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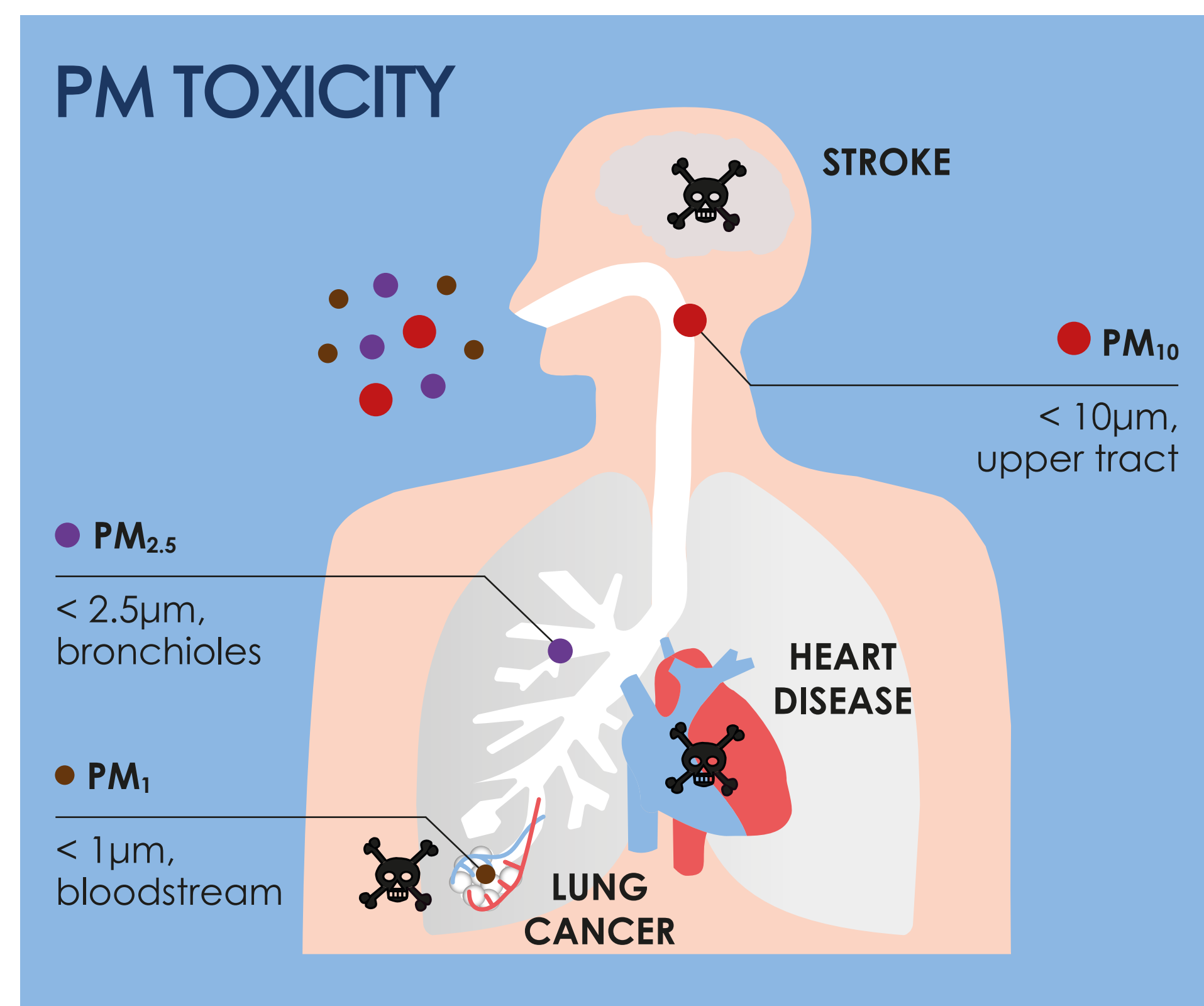
Designing low-cost sensors for high-quality air pollution monitoring

Marie-Laure Aix, Dominique J. Bicout

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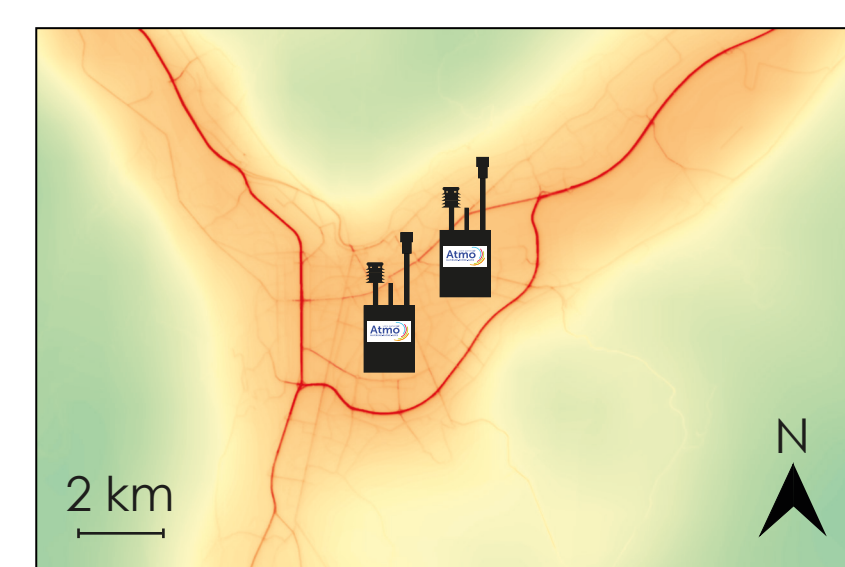
PARTICULATE MATTER

is highly toxic, especially small size particles reaching vital organs through blood. In Grenoble, the spatial distribution of particulate matter (PM) is heterogeneous but only two official background stations monitor small size PM. Therefore, public exposure to PM is poorly estimated. A solution is to build easy to move low-cost measurement stations which can be deployed at various locations in the city. But the data quality of such stations must be characterized beforehand. We have developed a low-cost station (LCS) solution and compared data from LCS with that from an official reference station (Atmo Auvergne Rhône-Alpes) used by authorities.



HETEROGENEITY

The local landscape in Grenoble plays a role in the heterogeneous distribution of particles.

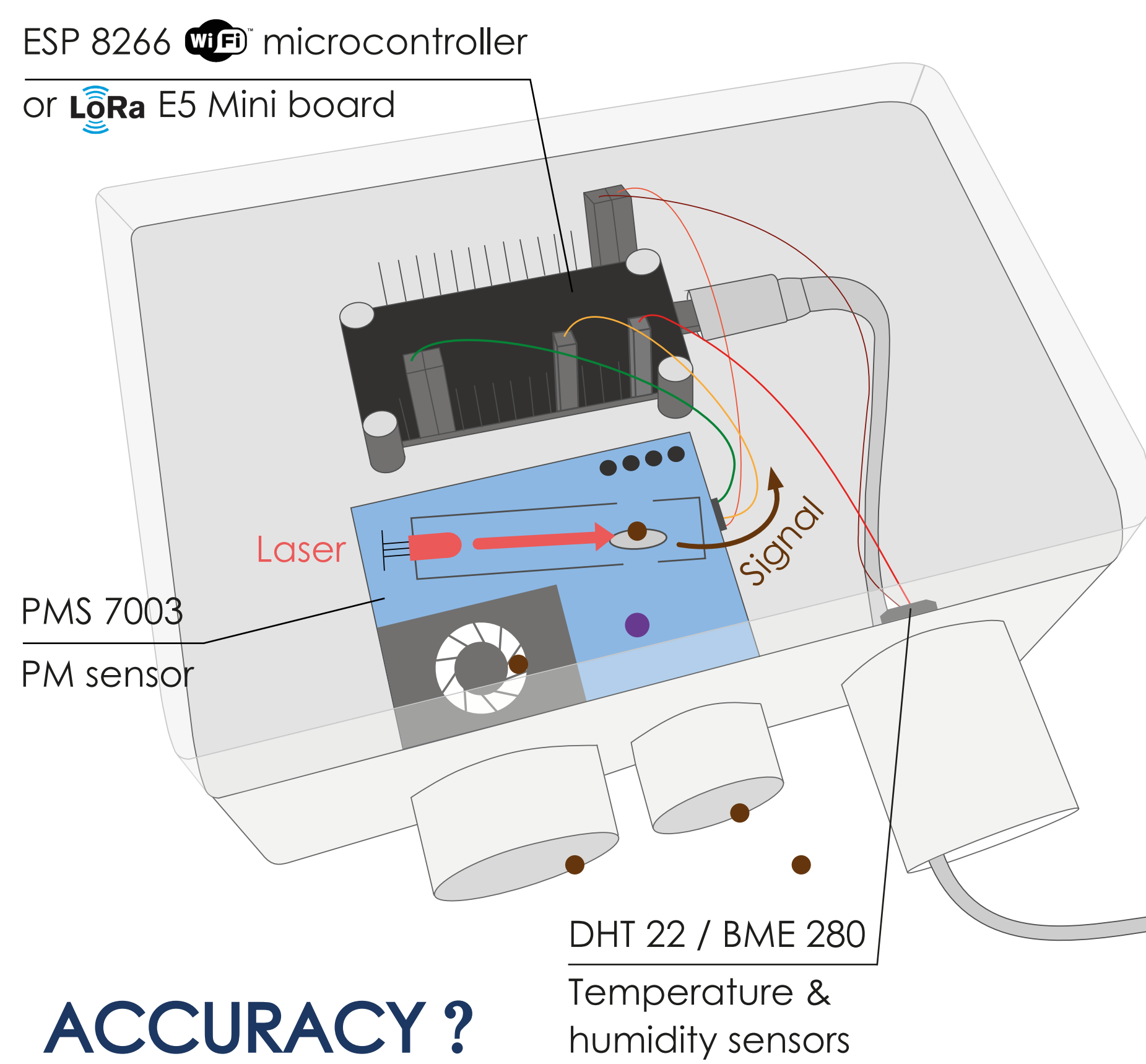


Only two official stations measure PM_{2.5}. They are highly accurate but they are expensive (10 - 100k€) and cannot be moved.

MATERIAL & METHODS

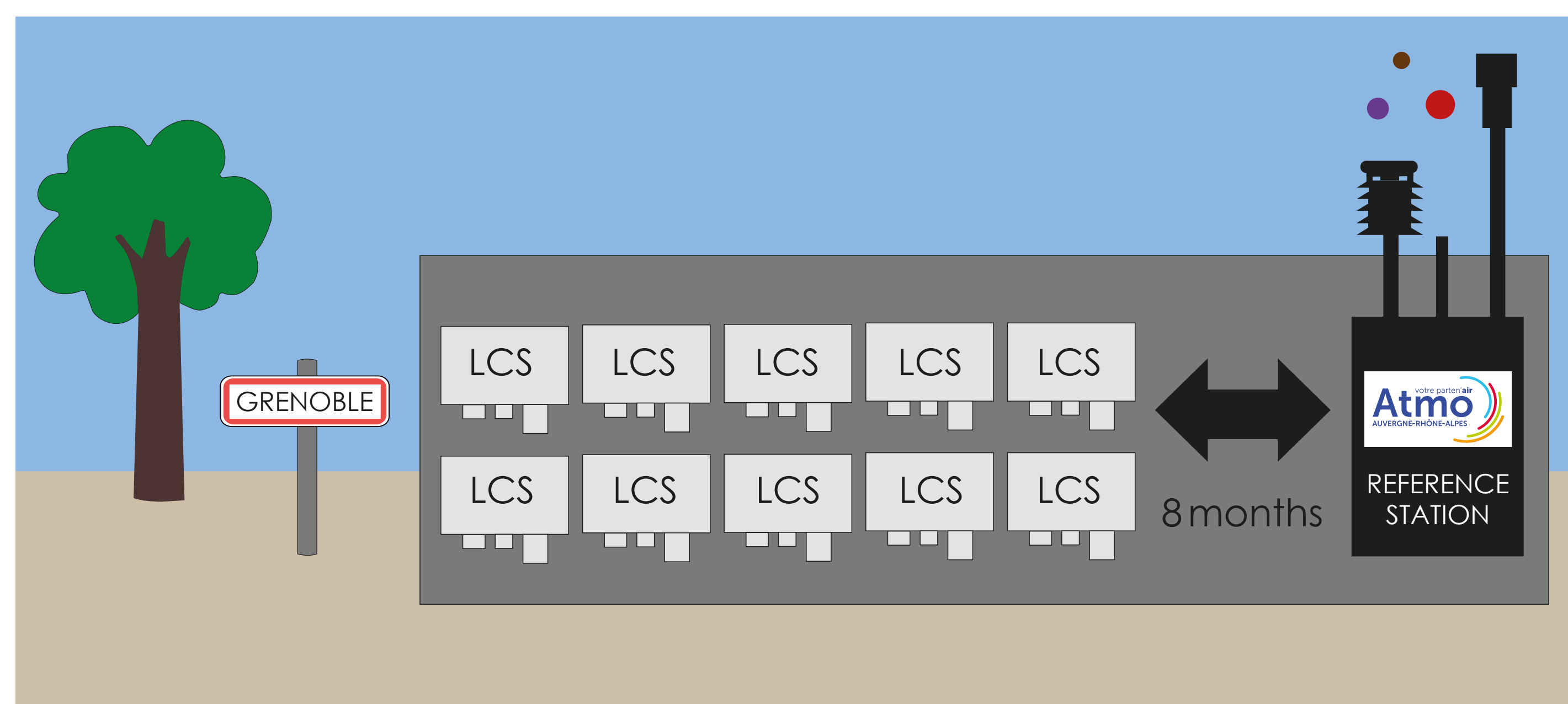
1. Prototyping

The solution was to build a cheap (65€) and easy to move low-cost station. We used an optical PM sensor in which a laser gets scattered by PM. An electric signal is then sent to a microcontroller where it is converted to a particle size and a number of particles in different size groups. The LCS also gives PM concentrations in µg/m³. We also assembled a humidity sensor because we knew humidity could influence particles growth.



ACCURACY ?

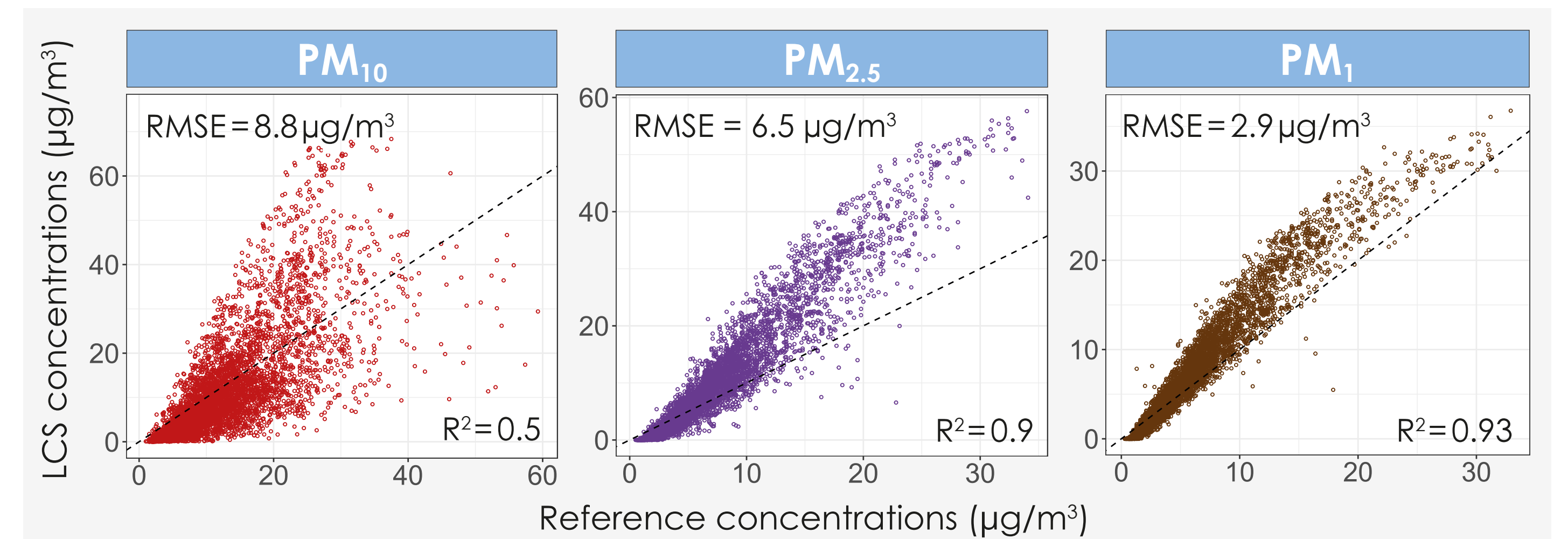
2. Colocation with reference



To evaluate the performance of low-cost stations, ten LCS were installed for 8 months next to the Atmo reference station in Grenoble for the comparison of PM concentrations.

RESULTS

1. Comparison with reference



R² refers to the correlation between the LCS and the reference PM concentrations, while the Root Mean Square Error (RMSE) reflects the accuracy as the closeness between LCS and reference values. An R² as close to 1 as possible and a RMSE as small as possible are both indicators of good sensor performance.

CALIBRATION IS NEEDED

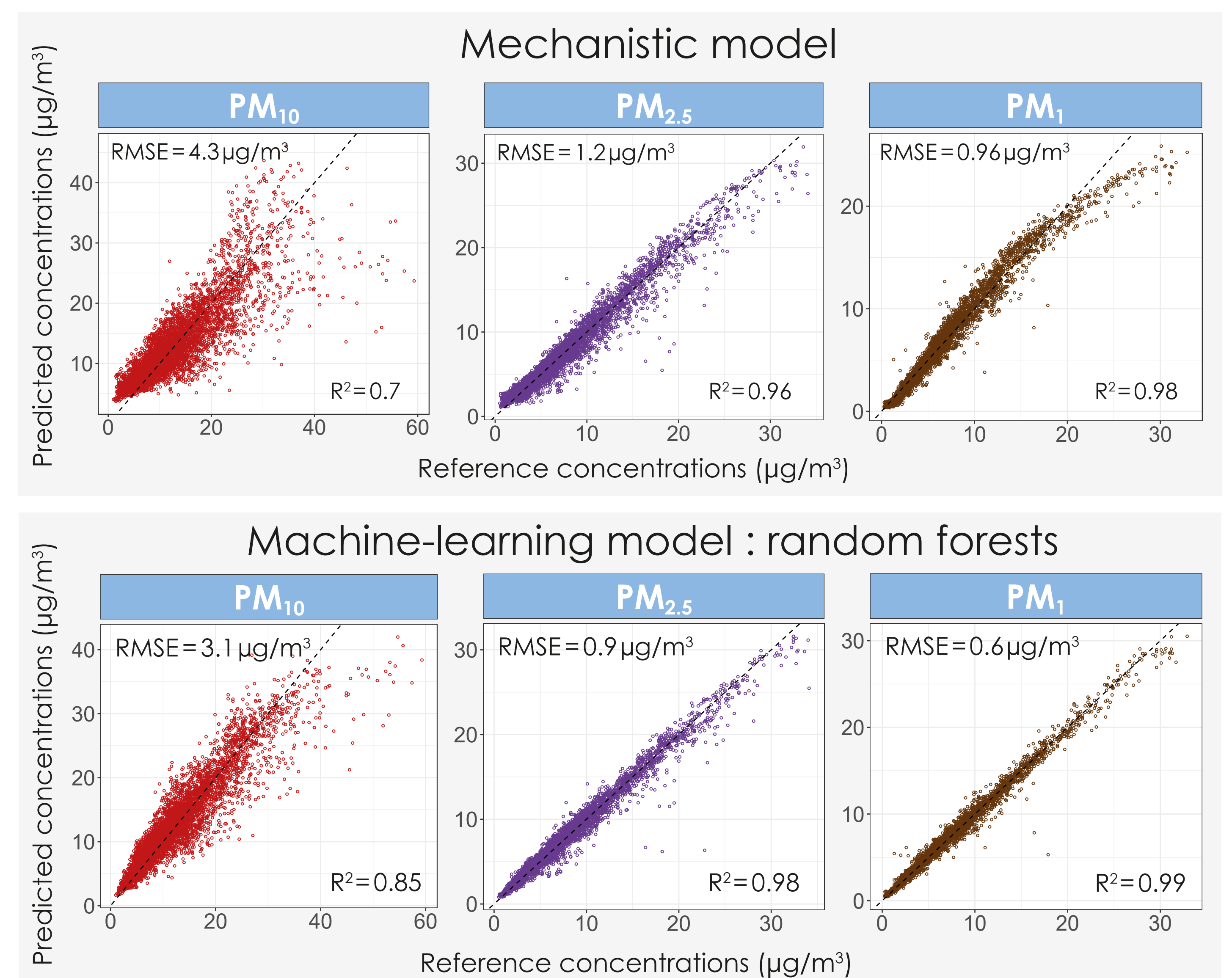
2. Calibration models

Two models involving both Temperature and Relative Humidity are used for calibration : a mechanistic model and the random forests from the machine-learning approach.

Model	Formula	Dataset
Mechanistic	$PM_{ref} = a + b \frac{PM_{lcs}}{\left(1 + c \frac{RH_{lcs}}{100 - RH_{lcs}}\right)^{\frac{1}{3}}} + d T_{lcs}$	100%*
Random forests	$PM_{ref} = a PM_{lcs} + b RH_{lcs} + c T_{lcs}$	Sliding window → 75%* TRAIN, 25% TEST

*100% means all 8 months dataset while 75-25% reflects a 6 months training + 2 months testing set

3. Models performance



CONCLUSION

- The performance of the models is higher for more toxic PM₁ and PM_{2.5}, than for PM₁₀.
- The best calibration method is achieved using machine-learning (random forests).
- Such calibrated low-cost stations can be deployed in Grenoble to monitor PM.**