM_{2.5}$, this value alone being enough for our objectives.

The LoRa network has a low bandwidth that prevent the continuous transmission of multiple sensor data. To mitigate this limitation during the measurement campaign, we found a cost-effective communication solution based on robust GSM/LTE mobile communications. The solution is based on low-cost subscriptions and on the usage of user-assembled OEM modems.

- Organizational limitations were related to the sanitary situation and the operational constraints associated to the management of buses in production.

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As a consequence, the mobile sensor platform started to operate partially and late compared to the planification made at the beginning of the project.

The main objective of the first year of experimentation was not to perform an air quality assessment but to test the platform installation and robustness, to assess the sensors' characteristics, as well as the LoRa connection. These tests were successful in two ways. Firstly, they helped in defining the proper organization and methodologies for the installation of mobile sensor modules in buses. Secondly, we could determine the proper communication system after several attempts with different broadband mobile modems.

During the second year of experimentation, the installation of mobile sensor modules in the metropolitan buses had to be done in conjunction with the maintenance department of Keolis, and required the installation of a dedicated power line and of a specific 3D printed body to hold the sensor on the roof. With the Covid-19 crisis and related work restrictions, we could not prepare all the buses as originally planned in the second quarter of 2020.

- Theoretical limitations are related to the way buses are managed in a metropolitan city, and on the limitation of sensors.

As a consequence, beyond the limitation of the geographical coverage, we cannot fully control and thus guaranty the time coverage of the air pollution in the city.

In the Rennes metropolitan transportation network, a single bus does not operate 24h/24, but only between 6 to 16h hours a day. However, they are used nearly every day. Each day the bus is generally allocated to a different line, with a time range potentially covering the full day, and even the night. With 8 active buses, it is not possible to often have a coverage during the night – for instance we had none in November – but the probability to have measurements every day during working hour is much higher. The higher the number of instrumented busses, the higher the probability of getting a full day coverage. It could be also possible in the future to give priority to a bus with sensor for a night line, if one is available.

Considering the laser technology used in our micro-sensors, we are not able yet to evaluate the measurement accuracy of the particles' matter density.

As shown in AQMO deliverable D6.2 [3] , micro-sensors are not scientific measurement apparatus. Alpha-sense's OPC-N3 [8] sensors are not accurately capturing the pollution for small value. This limitation has also been demonstrated by an independent study done by the SC-AQMD in the US [9] . This is not an issue for our purposes since we aimed at detecting point of interest where the air quality is degraded.

Despite the limitations in our approach and the experimental side of the platform, **the measurement campaign produced a significant amount of pertinent data that shall help in giving a trend of the pollution in the city area**, and eventually to provide points of interest that our partners or the metropolis will be able to study for a better management of the air pollution. This could also help designing the better place for static sensor, within Rennes or for other cities.

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2.3 The phase test of the data measurement campaign

The final measurement campaign done in 2020 was preceded by a testing measurement campaign combined with the deployment and the evaluation of the mobile sensor platform on two metropolitan buses. The campaign was done with two AtmoTrack [11] devices placed on the roof of two buses that have been later used for the main phase of the experiment. The data produced during this campaign validated the spatial coverage capacity of the bus lines, and the communication capabilities of our systems.

The data coverage of this experiment was around 140 km^2, e.g more than twice the surface of the city center area, but still five times lower than the total coverage achieved in the main experiment in 2020. All combined, a total of 372 days of measurements was achieved during the phase test, accounting for 20% of the initially defined target measurement period. The pollution values measured during this period, using the AtmoTrack data, are not considered in this report.

2.4 Elements of a drone-carried data measurement experimentation

In complement to the measurement campaign described in this report, a few experiments have been done in order to evaluate the possibility to carry the mobile sensor platform on a drone. The idea is to evaluate the consequence of replacing the bus by an energy and weight sensitive carrier.

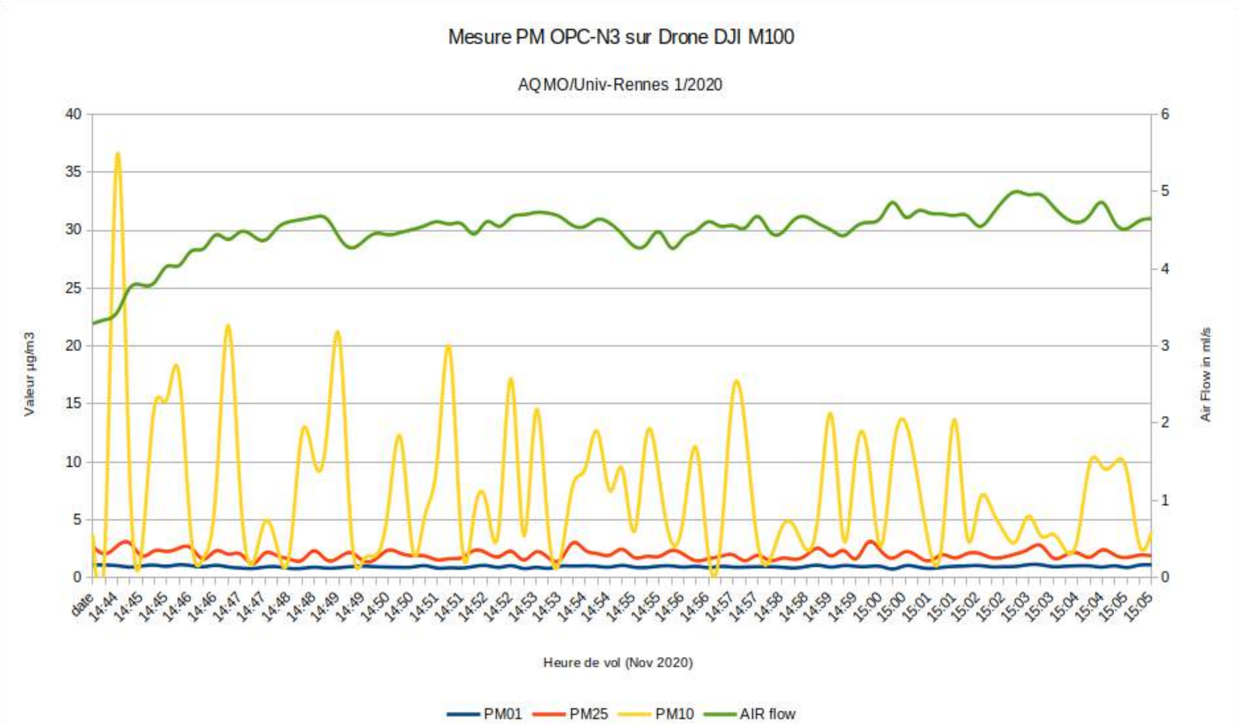

Figure 4, OPC-N3 measurements using a drone. We can see the low level of airflow (volume of air analysed per measure) and the particle measurement spike at the beginning of the experiment corresponding to the taking-off time. Once in altitude, the measurement seams stable.

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A significant part of the mobile platform has been properly setup and configured on the drone and two Alpha-sense OPC-N3 sensors were installed on its sides. With a total weight of 3.5kg, the autonomy has been estimated to 20 min. Figure 4 displayed the measurements made during one flight.

Experiments with drones are also ongoing at a larger scale by the AtmoVision [12] project in the Grand-Est region. Their result shown that this method is effective in the measurement of air pollution in locations that are difficult to access. In collaboration with AirBreizh, further tests of air-pollution measurements using drones are scheduled in 2021.

3 Data collected in 2020

Data collected during the main AQMO measurement campaign contained several information related to the mobile sensor platform: the location of the platform carrier (the bus), the communication conditions (in particular the LoraWan network), and – of course – the pollution value itself. It shall be considered that more data could have been added during this period such as temperature, humidity, PM_{10}, other communication conditions. They were not managed for technical reasons, mainly to stand with a “simple” design of the multi-modal communication system. Considering their pertinence for the public health, the choice was made to focus on the $PM_{2.5}$ values. The values are sent via the LoraWan network while the GPS location of the bus is transmitted via the mobile GSM network. The extended set of parameters could be easily considered in the future.

3.1 Topology and description of the data sets produced during the campaign

All the data sets produced by the mobile sensor platform are compliant with the data format specification described in the document "AQMO Sensor Platform, The Sensor Data Interface" [12] . The data is structured around a strict and mandatory spaciotemporal approach using the *GeoJson* format [14] . It is based on a geographical location annotated with a set of properties all associated with a time/date specification. A mandatory "station" property provides the minimal information about the date and the origin of the data. The sensor data format follows the *SenML* format [15] [16] [17] and provides a uniform way to model and perform queries on these data.

The two main data sets are the following:

- A data set containing the station location entries.

Stations are either in fixed locations or on mobile carriers. They are the basic data blocks for all AQMO data set elements. They are composed of:

  - A *GeoJson* geographical description using a "*Point*" coordinate
  - A single "*station*" property with a start date, a finish date, and a station policy (either "*fixed*" or "*mobile*" at this stage)

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Figure 5, picture of the fixed sensor module in IRISA Bâtiment 13

Station location entries are produced by an independent instrumentation of the sensor's carriers. A fixed sensor is illustrated in Figure 5. In the case of drones, its telemetry could be recorded using this method. The list of currently active stations is described in Table 1.

Table 1, List of stations currently registered in the AQMO mobile sensor platform (the 23/12/2020).

Station Name	Type	Carrier	# locations	First sampling date
LOPY-AQ03	Fix	Irisa Bât13	29	2020-03-18T19:47:53.797+00:00
parautarin02	Mobile	Bus n°742	342 921	2020-03-19T05:54:19.392+00:00
LOPY-AQ09	Fix	Bvd Charles Peguy	1	2020-05-14T12:35:37.486+00:00
parautarin30	Mobile	Bus n°916	149 766	2020-05-28T03:20:07.000+00:00
parautarin31	Mobile	Bus n°241	80 514	2020-05-28T16:17:45.000+00:00
parautarin33	Mobile	Bus n°915	99 979	2020-06-24T18:45:59.000+00:00
parautarin34	Mobile	Bus n°743	113 848	2020-06-24T21:51:48.000+00:00
parautarin32	Fix	Bureau13	80 326	2020-07-24T16:45:58.000+00:00
parautarin35	Mobile	Bus n°700	151 116	2020-10-22T08:13:23.640+00:00
parautarin36	Mobile	Bus n°701	115 902	2020-10-22T10:00:23.811+00:00
parautarin37	Mobile	Bus n°924	293 856	2020-10-22T14:37:44.180+00:00
Total	Number of unique locations: 1 428 258			**1895 (1394 mobile) aggregated days**

- A data set containing sensor measurement entries

Sensor measurement entries are natively built using the *SenML* format containing the measurement date and all the sensor data. For a given time, we know the association of each sensor with a given station. So, when a sensor data is received, sensor entries are built dynamically by the combination of all station location entries matching the measurement period. A new location entry made of either a "*Point*" or a "*LineString*" in the *GeoJson* terminology. The resulting sensor entries is the following:

- A *GeoJson* Geographical description using either a "*Point*" coordinate, or a path made with a "*LineString"* set of coordinates
- A fusion of the station properties
- A list of SenML sensor data values stored as properties

The sensor data values mention a timestamp in the time range of the station period. This abstract representation of mobile sensor data enables a free composition and sensor data entries. The list of currently active sensors is described in Table 2. We can notice that we currently still face issues with two mobile sensors that are not properly recorded in the data set. This lack of data is due to a mis-installation in buses 701 and 915 (sensors N3:03 and N3:17). This problem will be fixed as soon as the buses are available for maintenance.

Table 2, List of sensors currently registered in the AQMO mobile sensor platform (the 23/12/2020).

Sensor Name	Value Type	Current Bus or Location	#measurements	First sampling date
OPC_N3:04	PM2.5	Irisa Bât13	426 311	2020-03-19T00:44:27.991+00:00
OPC_N3:12	PM2.5	Bus n°742	159 446	2020-03-19T05:54:19.392+00:00
OPC_N3:05	PM2.5	Bvd C. Peguy	458 655	2020-05-14T11:59:11.270+00:00
OPC_N3:03	PM2.5	Bus n°701	46	2020-05-14T12:32:47.873+00:00
OPC_N3:16	PM2.5	Bus n°241	23 269	2020-05-28T03:30:24.000+00:00
OPC_N3:01	PM2.5	Bus n°916	1 630	2020-05-28T14:37:43.000+00:00
OPC_N3:17	PM2.5	Bus n°915	420	2020-06-24T18:45:59.000+00:00
OPC_N3:09	PM2.5	Bus n°743	31 641	2020-06-24T21:51:48.000+00:00
OPC_N3:14	PM2.5	Bus n°924	26 928	2020-07-24T16:45:58.000+00:00
OPC_N3:20	PM2.5	Bus n°700	72 810	2020-10-22T08:13:23.640+00:00
Total			**1 201 156**	**1995 aggregated days**

The mobile sensor platform database infrastructure contains other data sets related to the communication conditions of the LoRa network. The description of these datasets is beyond the scope of this document.

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3.2 Sensors values coverage over time and space

The measurement campaign was able to sample data over an area[1] of 672 km^2 – with most of the values located in a square of 60 km^2. Among the sensor values acquired by buses, 96% of the measurements were in the inner square (306 000 measures over 318 000). An illustration of the actual coverage is given in Figure 6. As we will see later in this report, this coverage is highly irregulars as it depends on the bus lines. As the most pertinent bus lines were selected for our study, their path should be related to the source of pollution associated to the traffic.

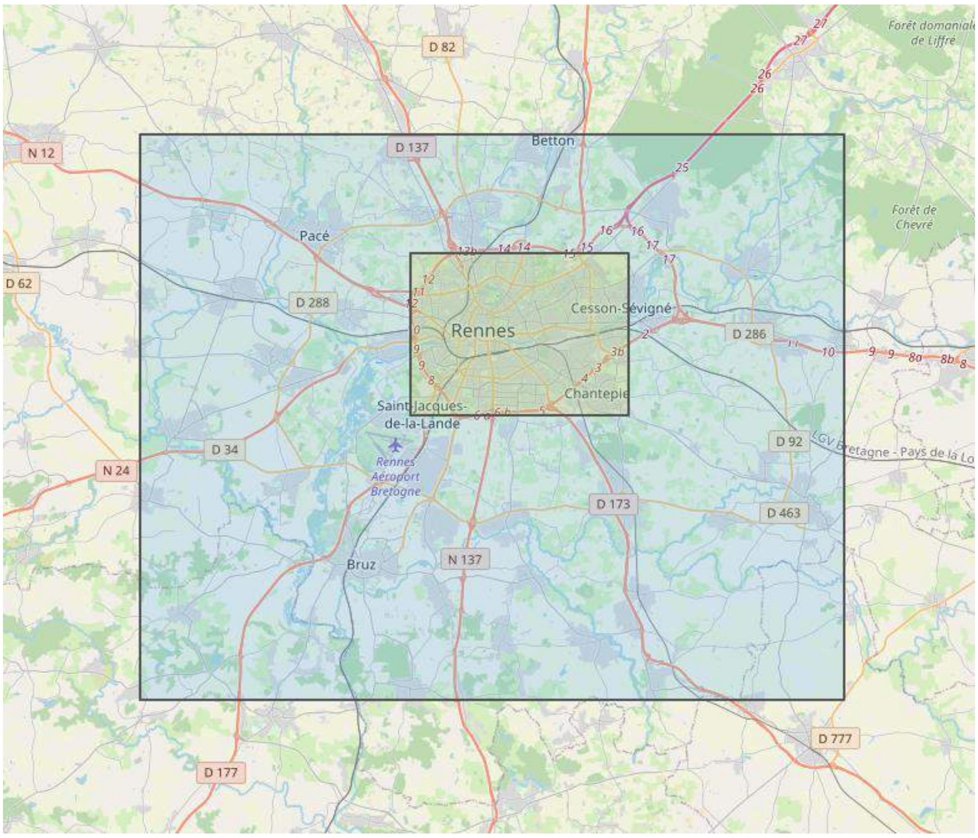

Figure 6, geographical coverage of the 2020 measurement campaign. The inner square accounts for 96% of the measurements.

The actual and detailed coverage of the measurement campaign is displayed on the metropolitan map in Figure 7. The figure is based on a projection of the measured data on a regular grid of 20x20m. The result shows that there are still many zones on the map that are not properly covered by the experiment (less than 50 measurements). However, the main roads of the city are reasonably covered (with few hundreds of measures) and some hot spots have a dense measurement rates: the center of the city, the bus parking lots, and the end of the bus lines.

[1] The large square is 1.87W-47.98N, 1.48W-48.18N the inner one 1.72W-48.08N, 1.6W,48.14N

Figure 7, Geographical coverage of sensor measurements

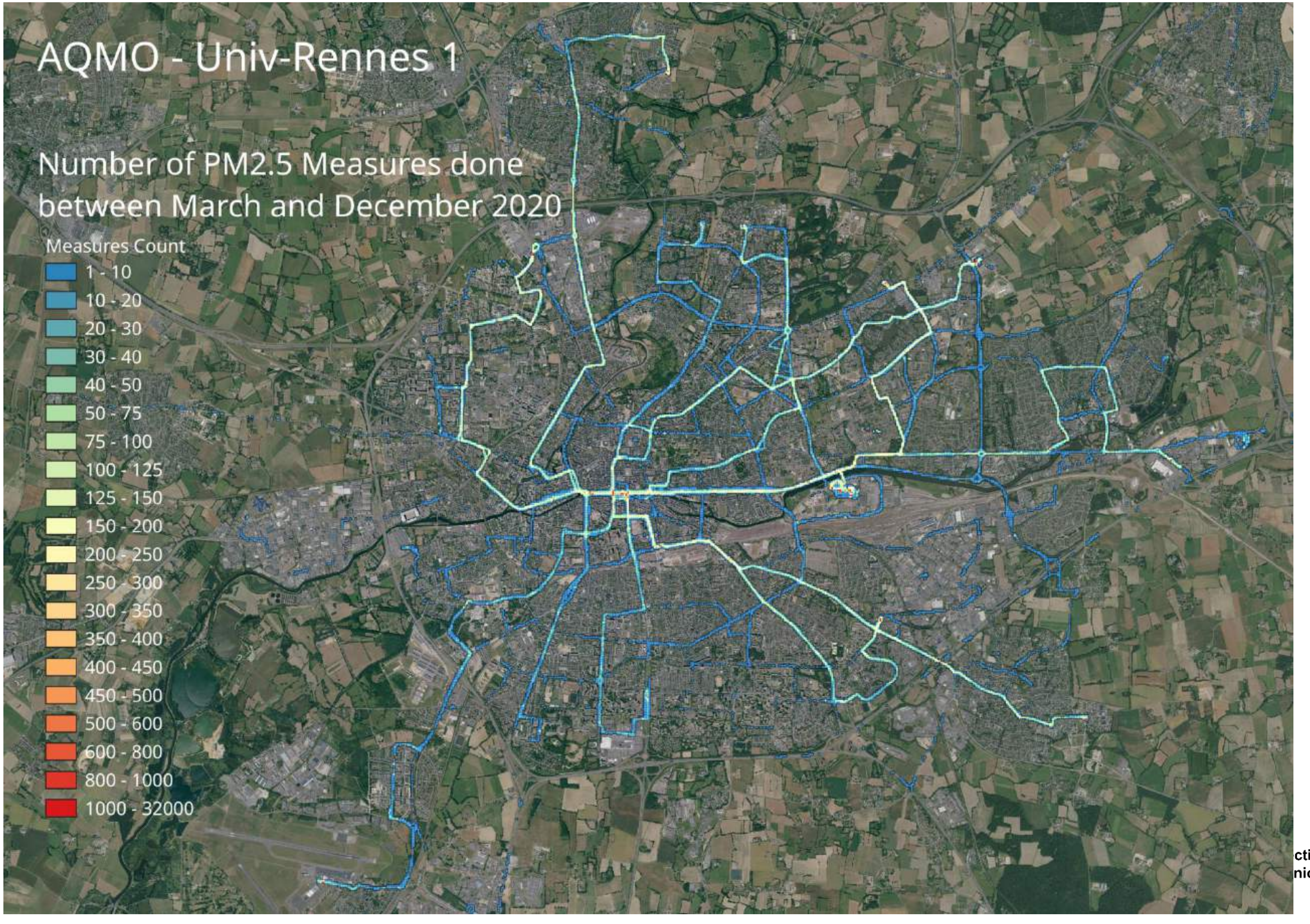

Figure 8 illustrates the consequences of the problems and limits we faced during the main campaign. The campaign is still ongoing and has seen its productivity increasing over time. The measurement rate shows that the maximum data collection was logically achieved by the end of the period, after the installation of the last three buses. Fortunately, a set of buses has been setup just before the first French lockdown period that lasted nearly two months between March and May 2020. The slow-down during the summer was due to a set of hardware and software failures that could not be fixed before September, the buses not being available for maintenance. More details on the limits and constraints of our approach are described in the section 2.2.

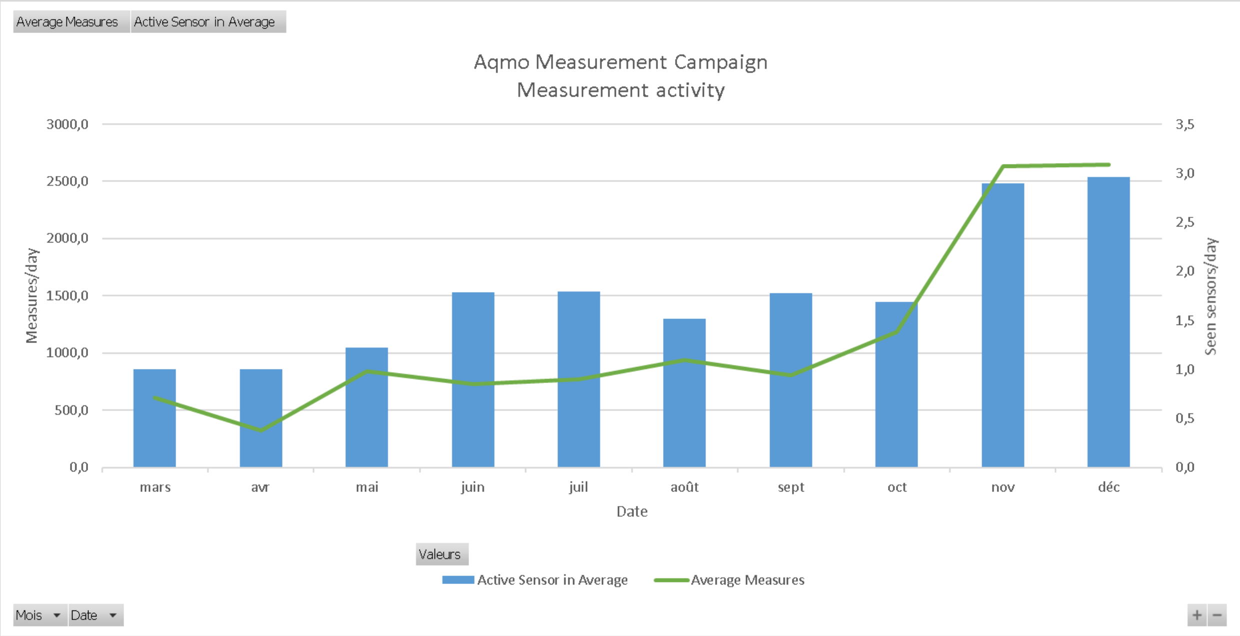

Figure 8, Measurements activities, increasing overtime.

The number of measurements collected per day is shown in Figure 9. At the beginning of the measurement campaign, the measurement was made by a single bus that was not operated every day. Starting from May, we installed two then three buses, and we started to obtain an increasing time coverage. As soon as we have achieved to setup eight buses, with around three of them active every day, the time coverage started to improve.

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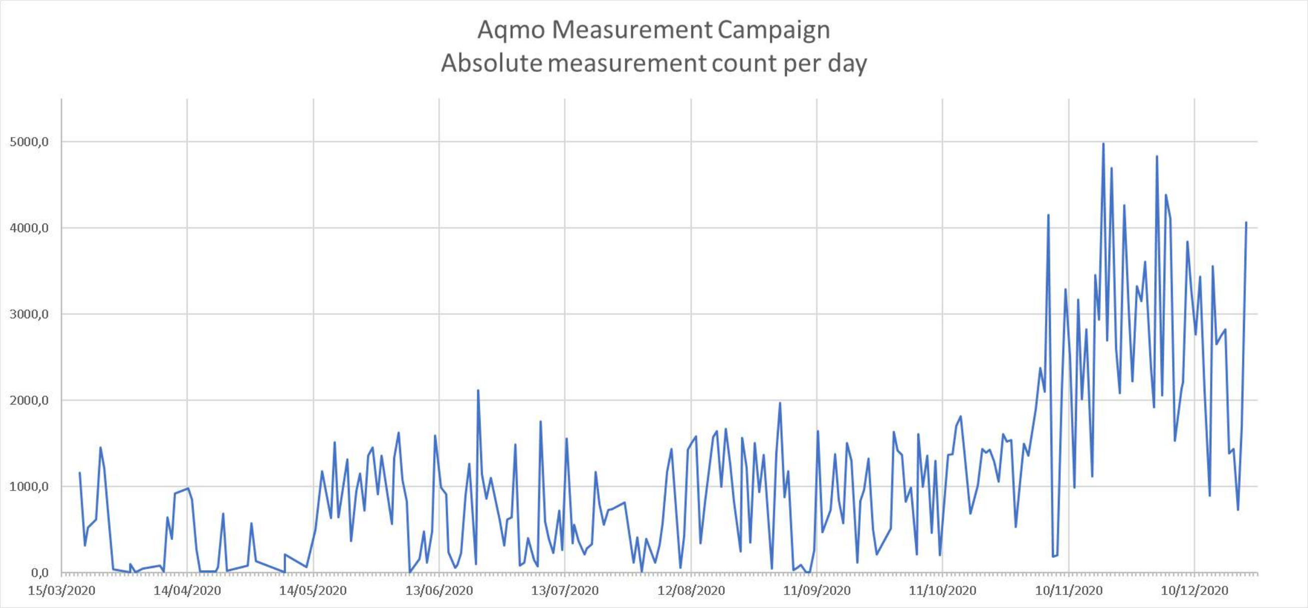

Figure 9, Number of measurements collected per day.

To conclude with this section, we can state that the approach taken for this project shown a strong potential in term of data coverage for the city. The mobile sensor platform is now able to propose a proper measurement platform using the metropolitan bus network. The measurement campaign is still going on, and the current limitations in time and geographical coverage shall be reduced quickly.

4 Fine particle pollution: a preliminary analysis of the AQMO data

This section proposes a preliminary data analysis of air pollution values acquired during the measurement campaign. A first section covers the comparison of the campaign's measurements with other measurements made during the project. The objective is to get some insights on how the sensors behaved during the experiment. A second section presents our main findings and results. It shall be stated that our objective is not to assess the air quality during the period. In this section, we will discuss the usage that a mobile sensor platform could have in the detection of points of interest in the city, and how they could be in theory exploited using simulation, or for adapting the global air pollution measurement framework.

4.1 Comparison of $PM_{2.5}$ measurements with other experiments

The data analysis performed in this section relies on differential measurements. As shown in Deliverable D6.2 [3] , the AlphaSense OPC-N3 sensors are not accurately reporting low levels of $PM_{2.5}$. However, as far as we have been able to verify it, they are precise, e.g they behave similarly between each-other and report a stable measurement over time. This important property allows us to compare the reported values in the long range. This is illustrated in Figure 10.

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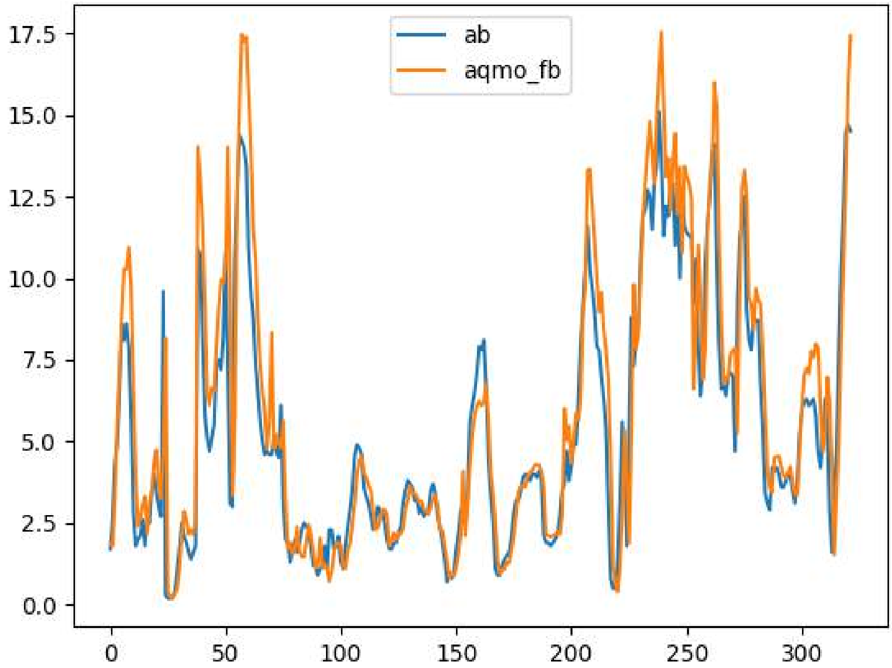

Figure 10, October 2020 data reported by AIR Breizh OPC-N3 (ab curve) and fixed OPC_N3:05 sensor (aqmo_fb curve). Values are hourly average, and indexed by the time of measurement

Another evaluation of the sensor precision can be done with the analysis of the $PM_{2.5}$ values measured by different mobile sensor platforms in deployment at the same time. Figure 11 shows the different average values obtained per hour by three different buses during November 2020. During this period at least two buses were measuring data around 60% of the time. We can see a good to very good correlation between measurements. The correlation values are shown in details in Table 3. It is computed with the average values get by hour when the two buses are active at the same time.

Table 3, correlation table between 3 mobile sensor measurements in November 2020

	Bus 700/742		**Bus 700/743**		**Bus 742/743**	
Number of Hours	258		96		66	
Correlation	0,784		0,861		0,676	
Number of Measures	29 921	22 287	10 648	4 765	5 970	3 582

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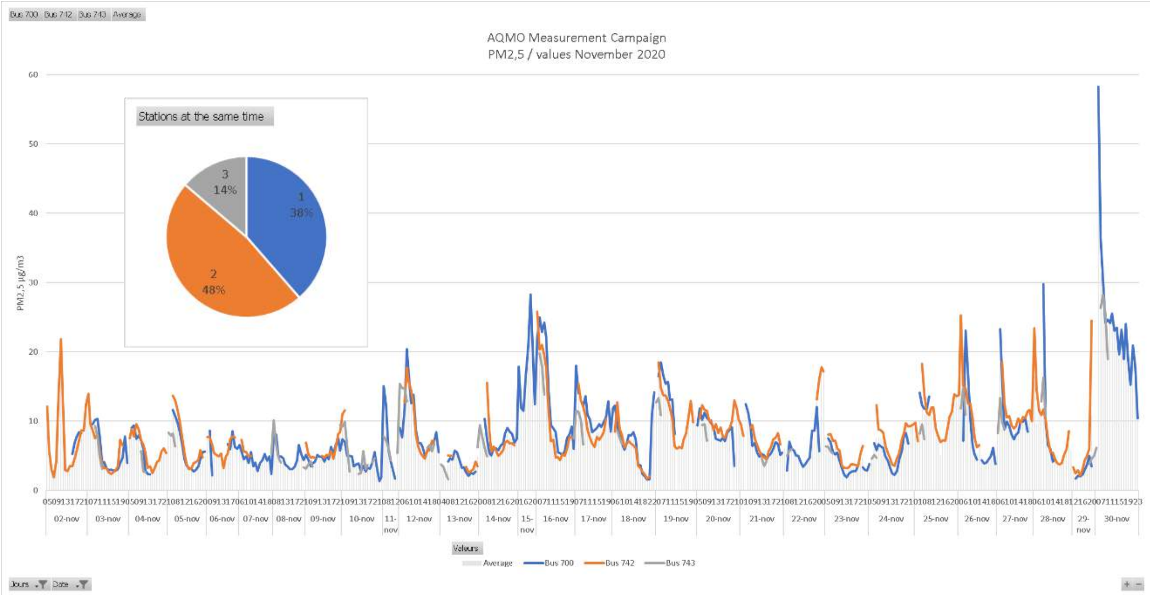

Figure 11, Average PM2.5 per hour for 3 different mobile sensors in November 2020 (curves), and proportion of measurements with 1, 2, or 3 sensors active at the same time (pie chart).

4.2 Detecting new points of interest

Figure 12 shows the geographical mapping of the aggregation of data for all buses. The first important point to notice is that the result of $PM_{2.5}$ measurements is not correlated with the number of measurements given in Figure 7. This implies that something is measured by sensors over the bus trips, and considering the large number of points, this differential measurement is consistent over time. The second information we can get is that the level of pollution measured globally corresponds to the values any-one could expect from our campaign. Nevertheless our coverage allowed to detect unexpected and therefore interesting points of interest that could not have been seen otherwise.

- The secondary roads of the city – out of the main traffic lines – show a significantly lower pollution value. More studies shall be done on these locations as the number of values is low

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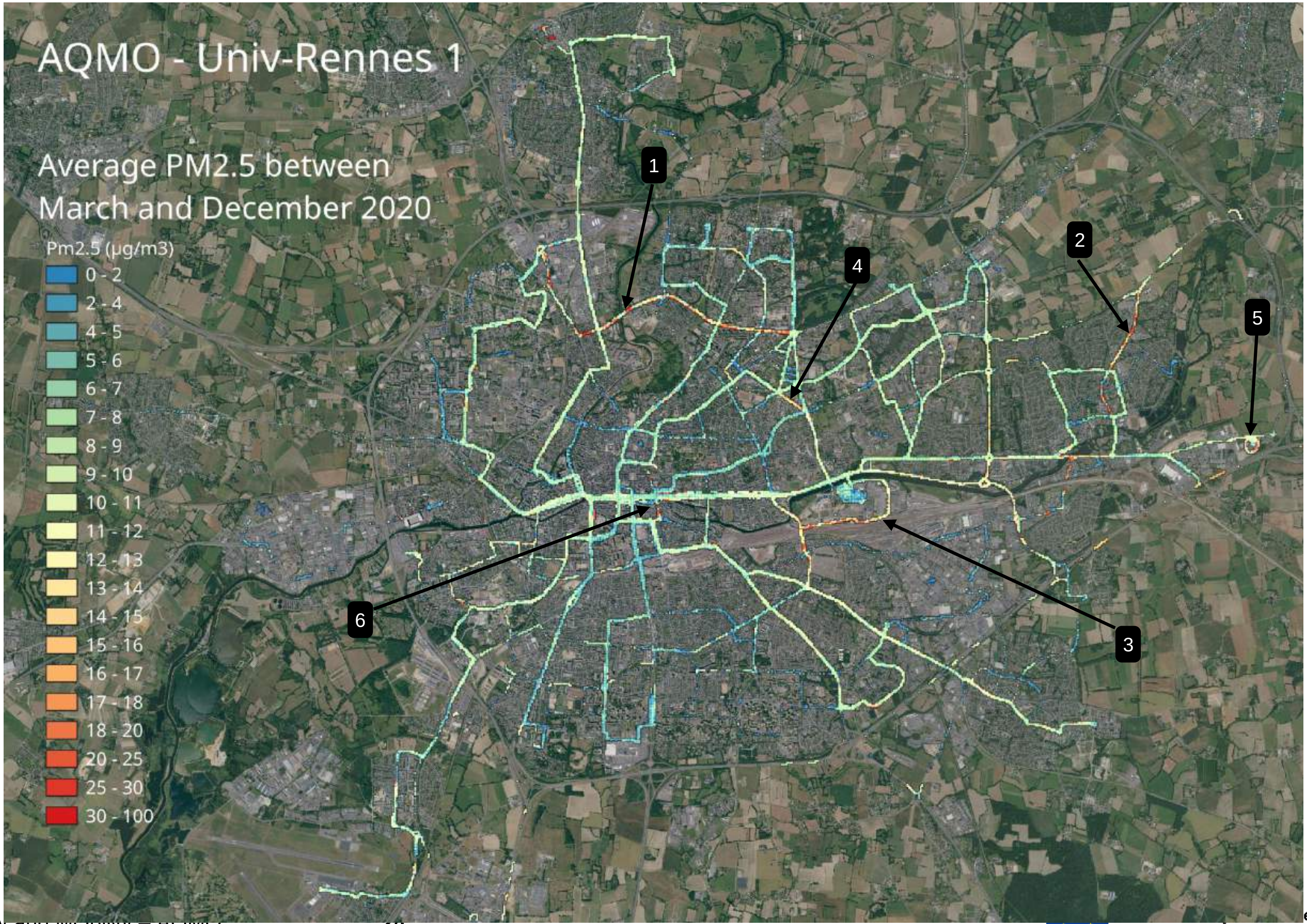
Figure 12, Map of the average PM2.5 values for 2020. https://data.aqmo.org/db/2020-12-28-AqmoAllperiod20m-avgPM25-HR.png (68Mo)



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- We can see five segments with a significantly higher level of PM2.5 (over 20 µg/m3)
  - Two of these segments are clearly identified as locations with a dense traffic. The segment n°1 is a known hotspot of the city, and the segment n°2 corresponds to a main escape axe for people working in city but living outside, in the suburbs
  - The segment n°3 is interesting as it does not correspond to a location with dense traffic but is located between the bus storage and maintenance location (not by itself affected) and the railway maintenance infrastructure
  - The segment n°4 is particularly interesting as it is located on a road that is not generally known as a hot spot. We can notice that a heavy construction works for the second metro line has perturbated the traffic, and redirections may have had a strong impact on the traffic congestions in the area
  - The segment n°5 is another point of interest, but we know that a major truck engine company has its buildings there and is taking in charge metropolitan buses for heavy maintenance. The mobile sensor platform is not deactivated when such a maintenance is scheduled. The question is still open if buses maintenance period shall be recorded by the platform
- Finally, the center of the city – point n°6 –, with a very dense traffic of buses, does not show the highest values of $PM_{2.5}$ in our campaign. It however shows a particle levels in the average range of measurement, like the main traffic roads of the city

From this brief analysis of our data, we clearly show that the measurement campaign is able to provide near real-time, ground based, point of interests of the particle pollution in the city. The quality and the usage of these points of interest still requires more efforts: the data shall be compared with more accurate measurement and with the results of numerical modelling. More importantly, the integration of this feedback in the global pollution evaluation and correction needs to be analyzed.

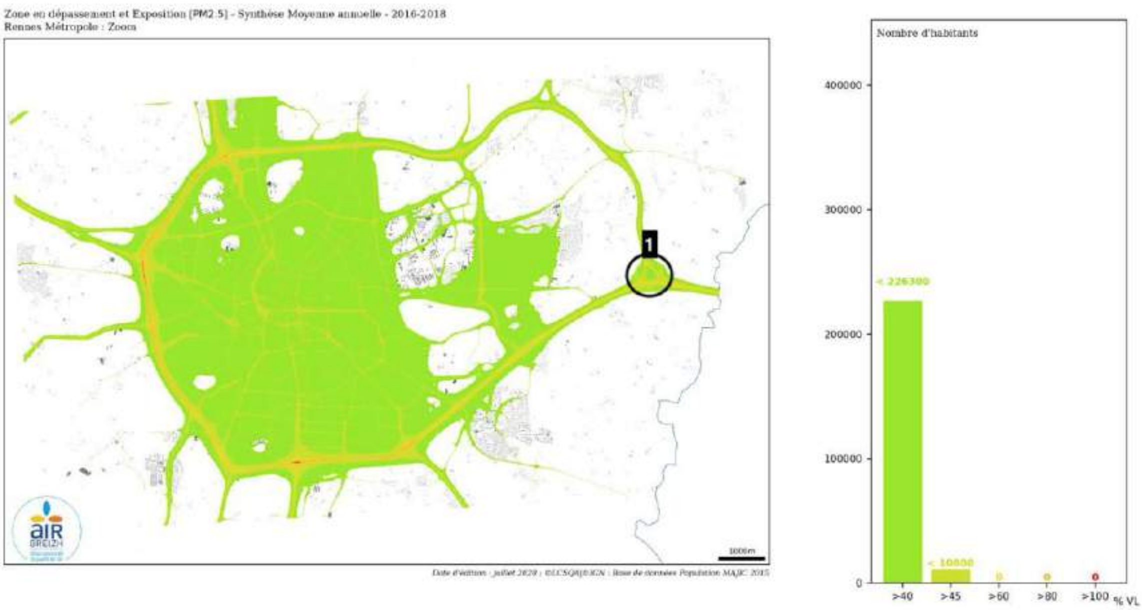

Figure 13, Chronic exposure of the population to PM2.5 in relation to the limit value - Rennes; Based on SIRANE simulations (see report on numerical models [5]).

In order to evaluate our results, we can compare our data with the simulations made during the project for the previous periods. Figure 13 shows the chronic exposure of the city population to the $PM_{2.5}$ for the 2016-2018 period. This map has been generated using the SIRANE numerical model and computed by Air Breizh. It is a good indicator of the current knowledge on air quality over Rennes City. We can see that such simulations provide pollution information at a different scale than our mobile measurement: highways are the major hotspots, and only large grain effects are seen at the block level. The model is not able to provide feedbacks on local and transient events as they are not taken into account in the model, and not provided as an input of the simulation. A possible outcome of our mobile sensor platform would be to systematically integrate source of pollutions measured on the ground and integrate them in the numerical simulations using data assimilation techniques. High resolution modeling requiring high-resolution measurements (spatial and time resolution), combined with large scale background information for the data assimilation that provide the starting state of the numerical simulation.

5 Conclusion

This report provides insights on the data collected by the AQMO platform and provides a valuable feedback on the problems and limitation of the deployment of a mobile micro-sensors network. Eight buses have been used up to now. The spatial and temporal coverage is satisfactory with this minimal number of mobile sensors. Reducing the number of equipped vehicles is an important factor as it allows either reducing the deployment and maintenance costs or using more expensive sensors. The platform has been robust enough to collect data over a long period of time. Missing service on the LoRaWan network is still to be explored. The multimodal transmission policy (LoRa & 4G) of the data will be changed as a next step and does not require changes in the platform and should increase the robustness of the data collection.

As described in Section 3 we have identified point of interests, some of them already captured by the SIRANE simulation and some that have not. The use of mobile micro-sensors in a continuous data collection is particularly useful to detect transitory situations that are not captured by surveillance stations (too few of them) nor by simulations, as the source of emission has not been detected. It should also be noted that the transitory phenomenon we are considering corresponds to an exposition of people above the threshold of alert. However, having detected a point of interest does not necessarily means there is an air quality issue; once detected, it requires an accurate assessment using scientific measurement apparatus and expert analysis.

These pilot experiments and methodology could be reuse over many metropolitan areas, over France, Europe or elsewhere across the world, providing both interesting scientific data for researcher, understandable data (provided in an efficient way) for citizen (allowing citizen science and/or actions of mitigation of pollution sources and pollution exposure) and policy makers to take informed decisions.

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