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Mapping street-level air quality to empower cities in the reduction of urban pollution

White paper

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Introduction

The World Health Organization (WHO) has showed the correlation between air pollution and human mortality through several studies. Indeed, the WHO estimates that about 7 million people die because of air pollution-related diseases every year. It was proven that particulate matter accounts for a nearly 2 years global life expectancy cut. In a recent report published in 2018 ("*Introducing the Air Quality Life Index*", M. Greenstone and C. Q. Fan, 2018), the University of Chicago has set an Air Quality Life Index which assess the impact of particulate matter pollution for humans: air quality has without a doubt become a major societal and sanitary issue.

Human beings are most of the time directly exposed to a complex mixture of air pollutants (nitrogen dioxide, ozone, carbon monoxide, particulate matter, etc.) emanating from various sources. As an example, 95% of urban citizens in Europe have been exposed to levels of ozone which exceed the regulatory levels in 2017 ("*Air quality in Europe — 2017 report*", EEA report; No 13/2017).

Tackling this complex issue requires both obtaining the most detailed air quality data and communicating it to citizens and communities in an efficient and specific way. The approach eLichens advocates for must enable:

- Citizens to avoid the most polluted areas of a city, whenever possible;
- Public health services to adapt and improve decision-making through observation and prediction at a local scale (e.g. traffic regulations);
- Public health services to communicate and educate citizens about air quality;
- Private organizations to optimize indoor ventilation, and thus offer everyone a better air quality in homes and other buildings (commercial, offices).

However, air quality monitoring is complex as the concentration of air pollutants strongly varies in space and time. Today, the two main ways to obtain relevant information about air pollution are:

- **Reference stations**. Although they provide accurate measurements, the gas and particulate analyzers they require are costly and heavy, thus limiting the deployment of such stations. In addition, their spatial cover is sparse;
- **Pollution maps and forecasts**. Existing solutions do not display pollution at street level (e.g. the Copernicus database) or are based on models that require extremely detailed input data (high resolution emission inventories, detailed city topography, vehicles characteristics, etc.). Besides, building such databases is a long, complex and costly process, making it impossible to generalize worldwide.

eLichens' Outdoor Air Quality Map and model

To overcome these limitations, eLichens has developed a new approach and designed a solution that empowers citizens and communities through increased knowledge, thus enabling more effective and local actions to limit exposure to particulate matter and other pollutants (nitrogen dioxide, ozone, carbon monoxide). eLichens' Outdoor Air

Quality Map is based on both local and global data and aims at displaying urban pollution at a high-resolution level. As shown in Figure 1, the displayed data lies on:

1. **a first assessment based on a high-resolution gas dispersion model**. The best State-Of-The-Art weather and chemical transportation models coupled with a street-level gas dispersion model are used to obtain an accurate assessment of air quality;
2. **Proprietary patented Data Management algorithms** which integrate real time measurements from a dense network of cost-effective Outdoor Air Quality Monitoring Stations designed by eLichens. The use of eLichens' affordable micro-sensors in those Stations makes it financially possible for communities and Smart cities to deploy many of them in an urban area, and therefore improve the output of the computer model.

A first proof of concept was carried out starting from January 2019 with the deployment of six of eLichens' Outdoor Air Quality Monitoring Stations in Grenoble, France. With only a few Stations and the exploitation of their measurements, we obtained significant results as described hereafter. Deploying more of these Stations would increase the performance of the solution even more.

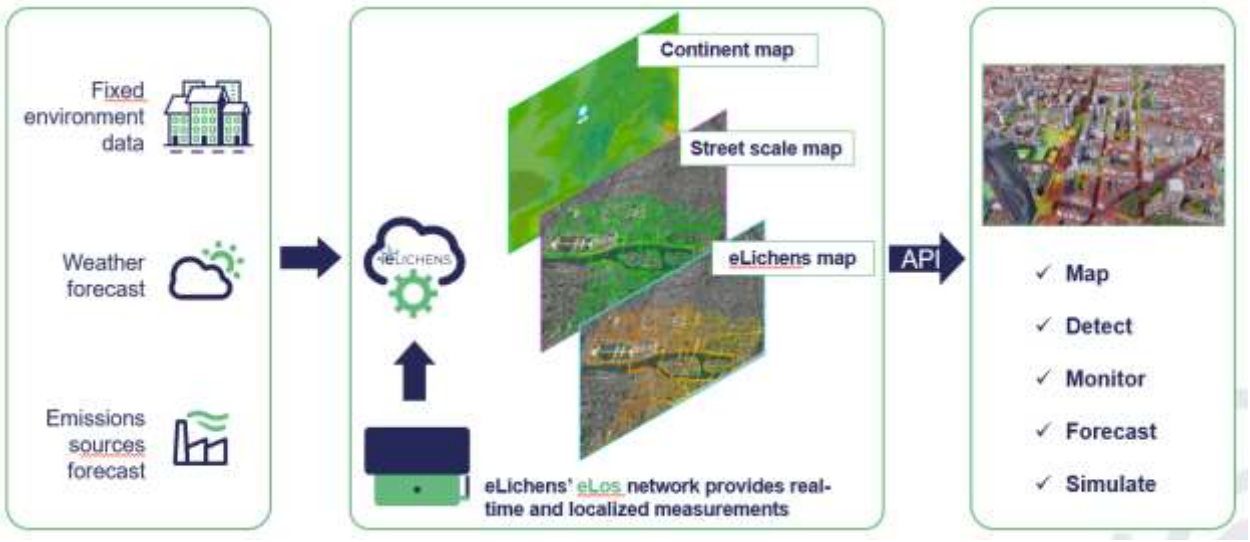


Figure 1: software architecture of eLichens' solution

eLichens' Outdoor Air Quality Monitoring Stations

Figure 2 shows eLichens' Outdoor Air Quality Map for the city of Grenoble in France. The six Outdoor Air Quality Monitoring Stations are indicated with eLichens' logo. The reference station used for performance evaluation and that belongs to the French Environmental Agency 'ATMO Auvergne Rhône-Alpes' is also highlighted by red marks.

Figure 2: eLichens Air Quality Map. eLichens' Stations (eLichens logo) and ATMO's reference station (red mark) are indicated.

As eLichens' solution is based on Outdoor Air Quality Monitoring Stations, efforts have been undertaken to improve their performance. Accuracy has then been evaluated by both eLichens and third parties.

1. Tests conducted by eLichens in December 2018 and January 2019: two Outdoor Air Quality Monitoring Stations were co-localized with a reference station of ATMO Auvergne Rhône-Alpes for one month. Figure 3 shows the correlation between measurements coming from eLichens' Stations and those coming from the ATMO reference station.

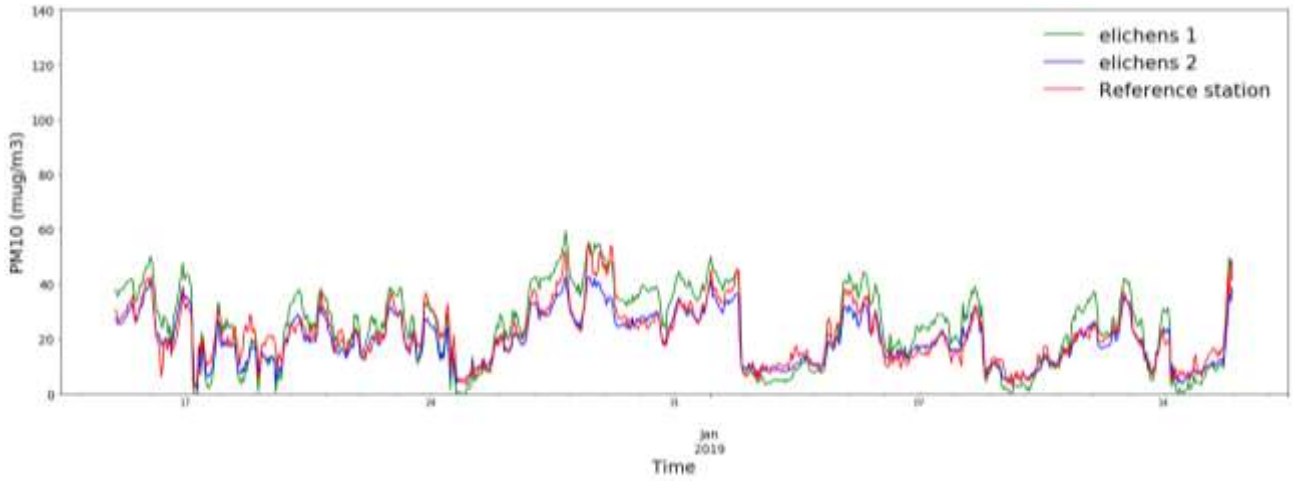


Figure 3: PM 10 comparison of the measurements coming from two eLichens Outdoor Air Quality Monitoring Stations and those coming from a reference station of ATMO Auvergne Rhône-Alpes (co-localized).

2. Tests conducted by third parties:
    a. In 2018, eLichens participated in an inter-comparison campaign organized by the Department of Air Quality at the Lawrence Berkeley National Laboratory, in California. As found in figure 4, our solution shows, for PM 2.5, an excellent agreement (R^2 of 0.98) with the analyzer used by the Lawrence Berkeley National Laboratory. As the comparison was done while forest fires were taking place in California, the span of the PM 2.5 concentrations was particularly important;
    b. Ongoing: extensive laboratory testing by the "Laboratoire National de Métrologie et d'Essais (LNE)", the French reference in metrology and in charge of the certification of new products, and field campaign by the "Laboratoire Central de Surveillance de la Qualité de l'Air (LCSQA)", in charge of the coordination of all the French regional air quality agencies.

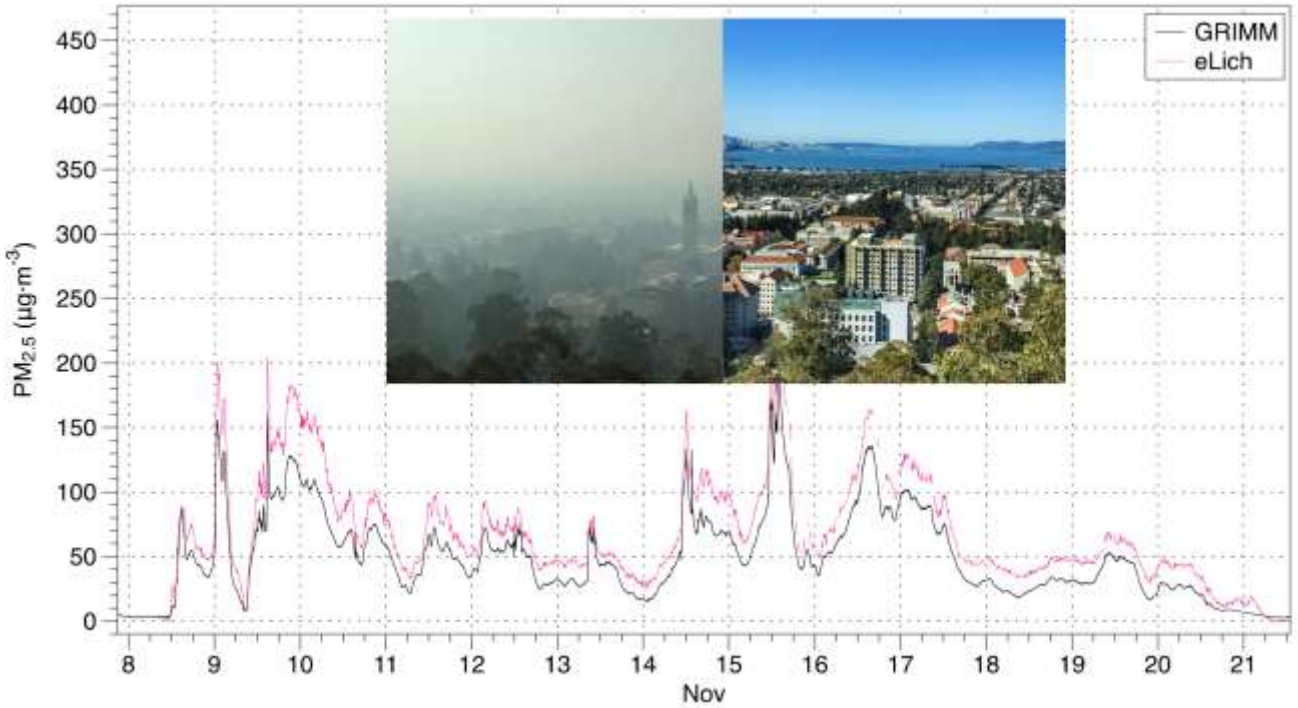


Figure 4: Comparison of the PM 2.5 measurement coming from eLichens' solution and a GRIMM analyzer (Model 1371). The comparison was done by Berkeley Lab (US) during a period with wild-land fires (8-21 Nov 2018). Figure by Berkeley Lab

eLichens is shown to meet scientific standards of "good air quality models"

The performance of pollution maps can be limited by the influence of random atmospheric processes, and consequently there is no such thing as a perfect model in air quality modeling. The evaluation of pollution maps' performance is thus a tricky exercise but fortunately, the evaluation proves of an air quality model has been

described in detail in Chang and al. paper[1]. Chang defines 5 criteria and indicates that a pollution model can be defined as “good” if these 5 criteria are between some given boundaries.

These 5 criteria and the corresponding bounds are:

Name	Description	Range for a “good” model
FB	Fractional bias	$-0.3 \leq FB \leq 0.3$
MG	Geometric mean bias	$0.7 \leq MG \leq 1.3$
NMSE	Normalized mean square error	$\sqrt{NMSE} \leq 2$
VG	Geometric variance	$VG \leq 1.6$
FAC	Fraction of predictions within a factor of two observations	$FB \geq 0.5$

The assessment of eLichens’ Outdoor Air Quality Map is done by comparing the concentration levels of pollutants computed by eLichens’ solution and those of ATMO reference stations. On figure 5, the extraction of data computed by eLichens’ model versus the one of the reference station have been represented over 2 different periods of time for PM10:

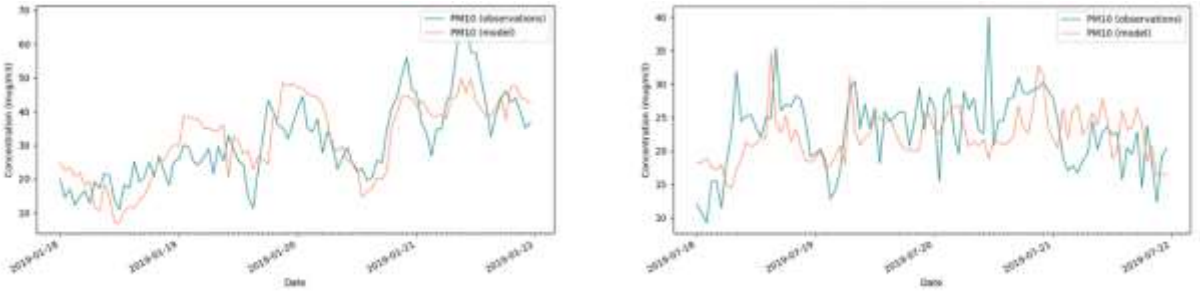


Figure 5: PM10 estimated by eLichens’ solution versus reference station

eLichens’ solution has been evaluated as follows:

1. Selection of the calculation points which are the closest to the ATMO reference station and extraction of the hourly outputs;
2. Computation of the 5 criteria defined above for both NO2 and PM10 for each week between January 2019 and September 2019.

The reference station is in an urban traffic environment and this station has not been used in the data management process defined by eLichens to avoid bias in the result. The performance of eLichens’ solution is illustrated on the figure below. For each criterion, the green area represents the range of a “good” model:

[1] Chang, J. & Hanna, “Air quality model performance evaluation”, S. Meteorol Atmos Phys (2004). https://doi.org/10.1007/s00703-003-0070-7

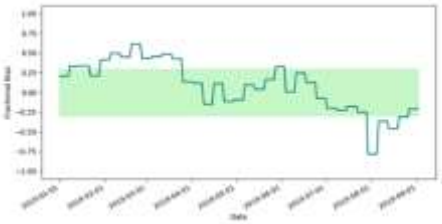
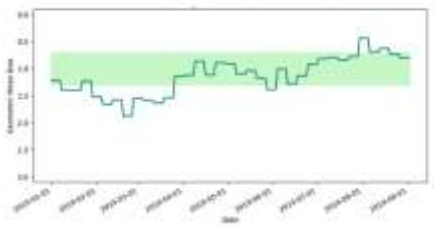
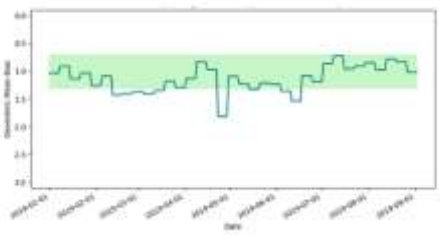
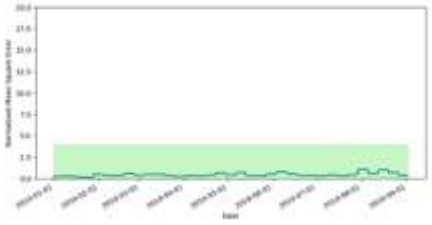
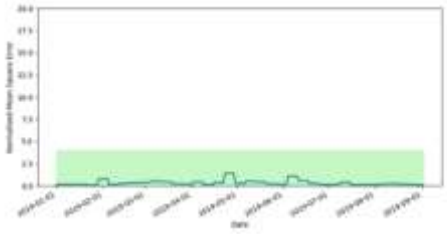
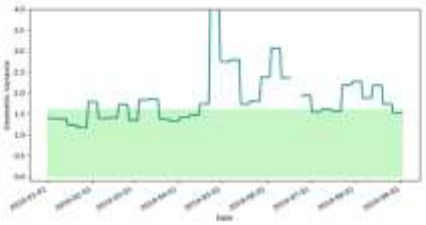
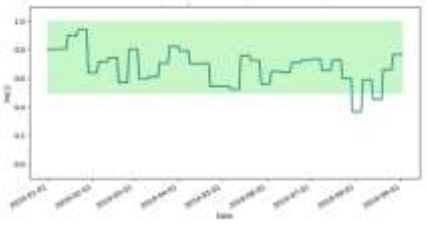
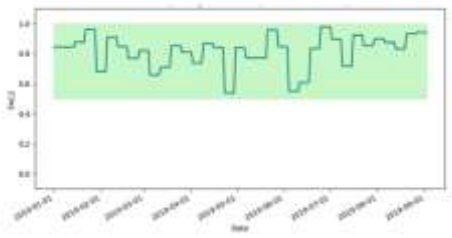
Criterion	**Nitrogen Dioxide** (NO2)	**Particulate Matter** (PM10)
FB Fractional bias		
MG Geometric mean bias		
NMSE Normalized mean square error		
VG Geometric variance		
FAC Fraction of predictions within a factor of two observations		

Figure 6: Performance of eLichens model each week overs 7 months

The performance of eLichens' technology is hence "good" from a scientific perspective for both NO2 and PM10 to track pollution on an hour-based time in the city center of Grenoble. These data can therefore be used to track pollution evolution in real time and with high accuracy, and to evaluate evolution of pollution over periods of time.

Conclusion and next steps

As mentioned in introduction, the results presented have been obtained thanks to a first proof of concept with the deployment of six of eLichens' Outdoor Air Quality Monitoring Stations in Grenoble, France. These results are "good from a scientific perspective" which means that they can be exploited to track pollution evolution in real time and with geographic accuracy.

"*At eLichens, we are convinced that this is just the first step and that our technology, which is based on data fusion between model-based information and real-time measurements, will settle new quality standards for air quality maps. eLichens has recently been laureate from the Innov'R program and thanks to a fruitful collaboration with local authorities, more Air Quality Monitoring Stations will soon be deployed in Grenoble, France. This program will help us take the technology to another level and make a breakthrough in the high-resolution pollution map performance by optimizing our data management algorithms and the whole solution"*, says Pierre Jallon – eLichens' CTO.

Therefore, eLichens' offer enriches most existing data and therefore enables:

1. Better measurement of impact of public actions and policies
2. Better communication toward the public and increase of awareness

During the next phase of this project, additional Outdoor Air Quality Monitoring Stations will be deployed so as to determine the optimal number of Air Quality Monitoring Stations to implement in an urban area in order to obtain the highest error reduction. This solution will also be deployed in other cities around the world, such as San Francisco, California.

eLichens' ambition is therefore to keep improving its Outdoor Air Quality offer for Smart Cities as they emerge over the globe and need the most accurate pollution data to better tackle local air quality issues by implementing relevant policies.

About eLichens

Founded in 2014, eLichens' mission is to pioneer smart sensor networks and provide relevant and comprehensive information about the air we breathe. As we enable air quality detection services through data fusion, cloud computing and analytics, we wish to engage in the creation of a safer environment for all. The company relies on a portfolio of patents, know-how and skills that enable a complete air quality solution (sensors and services) and address both consumer electronics and industrial markets. eLichens' offices are in Grenoble, France and San Francisco, USA.

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